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A DECISION SUPPORT SYSTEM FOR CONDUIT HYDROPOWER DEVELOPMENT

IONE LOOTS

A dissertation submitted in partial fulfilment of the requirements for the degree of

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DISSERTATION SUMMARY

A DECISION SUPPORT SYSTEM FOR CONDUIT HYDROPOWER DEVELOPMENT

IONE LOOTS

Supervisor: Mr M. van Dijk

Department: Civil Engineering

University: University of Pretoria

Degree: Master of Engineering (Water Resources Engineering)

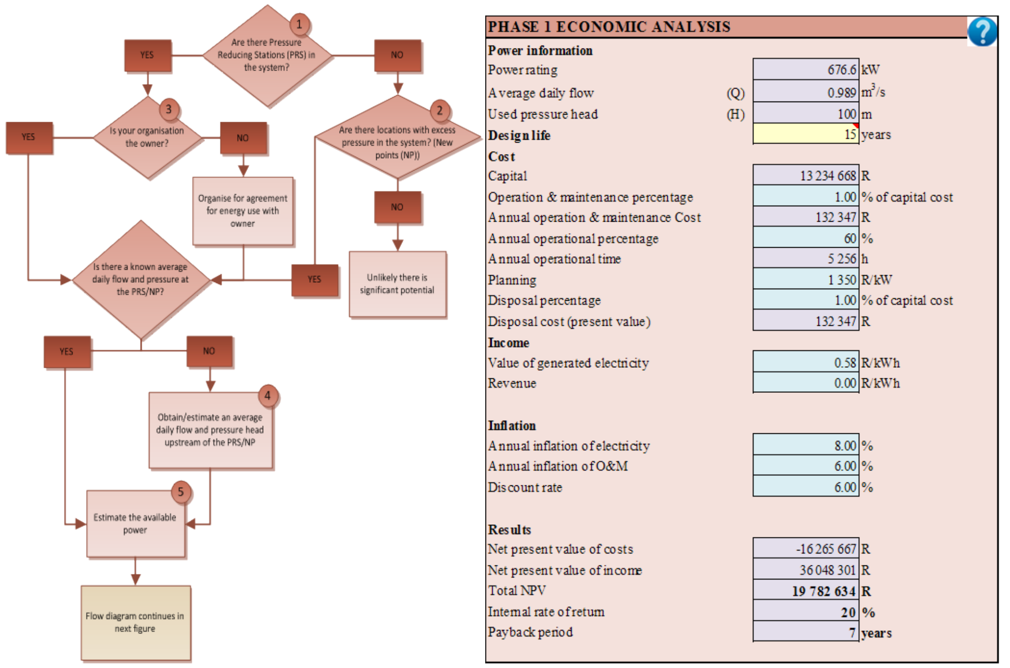
Cheap and reliable electricity is an essential stimulus for economic and social development. Currently fossil fuels are used for the majority of global electricity generation, but energy shortages and pressure on all industries to reduce CO_2 emissions provide incentives for growing emphasis on the development of alternative energy-generation methods. Presently hydropower contributes about 17% of global energy generation, which is only a fraction of its total potential. In Africa only 5% of its estimated hydropower potential has been exploited, making it the most underdeveloped continent in terms of hydropower.

An often overlooked source of hydropower energy is found in conduits, where pressure-reducing stations (PRSs) are installed to dissipate excess energy. The energy dissipated by these devices can instead be captured as hydroelectricity if turbines are installed in the conduits, either by replacing pressure-reducing valves (PRVs) with a turbine, or by installing the turbine in parallel with the PRV.

An initial scoping investigation indicated that significant potential exists for small-scale hydropower installations in water-distribution systems in South Africa. Almost all of the country's municipalities and water-supply utilities have pressure-dissipating stations in their water-distribution systems, where hydropower potential may exist.

This dissertation reflects the development of a Conduit Hydropower Decision Support System (CHDSS), summarised in a series of flow diagrams that illustrate the developmental process (**Figure i(a)** provides an example). A Conduit Hydropower Development (CHD) Tool was developed to facilitate the calculation of necessary factors (the Phase 1 Economic Analysis is shown in **Figure i(b)**). The objective of this CHDSS was to assist municipalities and engineers in identifying conduit hydropower potential in South Africa and to provide proper guidance for the development of potential sites.

The CHDSS (and supporting CHD Tool) were tested at three sites in the City of Tshwane Metropolitan Municipality to verify their applicability in different scenarios. The result was a practical decision support system for conduit hydropower development in South Africa.



(a) (b)

Figure i: Example of the CHDSS process flow diagram and CHD Tool (a); and (b) Phase 1 Economic Analysis

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/abbreviation	Description
AADD	average annual daily demand (Ml/d)
BA	basic assessment
BBEEE	Broad-Based Black Economic Empowerment
B/C	benefit/cost ratio
BHA	British Hydropower Association
BOO	build-own-operate
C_A	investment (capital) cost that is required to implement the alternative A
C_C	cross-flow turbine cost
C_{CC}	construction costs
C_{CE}	civil engineering design cost
CEC	capital expenditure cost

C_{Civil}	civil works cost
C_{CM}	construction management cost
$C_{Contingency}$	contingency cost
C_{CP}	commissioning cost of plant
C_{D}	system design costs
C_{DC}	documentation costs
C_{design}	design costs
C_{E}	electrical cost
C_{EM}	electro-mechanical cost
$C_{environmental\&social}$	costs of environmental and social assessment
C_{ES}	environmental impact scoping cost
$C_{E\&S}$	costs of environmental and social assessment
C_{F1}	Francis turbine cost (function 1)
C_{F2}	Francis turbine cost (function 2)
C_{F3}	Francis turbine cost (function 3)
C_{FixOM}	fixed annual operation and maintenance cost
C_{G}	generator cost
CHD Tool	Conduit Hydropower Development Tool
CHDSS	Conduit Hydropower Decision Support System
C_{I}	installation costs: this includes payment for casting, delivery and mounting of equipment within the civil works
$C_{installation}$	installation costs
$C_{investigation}$	investigation costs
C_{K1}	Kaplan turbine cost (function 1)
C_{K2}	Kaplan turbine cost (function 2)
C_{L}	licensing cost

C_{LCC}	life-cycle cost
$C_{legal\&regulatory}$	legal and regulatory costs
C_{LF}	application and follow-up costs
C_{LR}	legal and regulatory package report cost
C_{M}	mechanical cost
C_{MC}	manufacturing costs
$C_{M\&C}$	mounting and connecting cost
$C_{M\&E}$	mechanical and electrical design cost
CO_2	carbon dioxide
C_{OT}	cost of other turbine types
CoT	City of Tshwane
C_{P}	purchase costs: these include costs of materials and equipment
C_{PB}	project formulation baseline report costs
C_{PEL}	Pelton turbine cost
C_{PM}	project management costs
C_{Pr}	overall project cost
C_{Prop}	propeller turbine cost
$C_{purchase}$	purchase costs
$C_{P/T}$	Pelton or Turgo turbine cost
C_{QC}	quality control costs
C_{S}	start-up costs
C_{SA}	capital cost of the proposed alternative
C_{SC}	logistic support and control cost
C_{SE}	social benefit/dis-benefit evaluation
C_{SK}	Semi-Kaplan turbine cost
C_{ST}	transformer and switchyard cost

$C_{\text{start-up}}$	start-up cost
C_{T}	turbine cost
C_{TC}	equipment transport costs
C_{TE}	equipment transport costs
C_{TOR}	test and evaluation costs
C_{Trans}	transformer cost
$C_{\text{Transmission}}$	transmission cost
C_{TransROW}	transmission right-of-way cost
c_{u}	unit cost
C_{VarOM}	variable operation and maintenance cost
D	diameter of penstock or pipe
Dem	system's daily demand (kWh or MWh)
DBSA	Development Bank of Southern Africa
DME	Department of Minerals and Energy
DoE	Department of Energy
d_{r}	discount rate or escalation rate
DSS	decision support system
EIA	environmental impact assessment
ESHA	European Small Hydropower Association
EUL	expected useful life
FC	fixed cost
F_{v}	final value
g	gravitational acceleration (typically 9.81 m/s^2)
H	effective pressure head (m)
HES	Hydropower Evaluation Software
h_{f}	friction loss (m)

h_l	secondary losses (m)
I	electrical current (A)
IHA	International Hydropower Association
IMQS	Infrastructure Management Query Station
IPC	initial planning cost
IPP	independent power producer
IRP	integrated resource plan
IRR	internal rate of return
K	secondary loss coefficient
L	length of penstock (m)
L_T	transmission line length (miles)
LCC	life cycle cost
M	facility maintenance cost
M_0	facility maintenance cost of the null alternative
M_A	facility maintenance cost of the proposed alternative
n	number of years
N	number of turbines
NERSA	National Energy Regulator of South Africa
NPV	net present value of benefits
OMC	operation and maintenance cost
O&M	operation and maintenance
P	mechanical power output (W)
P_{actual}	actual power output of turbine (W)
$P_{theoretical}$	theoretical output at 100% efficiency (W)
P_1	pressure at Station 1 ($N/m^{2)}$
P_2	pressure at Station 2 (N/m^2)

PRS	pressure-reducing station
PRV	pressure-reducing valve
PW	present worth
PWOC	present worth of cost
Q	flow rate through the turbine (m^3/s)
r	rate at which the left-hand and right-hand sides of the equation are equal, resulting in an NPV of zero
REBID	Renewable Energy Bidding
REFIT	Renewable Energy Feed-In Tariff
ROI	return on investment
RUL	remaining useful life
SANEDI	South African National Energy Development Institute
U	user costs
U_0	user costs of the null alternative
U_A	user costs of the proposed alternative
USA	United States of America
USBR	United States Bureau of Reclamation
V	potential difference (V)
v	velocity of water in penstock or pipe (m/s)
v_1	velocity of the flow at Station 1(m/s)
v_2	velocity of the flow at Station 2 (m/s)
VC	variable costs
Z_1	elevation of the water above datum line, in the streamline at Station 1 (m)
Z_2	elevation of the water above datum line, in the streamline at Station 2 (m)
η	hydraulic efficiency of the turbine (%)
λ	friction coefficient of penstock or pipe (m)
ρ	hydraulic efficiency of the turbine (%)

1 INTRODUCTION

1.1 BACKGROUND

Until recently, when electricity demand exceeded the power-generating capacity, electricity supply in South Africa did not receive much attention from users. This could perhaps be attributed to the success with which Eskom used to provide an uninterrupted supply of electricity to the South African grid. However, the utility's ability to provide 'cheap, reliable and abundant supplies of electricity to meet the demands of the increasingly industrialized economy' (Janisch, 1983), is fast changing. South Africa is currently facing an energy crisis which places additional importance on harvesting energy from all available feasible renewable sources.

The development of renewable energy such as hydropower is therefore vital.

Currently hydropower contributes about 17% of global energy generation. This is only a fraction of its potential. Africa is the most underdeveloped continent with regard to hydropower generation with only 5% of the estimated potential exploited (Price and Probert, 1997; ESHA, 2006; Jonker Klunne, 2011).

The energy found in conduits is often disregarded as a potential source of electricity. In almost every water-transfer scheme and water-distribution system, excess energy can be found in conduits. If this excess energy is not dissipated it may damage the pipeline or other related infrastructure. Pressure-reducing stations (PRSs) are installed to dissipate excess energy at specific points along a conduit, as well as upstream of water-treatment plants and reservoirs. The energy dissipated by these devices can instead be captured as hydroelectricity through the installation of turbines in the conduit.

An initial scoping investigation done by Van Vuuren (2010) indicated that there is substantial potential for pico- (up to 20 kW), micro- (20 kW to 100 kW), and mini- (100 kW to 1 MW) hydropower installations in water-distribution and transfer systems in South Africa. The country has 284 municipalities and various water-supply utilities, almost all of which have pressure-dissipating stations in their water-distribution systems, where hydropower may be generated.

1.2 PROBLEM STATEMENT

Currently there is no substantial development in South Africa's conduit hydropower market, despite its significant potential. A lack of both knowledge and technical understanding of conduit hydropower has been identified as a major contributing factor to the lack of development. The need for a user-friendly system to guide municipalities and potential power producers through the process of conduit hydropower development was therefore identified.

1.3 HYPOTHESIS

It was hypothesised that a user-friendly Conduit Hydropower Decision Support System (CHDSS) could be written to facilitate the process of conduit hydropower development, specifically in South Africa. The CHDSS could be structured to guide potential power producers through the necessary developmental requirements in a step-by-step manner. It could be illustrated visually using process flow diagrams and could be supported by an Excel-based tool to simplify the necessary calculations.

1.4 OBJECTIVES OF STUDY

The objective of this study was to develop a Conduit Hydropower Decision Support System (CHDSS) which would assist municipalities and engineers in identifying conduit hydropower potential in South Africa, as well as providing proper guidance for the development of identified sites. The objective was divided into four components:

- Firstly, the procedural approach including all relevant practical, technical and economic aspects of conduit hydropower had to be established and communicated visually.
- Secondly, a Conduit Hydropower Development Tool (CHD Tool) had to be formulated as a Microsoft Excel-based spreadsheet to facilitate the calculations necessary for conduit hydropower development, focusing on hydropower potential and the review of economic feasibility.
- Thirdly, all the aspects of the CHDSS had to be discussed and guidance given on the calculation and implementation of each of the aspects.
- Fourthly, the developed CHDSS had to be tested and validated using case studies.

1.5 SCOPE OF THE STUDY

This study entailed the development of a CHDSS for investigation and development of conduit hydropower in pressurised bulk-supply and distribution systems in South Africa, with a specialised focus on municipal systems. The CHDSS included developmental procedures for three phases of conduit hydropower development, namely pre-feasibility; feasibility; and detailed design.

The evaluation of various financing options fell beyond the scope of this thesis. The internal rate of return (IRR) and net present value (NPV) methods were deemed sufficient as they constitute the main evaluation metrics of a basic financial cost-benefit analysis.

1.6 METHODOLOGY

To achieve the objectives the following methodology was used:

- Comprehensive research on small-scale conventional and conduit hydropower was conducted. This included the attendance of conferences and workshops to assess current trends and potential developments in the small hydropower industry, as well as a literature review.
- The information gathered in the literature review was included in the formation of a CHDSS. A systematic approach was followed for the development of the CHDSS to ensure that all relevant factors, including all practical, technical and economic aspects of conduit hydropower, were considered. The procedure for determining hydropower potential was illustrated through a series of flow diagrams, divided into three phases:
    - First Phase: Pre-Feasibility Investigation
    - Second Phase: Feasibility Study
    - Third Phase: Detailed Design
- For each phase the CHDSS process flow diagram was linked to a Conduit Hydropower Development Tool (CHD Tool) that incorporates the thought process and calculations of each phase. This CHD Tool was developed as a Microsoft Excel spreadsheet aimed at guiding designers through conduit hydropower project development by including all the relevant calculations in a user-friendly format.
- All the aspects of the CHDSS were discussed in a guideline format. Each section of the guideline was linked to a correlating step in one of the CHDSS flow diagrams. The purpose of this guide was to elaborate on the necessary steps of the process and to guide users in the application of these steps.
- The CHDSS was tested at three sites in the City of Tshwane Metropolitan Municipality with differing characteristics and its applicability was thereby confirmed for a variety of sites.

- The result of this dissertation was a practical CHDSS for conduit hydropower development in South Africa.

1.7 ORGANISATION OF THE REPORT

The report consists of the following chapters and appendices:

- Chapter 1 presents an introduction to the report. It provides the background to the study; the problem statement; the study objective and scope; and the methodology followed during the study.
- Chapter 2 is a literature review focusing on various aspects pertaining to hydropower, specifically small-scale and conduit hydropower. These aspects include: the fundamentals of hydropower potential evaluation and development; economic analysis methods; hydropower evaluation tools; and case studies. This chapter also provides background information on the current and projected energy situations in South Africa.
- Chapter 3 explains the procedural approach to the development of the Conduit Hydropower Decision Support System (CHDSS), illustrated by using flow diagrams and supported by a Microsoft Excel-based Conduit Hydropower Development Tool (CHD Tool).
- Chapter 4 describes all the aspects of the developed CHDSS.
- Chapter 5 provides a discussion of the three case studies conducted on sites in the City of Tshwane Metropolitan Municipality's water-distribution network, using the developed CHDSS and CHD Tool.
- Chapter 6 serves as a conclusion of the study and includes recommendations for implementation and identifies areas that need to be researched in subsequent studies.
- Chapter 7 lists the references used in the study.
- Appendix A includes the relevant NERSA and Eskom application forms.
- Appendix B provides a list of turbines, including their ranges and manufacturers.
- Appendix C explains all the assumptions and cost functions used in the CHD Tool.
- Appendix D provides an example of a completed NERSA Electricity Generation Application Form.
- Appendix E includes the calculations used in the three case studies.

2 LITERATURE REVIEW

2.1 ENERGY SITUATION IN SOUTH AFRICA

2.1.1 BACKGROUND

Until fairly recently, electricity supply in South Africa has not received much attention from users. This could perhaps be attributed to the success with which Eskom used to provide an uninterrupted supply of electricity to the South African grid. However, the utility's ability to provide 'cheap, reliable and abundant supplies of electricity to meet the demands of the increasingly industrialized economy' (Janisch, 1983), is fast changing. Presently, South Africa is facing an energy crisis which places additional importance on harvesting all available feasible renewable energies. The rolling power outages that hit the country at the start of 2008 made all citizens aware of the fact that demand for electricity is now grossly outpacing supply.

Worldwide there is still a vast dependence on fossil fuels to generate electricity, the most abundant fossil resource being coal (Lloyd and Subbarao, 2009). Eskom's document 'Understanding Electricity' (Eskom, 2013a) indicates that in South Africa, approximately 90% of electricity provided is generated in coal-fired power stations. This is due to the relative abundance, availability and the low cost to mine coal in the country, thereby making other forms of electricity generation largely unfeasible. As stated by the Department of Minerals and Energy (DME) (2003), South Africa relies heavily on coal and has developed an 'efficient, large-scale, coal-based power generation system that provides low-cost electricity' across the country. The result is that coal will remain economically viable and will continue to be the most attractive source of energy in South Africa from a financial perspective for many more years. However, from an environmental and sustainability perspective, feasible alternative sources of energy need to be explored and evaluated against the relative environmental cost of coal (Evans et al., 2009).

2.1.2 CURRENT SOURCES OF ENERGY IN SOUTH AFRICA

Other than coal-fired power stations, electricity supplied in South Africa is also generated in nuclear power stations, hydroelectric schemes, pumped storage schemes, open cycle gas turbines and wind farms. The most recent figures for the breakdown of GWh produced in South Africa by the different electricity generation technologies were found in a report published by Statistics South Africa (2012). This report reflected electricity generation in South Africa in 2011. A total of 240 528 GWh was produced.

Eskom generates 95% of South Africa's electricity with the remaining 5% made up by a small group of private individuals who generate mainly for their own use (DME, 2007). Eskom owns 11 coal-fired power stations (with two more currently under construction), a nuclear power station, two pumped storage schemes (with a third under construction), six hydroelectric power stations, one wind farm (with one under construction) and four open cycle gas-fired turbines which are used only for peak demands (Eskom, 2012a). **Figure 2-1** shows the net maximum generating capacity mix of the different technologies. The locations of the various power stations in South Africa are shown in **Figure 2-2**.

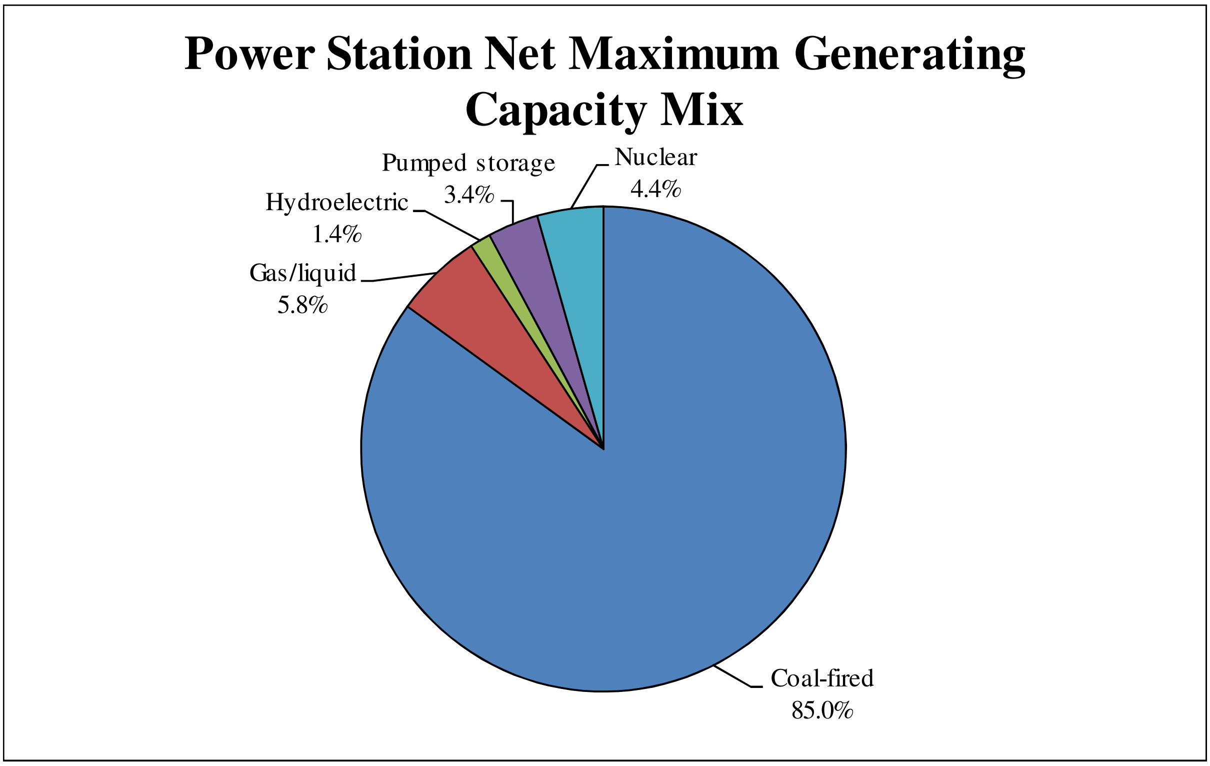


Figure 2-1: Power station net maximum generating capacity mix (Eskom, 2012a)

Table 2-1: Eskom operated hydropower stations in South Africa (Eskom, 2008a; Eskom, 2012a)

Station name	Power output
Gariep	360 MW
Vanderkloof	240 MW
First Falls	6.4 MW
Second Falls	11 MW
Ncora	2.4 MW
Colley Wobbles	42 MW

Figure 2-2: Location of Eskom's power stations in South Africa (Eskom 2008a; Eskom, 2012a)

2.1.3 ELECTRICITY PRICE INCREASES

For many years, the average increase in electricity tariffs in the country was below inflation. However, this situation changed in 2003, as indicated in **Figure 2-3** (Eskom, 2007). Since April 2008, electricity tariff increases have been significantly above inflation every year, with inflation-adjusted prices increasing about threefold between 1997 and 2012, as illustrated in **Figure 2-4**. NERSA has recently approved an average annual tariff increase of 8% for the next five years until April 2017. This will result in an average electricity tariff increase of more than 220% between 1997 and 2017 (Eskom, 2012b; Eskom 2012e; Eskom 2013b), as shown in **Figure 2-5**.

The main reason for the significant hike in electricity prices is because electricity generation has been subsidised for many years. It was therefore supplied at below cost to consumers. However, this practice is not sustainable and electricity prices need to become cost-reflective to support a sustainable industry in future (Eskom, 2012b).

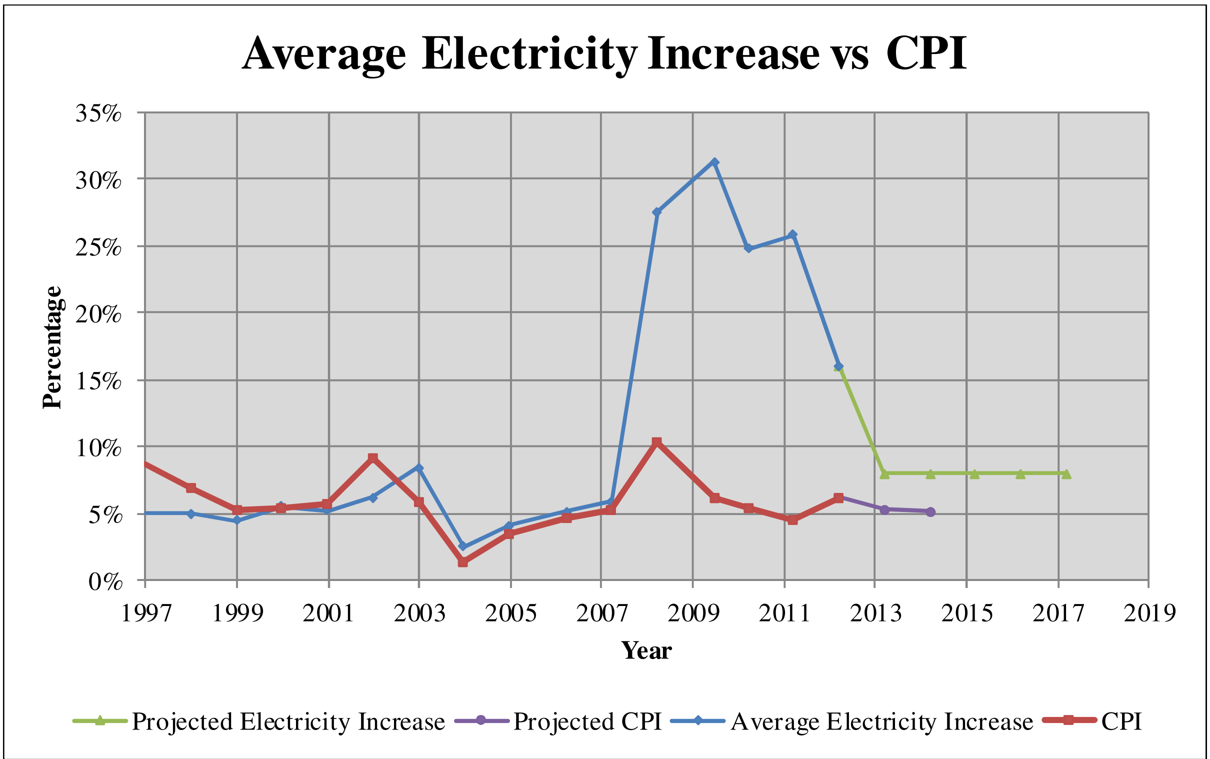


Figure 2-3: Average energy increases vs. CPI (Eskom, 2007; 2012b; Eskom 2012e; National Treasury, 2012; Eskom 2013b)

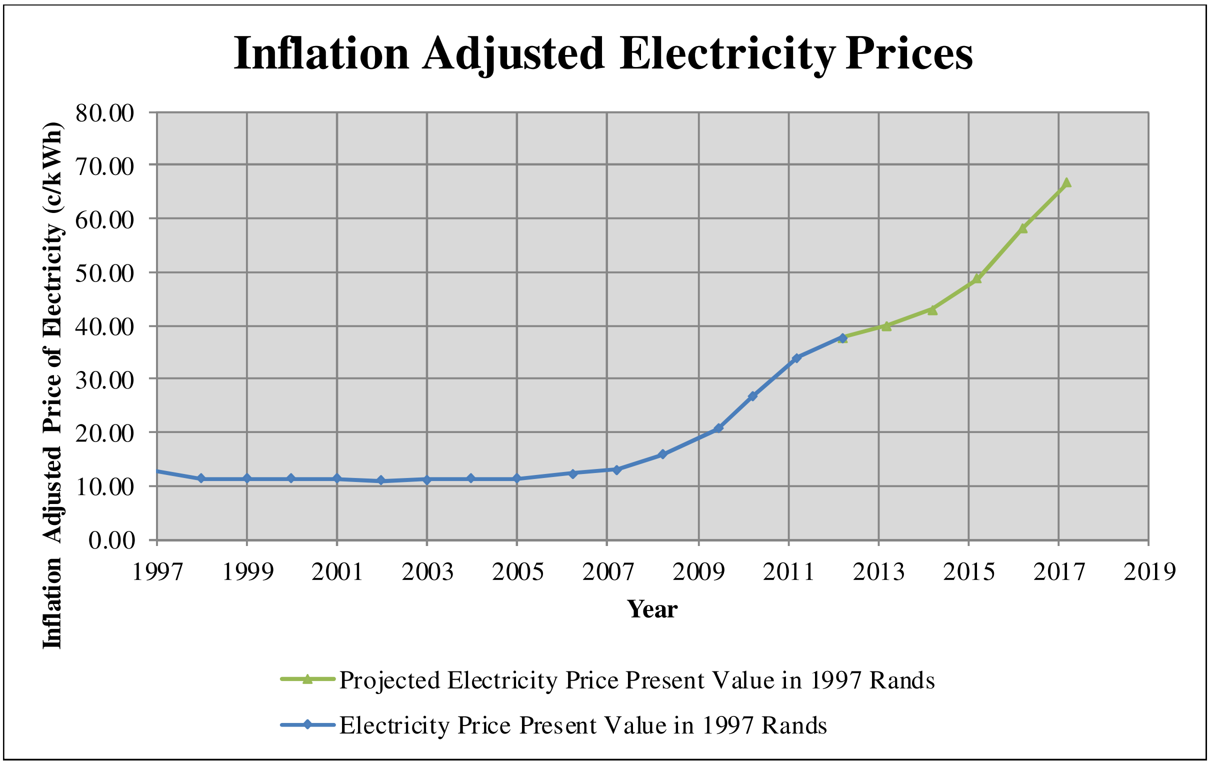


Figure 2-4: Inflation-adjusted electricity prices (Eskom, 2007; 2012b; Eskom 2012e; National Treasury, 2012; Eskom 2013b)

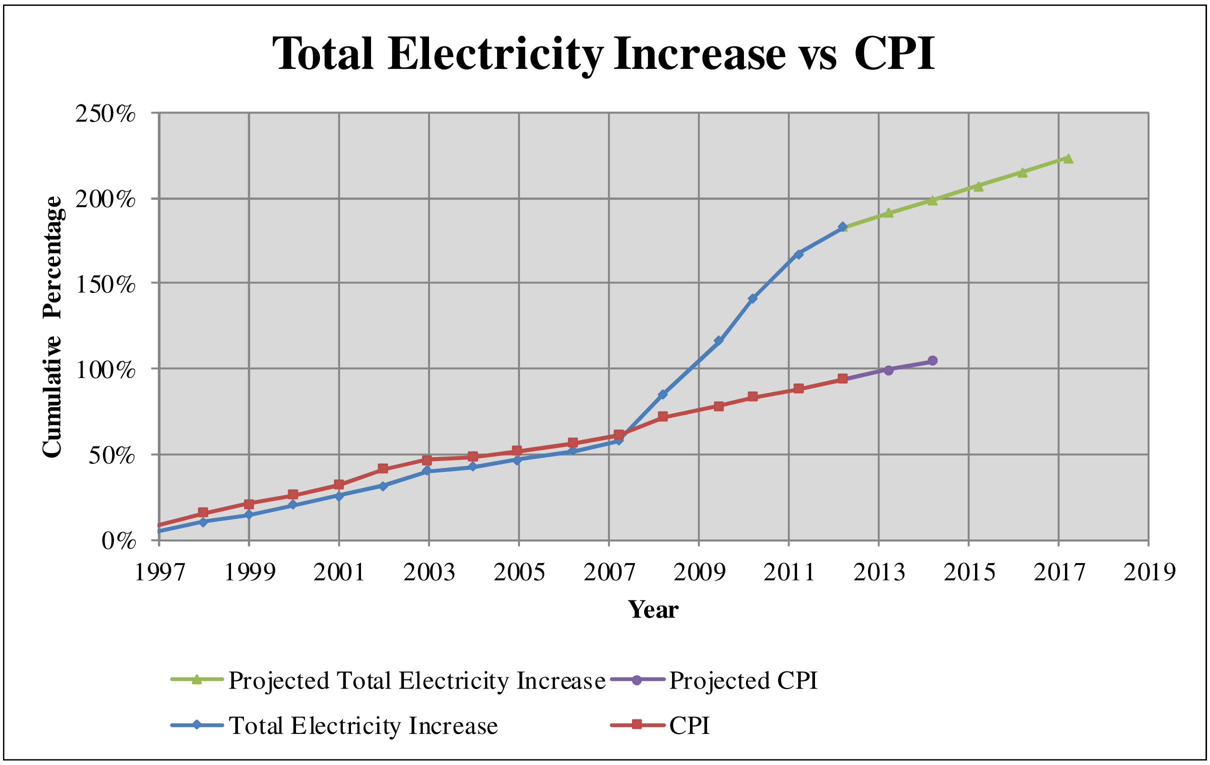


Figure 2-5: Total energy increases vs. CPI (Eskom, 2007; 2012b; Eskom 2012e; National Treasury, 2012; Eskom 2013b)

2.1.4 CURRENT ELECTRICITY PRICES IN SOUTH AFRICA

Eskom has different tariff structures for various users. These structures include: Nightsave, Megaflex, Miniflex, Public Lighting and Business Rate (for urban applications); Ruraflex, Nightsave, Landrate and Landlight (for rural applications); and Homepower and Homelight (for residential applications) (Eskom, 2012c).

As an example, the electricity cost for a local authority that uses the Megaflex tariffs is shown in **Figure 2-7**, with the peak and off-peak periods depicted in **Figure 2-6**. In this tariff structure, charges are levied for (Eskom, 2012c):

- Active energy use charge (paid per kWh of used and divided into peak- , standard-, and off-peak times and correlated to voltage used and distance from Johannesburg).
- Rural and environmental charges (paid per kWh).
- Reactive energy charge ('applicable for every kilovar-hour (kVArh) registered higher than 30% of the kWh used during peak and standard periods' (Eskom, 2012c) during high-demand season).
- Distribution network demand charge (paid for the demand supplied during peak and standard periods per delivery point, per month).
- Distribution network access charge (paid monthly and based on the greater of the notified maximum demand and yearly capacity used, per delivery point).
- Service charge (paid monthly and based on a daily rate per account).
- Administration charge (paid for each point of delivery and based on a daily rate).

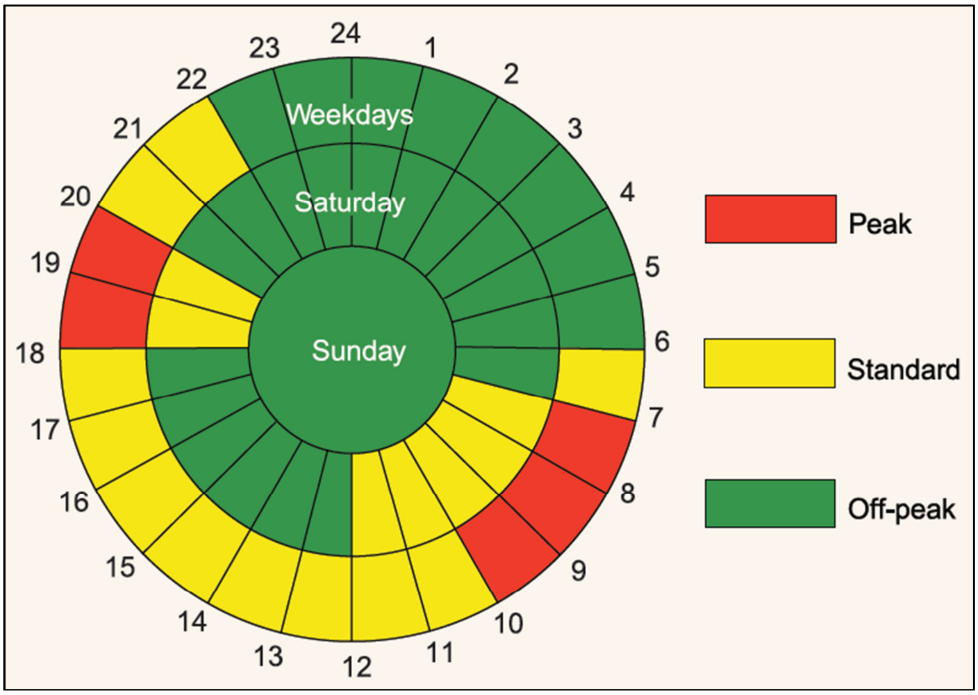


Figure 2-6: Eskom's defined time periods for Megaflex (Eskom, 2012c)

		Active energy charge [c/kWh]												Transmission network charges [R/kVA/m]	
Transmission zone	Voltage	High demand season [Jun - Aug]						Low demand season [Sep - May]							
		Peak		Standard		Off Peak		Peak		Standard		Off Peak			
			VAT incl		VAT incl		VAT incl		VAT incl		VAT incl		VAT incl		VAT incl
≤ 300km	< 500V	216.99	247.37	56.37	64.26	30.10	34.31	60.54	69.02	37.06	42.25	25.89	29.51	R 5.40	R 6.16
	≥ 500V & < 66kV	210.06	239.47	54.61	62.26	29.16	33.24	58.65	66.86	35.95	40.98	25.13	28.65	R 4.94	R 5.63
	≥ 66kV & ≤ 132kV	202.47	230.82	52.68	60.06	28.18	32.13	56.58	64.50	34.70	39.56	24.28	27.68	R 4.81	R 5.48
	> 132kV	195.39	222.74	50.91	58.04	27.28	31.10	54.65	62.30	33.55	38.25	23.53	26.82	R 6.09	R 6.94
> 300km and ≤ 600km	< 500V	219.14	249.82	56.90	64.87	30.37	34.62	61.13	69.69	37.39	42.62	26.15	29.81	R 5.46	R 6.22
	≥ 500V & < 66kV	212.11	241.81	55.12	62.84	29.43	33.55	59.22	67.51	36.26	41.34	25.36	28.91	R 4.98	R 5.68
	≥ 66kV & ≤ 132kV	204.44	233.06	53.18	60.63	28.47	32.46	57.13	65.13	35.01	39.91	24.51	27.94	R 4.84	R 5.52
	> 132kV	197.32	224.94	51.42	58.62	27.52	31.37	55.19	62.92	33.86	38.60	23.69	27.01	R 6.15	R 7.01
> 600km and ≤ 900km	< 500V	221.28	252.26	57.44	65.48	30.61	34.90	61.70	70.34	37.75	43.04	26.37	30.03	R 5.52	R 6.29
	≥ 500V & < 66kV	214.23	244.22	55.64	63.43	29.71	33.87	59.77	68.14	36.59	41.71	25.58	29.16	R 5.04	R 5.75
	≥ 66kV & ≤ 132kV	206.47	235.38	53.69	61.21	28.71	32.73	57.65	65.72	35.32	40.26	24.73	28.19	R 4.89	R 5.57
	> 132kV	199.30	227.20	51.86	59.12	27.79	31.68	55.74	63.54	34.17	38.95	23.92	27.27	R 6.23	R 7.10
> 900km	< 500V	223.48	254.77	58.00	66.12	30.92	35.25	62.29	71.01	38.08	43.41	26.63	30.36	R 5.54	R 6.32
	≥ 500V & < 66kV	216.33	246.62	56.18	64.05	29.98	34.18	60.35	68.80	36.92	42.09	25.84	29.46	R 5.09	R 5.80
	≥ 66kV & ≤ 132kV	208.53	237.72	54.19	61.78	28.97	33.03	58.21	66.36	35.68	40.68	24.95	28.44	R 4.91	R 5.60
	> 132kV	201.26	229.44	52.37	59.70	28.01	31.93	56.22	64.09	34.49	39.32	24.15	27.53	R 6.27	R 7.15

Electrification and rural subsidy [c/kWh]		Environmental levy charge [c/kWh]				Reactive energy charge [c/kvarh]			
All seasons		Apr 2012 to Jun 2012		Jul 2012 to Mar 2013		High season		Low season	
	VAT incl		VAT incl		VAT incl		VAT incl		VAT incl
4.56	5.20	2.00	2.28	3.50	3.99	8.72	9.94	0.00	0.00

Distribution network charges				
Voltage	Network access charge [R/kVA/m]		Network demand charge [R/kVA/m]	
		VAT incl		VAT incl
< 500V	R 10.80	R 12.31	R 20.49	R 23.36
≥ 500V & < 66kV	R 9.90	R 11.29	R 18.78	R 21.41
≥ 66kV & ≤ 132kV	R 9.59	R 10.93	R 18.20	R 20.75
> 132kV	R 0.00	R 0.00	R 16.41	R 18.71

Monthly utilised capacity	Service charge [R/Account/day]		Administration charge [R/POD/day]	
		VAT incl		VAT incl
> 1 MVA	R 123.36	R 140.63	R 55.59	R 63.37
Key customers	R 2 417.62	R 2 756.09	R 77.20	R 88.01

Figure 2-7: Megaflex local authority rates 2012-2013 (Eskom, 2012c)

2.1.5 RENEWABLE ENERGY IN SOUTH AFRICA

With South Africa experiencing serious electricity shortages in recent years, it has become essential to accelerate the plans for future electricity development. The Cabinet approved the Integrated Resource Plan (IRP) for Electricity (2010 – 2030) as the basis for South African power generation for the next 20 years.

The approved plan is geared towards a low carbon future and aligned with the country's long-term mitigation scenarios in line with national government's aspiration. It is envisaged that 42% of the new build programme, excluding the current committed Eskom build programme, will be from renewable energy sources between 2011 and 2030 (Eskom, 2011a). By 2030, it is anticipated that the percentage of energy generated from CO_2-free sources (including nuclear energy) will be nearly 30% (Eskom, 2011a). South Africa has significant potential for renewable energy production in many forms, as shown in **Figure 2-8**.

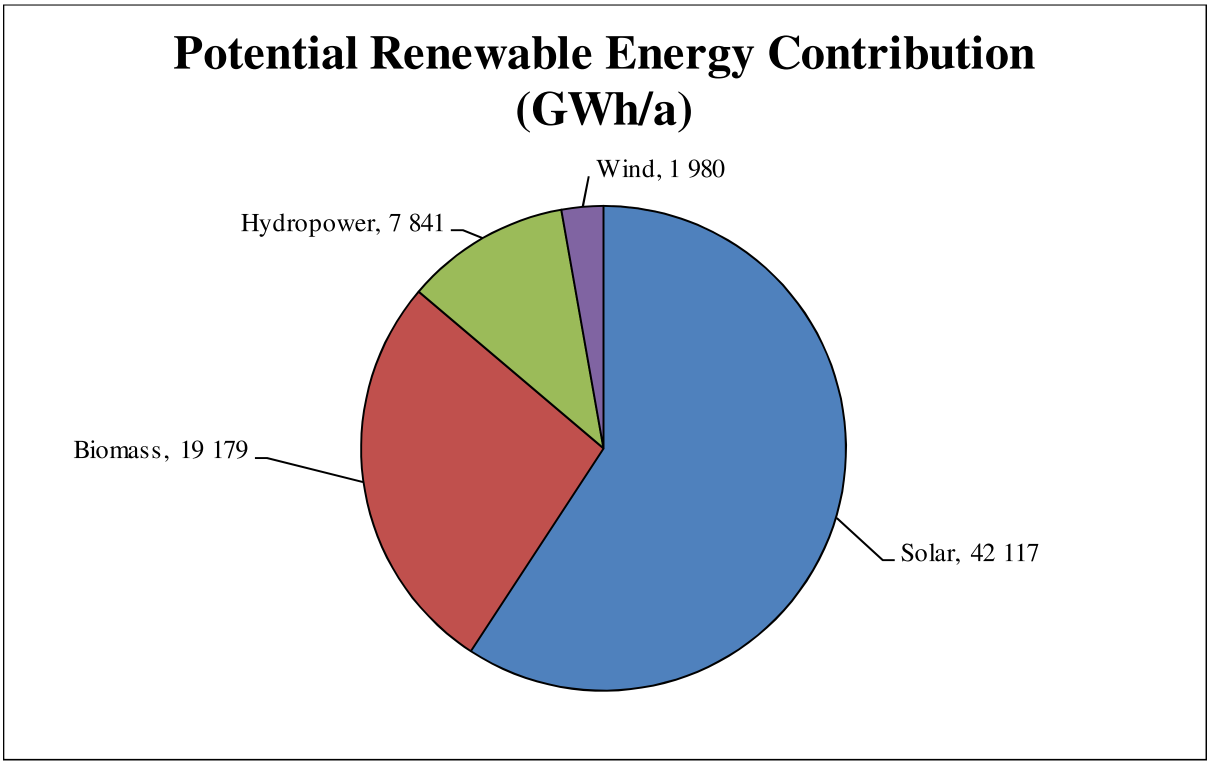


Figure 2-8: Potential contribution of different forms of renewable energy (DME, 2003)

2.1.6 CHALLENGES FOR RENEWABLES IN SOUTH AFRICA

In the past, one of the major stumbling blocks for hydropower development in South Africa has been economic feasibility, due to Eskom's low renewable energy tariffs. However, the government has had to reconsider these tariffs due to the country's level of carbon emissions, coal reliance and energy crisis (Reuters, 2009).

Therefore the National Energy Regulator of South Africa (NERSA) announced a set of Renewable Energy Feed-In Tariffs in March 2009. This was primarily aimed at covering generation costs, while allowing for sufficiently attractive profit potential to stimulate investment (NERSA, 2009). The initial REFIT tariff for small hydropower was 94c/kWh but was reduced to 67.1c/kWh in March 2011.

The Department of Energy (DoE), with endorsement from NERSA, introduced the Integrated Resource Plan (IRP) for Electricity for South Africa 2010 – 2030. After a public participation process a Final Policy Adjusted IRP 2010: New-Build Technology Mix was adopted. The DoE allocated a total of 3 725 MW for development, divided among various renewable energy technologies. The hydropower sector has been allocated 75 MW to be commercially operational by June 2014 based on a REBID scheme where IPPs would competitively tender to implement projects. This Renewable Energy Bidding (REBID) scheme replaced the REFIT scheme (DoE, 2011).

Some of the specific challenges that developers are faced with in the REBID process include (Viljoen and Wilson, 2011):

- Vague selection criteria
- Strict bidding conditions
- Limited experience on the part of the procurement authority
- Lack of equitable rules, costs and transparency of energy transport over the grid
- Sophisticated grid-code requirements for small generators

2.2 AN OVERVIEW OF HYDROPOWER

2.2.1 INTRODUCTION

The following section will provide background information on various conventional and unconventional types of hydropower. Hydropower size classification, the potential for hydropower development in South Africa and the advantages of hydropower over other energy generation methods will also be discussed.

2.2.2 CONVENTIONAL TYPES OF HYDROPOWER

Normally one would associate hydropower generation with large dams and associated generating facilities; however, hydropower can be generated in various ways. The common denominator in all schemes is flowing and falling water (Natural Resources Canada, 2004). The following sections will describe the different types of conventional hydropower schemes, including: storage schemes; run-of-river schemes; pumped storage schemes; and tidal hydropower.

2.2.2.1 Storage schemes

Conventional hydropower depends on water from a reservoir that can provide power when needed, either to meet a fluctuating demand or a peak load. Dams are associated with significant environmental impacts and are normally only constructed for large-scale projects, as dam construction makes small schemes economically unfeasible.

However, small schemes may be retrofitted, or planned, in dams that are built for other purposes, like flood control, irrigation, recreation or water abstraction. In some cases, electricity can be generated with the discharges associated with the dam's fundamental use or ecological flows (ESHA, 2004).

2.2.2.2 Run-of-river schemes

Run-of-river schemes involve the diversion of either a portion or all of a river flow through a turbine to generate electricity; or turbines are installed directly in a river channel (Harvey et al., 1993). Therefore, the hydropower plant can only use the water that is available in the natural river flow.

In some irrigation canal systems, turbines can be installed to generate electricity, either through diversion or in the canal system itself. These systems will normally consist of high-flow, low-head installations (ESHA, 2004).

2.2.2.3 Pumped storage schemes

Pumped storage schemes are used to generate peak-time electricity. During off-peak hours water is pumped to an upper dam and when peak-time electricity is needed this water is released through turbines and released into a lower dam. More energy is required in the pumping phase than energy generated and this makes these systems net energy consumers (Egré and Milewski, 2002).

However, some recent projects have utilised hybrid systems where pumped storage is combined with a renewable energy, like wind power, with high generation randomisation. These schemes use the upper dam of a pumped storage system as a battery while renewable energy is generated. The stored water is then released through the turbines when electricity is needed (Bueno and Carta, 2006).

2.2.2.4 Tidal hydropower

Hydropower generation utilising tidal energy is also a growing industry. Low-head turbines and wheels are used to extract energy from unconstrained, reversible water currents, found in oceans and tidal estuaries (Gorlov, 2002).

2.2.3 HYDROPOWER IN DISTRIBUTION SYSTEMS

According to Van Dijk et al. (2012a), there are 5 areas with energy-generation potential in the water-supply and -distribution systems. These are shown in **Figure 2-9** and summarised below:

1. Dam releases
2. Water-treatment works (raw water)
3. Potable water at reservoirs (PRV)
4. Potable water at pressure-reducing stations (PRSs) in the supply network
5. Treated effluent

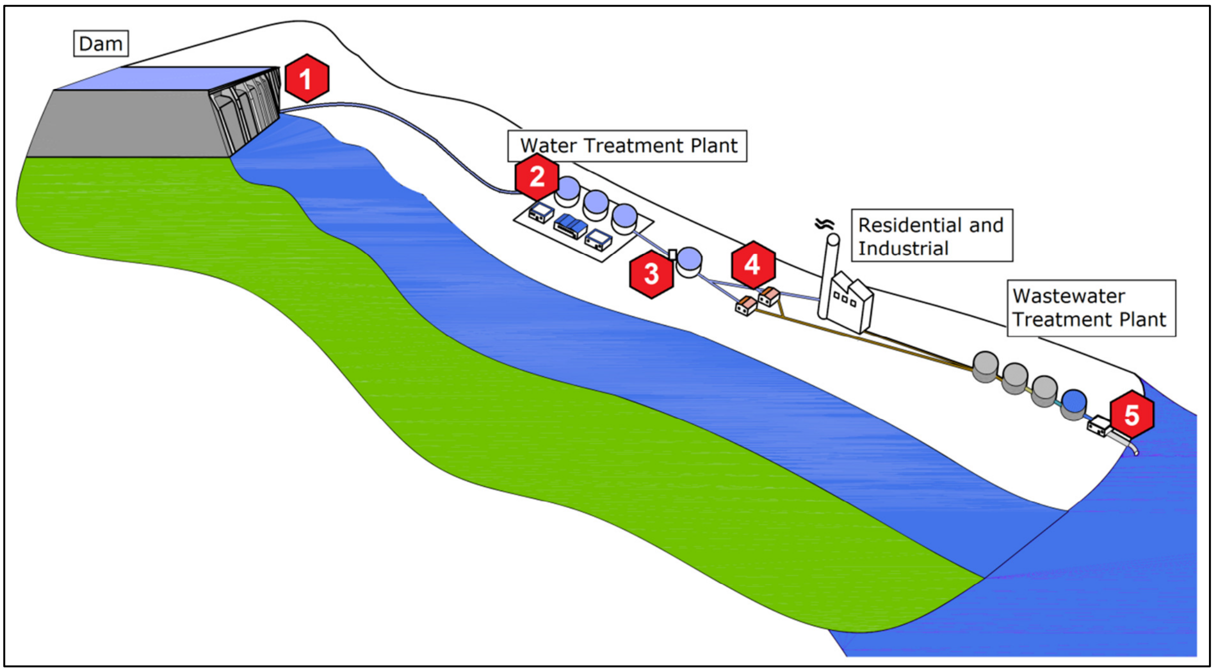


Figure 2-9: Potential energy-generation locations in WDS (Van Dijk et al., 2012a)

2.2.4 ADVANTAGES OF HYDROPOWER

Hydropower has the following advantages over other forms of energy production in terms of economic, social, and environmental impacts:

- Firstly, hydropower is a form of clean renewable and sustainable energy as it makes use of the energy in water due to flow and available head, without actually consuming the water itself. Unlike the burning of coal, oil and natural gas, it does not emit any atmospheric pollutants such as carbon dioxide, sulphurous oxides, nitrous oxides or particulates such as ash (Frey and Linke, 2002).
- Secondly, hydropower schemes often have very long operational lifetimes (50 years or more) and high efficiency levels (70% to 90%) (BHA, 2005).
- Operating costs per annum can be as low as 1% of the initial investment costs (Oud, 2002).

- A fourth advantage is that hydropower schemes often have more than one purpose. Hydropower through water storage can help with flood control and supply water for irrigation or consumption, and dams constructed for hydropower can also be used for recreational purposes (Frey and Linke, 2002).
- Different forms of hydropower, including reservoir, pumped storage and run-of-river systems of different sizes, are available and can be used for different forms of electricity generation (IHA, 2005).

2.2.5 HYDROPOWER SCHEME SIZE CLASSIFICATION

Presently, there is no universally accepted classification system for hydropower scheme sizes (Jonker Klunne, 2012a). In some cases, all installations smaller than 20 MW, or even 25 MW, are referred to as ‘small’, although 10 MW is common. According to Taylor and Upadhyay (2005) ‘mini-hydro typically refers to schemes below 1 MW, micro-hydro below 100 kW and pico-hydro below 5 kW’. However, it seems that in the South African context, the classification given in **Table 2-2** tends to be the standard.

Table 2-2: Hydropower classification (Barta, 2002)

Category	Power output
Pico	Up to 20 kW
Micro	20 kW to 100 kW
Mini	100 kW to 1MW
Small	1 MW to 10 MW
Macro (or large)	>10 MW

In addition to power-output classification, a scheme can also be categorised according to the type of layout, considering the type of hydropower, as discussed in **Chapter 2.2.2**, as well as the head (as described in **Table 2-3**).

Table 2-3: Scheme classification according to head (ESHA, 2004)

Classification	Head (m)
High head	>100
Medium head	30-100
Low head	2-30

2.3 HYDROPOWER POTENTIAL IN SOUTH AFRICA

2.3.1 INTRODUCTION

Worldwide, hydropower is the most established and reliable renewable energy technology. Traditionally, hydropower is used in large dams where the outlet flow is used to spin a turbine to generate electricity. However, South Africa has rather limited conventional water resources suitable for large-scale hydropower projects. Still, small hydropower has played a historically significant role in the implementation of electricity projects both in South Africa and the rest of the continent, with the first project in South Africa being a 300 kW station on Table Mountain in 1895 (Barta, 2002).

Unfortunately, many of the small-scale hydropower stations have fallen into disrepair. In many cases in South Africa, this was due to the availability of cheap and reliable electricity from Eskom at the time, but in others it was because of poor maintenance and general neglect (Jonker Klunne and Michael, 2010).

2.3.2 CURRENT SITUATION

An overall assessment of hydropower potential in South Africa was conducted in a baseline study in 2002. The information collected in this study ‘enabled the formation of a much needed hydropower potential database for the future reference and planning of water resources development in South Africa’ (Barta, 2002). The capacity of installed hydropower and future potential for hydropower development are summarised in **Table 2-4**.

An ‘African Hydropower Database’, with a section focusing on South African hydropower installations can be accessed on the Internet (Jonker Klunne, 2013a).

Table 2-4: Assessment of hydropower according to feasible categories (Barta, 2002)

Hydropower category	Installed capacity	Potential for development	
		Firm	Long-tern
(Power output range)	**(MW)**	**(MW)**	**(MW)**
Pico (up to 20 kW)	0.02	0.10	60.20
Micro (20 kW to 100 kW)	0.10	0.40	3.80
Mini (100 kW to 1 MW)	8.10	5.50	5.00
Small (1 MW to 10 MW)	25.70	63.00	25.00
Subtotal for pico/micro/mini and small hydro	**33.92**	**69.00**	**94.00**
Large conventional hydropower (>10 MW)			
• Run-of-river (e.g. direct intake weir)	-	1 200	150
• Diversion fed (e.g. pipe, canal or tunnel)	-	3 700	1 500
• Storage regulated head (e.g. barrage or dam)	653	1 271	250
Total for renewable hydropower in SA	**687**	**5 160**	**1 994**
Large pumped storages (>10 MW)	1 580	7 000	3 200
GRAND TOTAL (for all hydropower in SA)	**2 267**	**12 160**	**5 194**
Imported macro hydroelectricity (>10 MW)	800	1 400	35 000 (+)
Note: This table does not include the potential for development in distribution systems.			

2.3.3 DEVELOPMENT OPPORTUNITIES

Barta (2002) indicated that different types of hydropower would be appropriate for development in various regions in South Africa. The list of potential hydropower types includes:

- Rehabilitation or upgrading of existing hydropower installations (approximately 11 MW).
- Run-of-river hydropower schemes (approximately 270 MW).
- Conventional storage hydropower plants (approximately 1 500 MW).
- Pumped storage schemes (more than 10 000 MW).
- Tidal hydropower (potential not available).

- Imported hydropower, mainly from the Democratic Republic of the Congo and Zambia (more than 36 000 MW).

An initial scoping investigation by Van Vuuren (2010) indicated that significant potential exists for pico/micro/mini hydropower installations in supply distributions in South African municipalities. The country has 284 municipalities and various water-supply utilities, most of which have pressure-dissipating stations in their water-distribution systems, where hydropower potential exists.

2.4 FUNDAMENTALS OF HYDROPOWER POTENTIAL EVALUATION

2.4.1 PLANNING

When planning a hydropower plant, important information to be gathered includes: the available head; the proximity of the site to a grid connection; possible environmental impacts; regulatory requirements; public inquiry; construction requirements; electricity use; and cost implications of the planned system (Natural Resources Canada, 2004; ESHA, 2004; BHA, 2005).

It is also important to assess the organisational and technical capability of the future operators of a planned scheme. Micro-hydropower schemes are often installed in rural communities, far away from the skills centres of the cities. Therefore a sound management system should be an integral part of the planning phase (Harvey et al., 1993).

Harvey et al. (1993) proposes the following golden rule for feasibility phase planning: 'O[peration and] M[aintenance] first, plant factor second, engineering design last.' It is essential to include a full operation and maintenance study in the planning stages.

2.4.2 PRACTICABILITY OF SITES

The first step in planning a hydropower plant would be to identify potential sites. According to Natural Resources Canada (2004), '[t]he best geographical areas for (conventional) micro-hydropower systems are those where there are steep rivers, streams, creeks or springs flowing year-round, such as in hilly areas with high year-round rainfall.'

A hydropower scheme is dependent on both the flow through the system and the head drop through the system (Harvey et al., 1993). It is important to gather sufficient data to determine the design flow and head. Power and energy requirements should also be examined to determine the necessary capacity of the turbine and the applicability of the chosen site (Natural Resources Canada, 2004).

2.4.3 BASIC COMPONENTS

Conventional micro-hydropower systems typically include civil works, like dams, spillways, energy dissipating structures, intakes, de-siltation systems, channels, penstocks, powerhouses and tailraces. The electromechanical components include turbines, generators, drive systems and controllers (ESHA, 2004). Electrical components consist of grid connections and the distribution network (Natural Resources Canada, 2004).

The basic components of a typical small hydropower system are illustrated in **Figure 2-10** (Natural Resources Canada, 2004). The basic components of conventional hydropower systems will be discussed in more detail in **Chapter 2.5**.

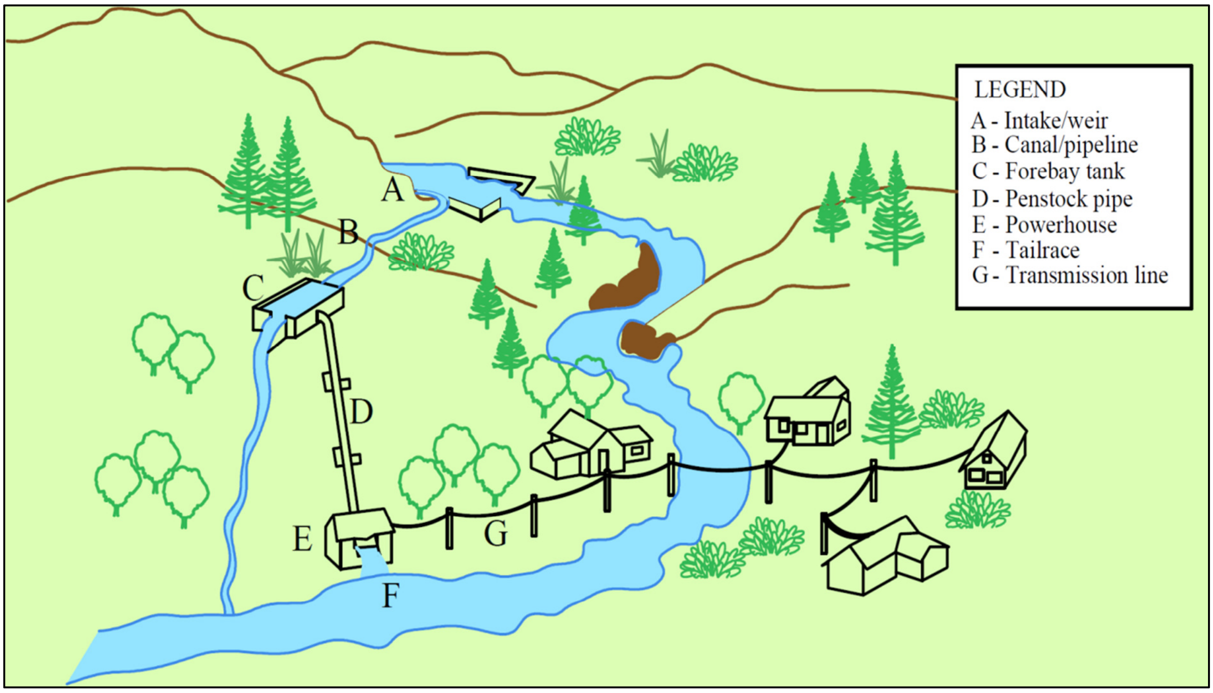


Figure 2-10: Typical run-of-river hydropower components (Natural Resources Canada, 2004)

2.4.4 POWER CALCULATION

2.4.4.1 Relevant Equations

Hydropower works on the principle that water pressure is used to rotate a mechanical shaft in the hydro turbine. This rotation is used to power a generator that converts the energy into electricity. The potential power output of a hydropower installation is directly proportional to the flow (m^3/s) and available pressure head (m), as illustrated in **Equation 2-1** (BHA, 2005):

$$P=\rho gQH\eta \qquad \textbf{Equation 2-1}$$

where:

P = mechanical power output (W)

ρ = density of water (kg/m^3)

g = gravitational acceleration (9.81 m/s^2)

Q = flow rate through the turbine (m^3/s)

H = effective pressure head across the turbine (m)

η = hydraulic efficiency of the turbine (%)

Bernoulli's energy equation is based on the principle of conservation of energy and can be used to calculate the variation in pressure and velocity along any continuous streamline (Chadwick et al., 2004). The energy equation, accounting for losses in the streamline, is shown in **Equation 2-2**, with the equations for friction and secondary losses given in **Equation 2-3** and **Equation 2-4**, respectively.

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2+h_f+h_l$$ **Equation 2-2**

where:

P_1 = pressure at Station 1 (N/m^2)

ρ =density of water (kg/m^3)

g = acceleration due to gravity (m/s^2)

v_1 = velocity of the flow at Station 1 (m/s)

Z_1 = elevation of the water above datum line, in the streamline at Station 1 (m)

P_2 = pressure at Station 2 (N/m^2)

v_2 = velocity of the flow at Station 2 (m/s)

Z_2 = elevation of the water above datum line, in the streamline at Station 2 (m)

h_f = friction loss (m)

h_l = secondary losses (m)

and

$$h_f=\frac{\lambda L V^2}{2gD}$$ **Equation 2-3**

$$h_l=\frac{KV^2}{2g}$$ **Equation 2-4**

where:

h_f = friction loss (m)

h_l = secondary losses (m)

λ = friction coefficient of penstock or pipe (m)

L = length of penstock (m)

v = velocity of water flow in penstock pipe (m/s)

g = acceleration due to gravity (m/s^2)

D = diameter of penstock or pipe (m)

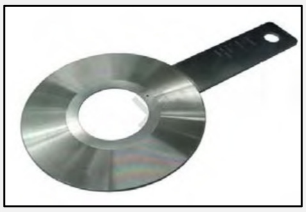
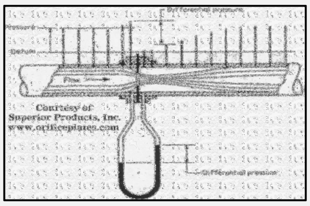
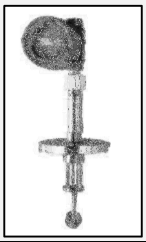
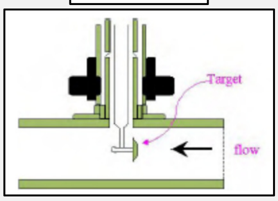
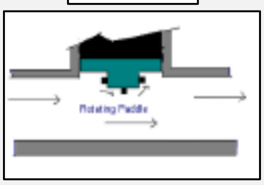
K = secondary loss coefficient (K is normally 0.5 at inlet and 1 at outlet)

2.4.4.2 Flow and pressure measurement

A measuring weir is typically used for river flow measurement and the available head determined using the height difference between upstream and downstream water surfaces (BHA, 2005). However, as the focus of this study is on conduit hydropower, flow and pressure measurement in pipes will be discussed in detail.

Flow in pipes can be measured using various types of meters. **Table 2-5** was adapted from Down (2002) and provides a summary of some typical flow meters and their applications. **Table 2-6** provides a comparison between the usefulness of the various flow meters in different circumstances (Down, 2002).

Table 2-5: Typical flow meters (Down, 2002)

Flow-meter type	Description	Figures	Discussion
Differential flow meter	Based on differential pressure as a liquid passes through a flow restriction in the pipe. Orifice plates and venturis are typical examples.	 	Differential flow meters are seen as reliable instruments, but they have the disadvantage of restricting flow. Maintenance is necessary once or twice yearly to ensure that the opening has not become rougher or larger.
Target flow meter	These instruments have an object, or 'target' centred in the conduit that measures flow rate by the force imposed on the target.	 	This type of flow meter also causes a flow restriction, but less so than an orifice plate or venturi.
Propeller flow meter	Flow meters with axial vanes that spin at a rate correlating to flow rate can also be used.	 	These meters cannot be used in conduits with impurities or solids, as damage to the propeller must be avoided. However, in clean water they are very reliable and accurate if placed in a straight section.

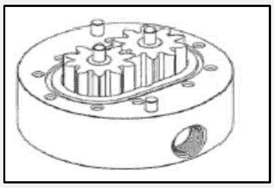
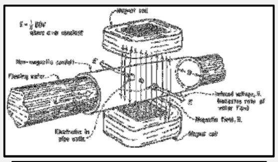
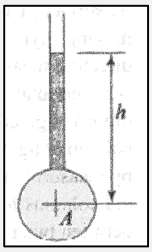
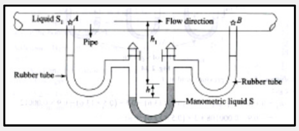
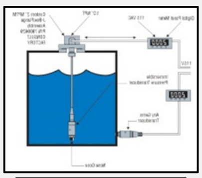
Volumetric flow meter	Volumetric meters measure flow by counting the filling and discharging of fixed volumes of liquid.	 	These meters are typically used for small quantities. As with other intrusive meters, erosion will occur with time.
Magnetic flow meters	Flow velocity is determined by a magnetic field.	 	These meters have to be used with conductive fluids and an electrically insulated pipe. This meter is not intrusive and therefore does not constrict flow.
Ultrasonic flow meters	This meter is clamped onto a pipe and emits an ultrasonic signal that is echoed from a particle in the water. The transit time is used to determine flow velocity.		These meters are lightweight and can be clamped to any pipe and removed again easily. This meter is not intrusive and therefore does not constrict flow.

Table 2-6: Flow-meter selection (Down, 2002)

Flow-meter type	High viscosity	Particulate	Turbulence	Large flow turn-down
Differential	Poor	Poor-fair	Poor	Poor
Propeller	Poor	Poor	Fair	Very good
Volumetric	Very good	Fair	Good	Very good
Magnetic	Very good	Very good	Very good	Good
Ultrasonic	Very good	Very good	Very good	Fair

Pressure can be measured with a number of different instruments (**Table 2-7**). Bourdon and diaphragm transducers can be set to read gauge or absolute pressures and can be used with dial gauges or electronic logging systems (Gems Sensors and Controls, 2013).

Table 2-7: Typical pressure transducers (Ojha et al., 2010; Gems Sensors and Controls, 2013)

Pressure transducer type	Description	Figures	Discussion
Piezometer	This is one of the simplest forms of pressure measurement and consists of a glass tube inserted in the wall of a pipe and its other end is open to the atmosphere.		There are various limitations to this device, including the impracticality of reading very high pressure (due to the long tube necessary) or negative pressure (unless altered).
Manometer	These instruments use liquid columns for measuring pressure at a point, or differential pressure between two points or systems.		These devices can measure rapid pressure changes, large pressures and negative pressure.
Bourdon gauge	This type of gauge uses a hollow tube that changes its curvature as the liquid pressure changes. This in turn rotates the gauge dial.		These devices are commonly used, as they can measure positive and negative pressures accurately.
Diaphragm gauge	This type of gauge uses a diaphragm that deforms as pressure changes. This is transmitted to a pointer that records the pressure.	 	These devices are commonly used, as they can measure positive and negative pressures accurately.

2.4.5 FLOW-DURATION CURVES

In order to determine the design flow rate to be used in the power equation, flow-duration curves have to be drawn. These curves indicate the probability of the amount of days per annum that a certain flow will be exceeded. Below are two typical examples of flow-duration curves. **Figure 2-11** shows a stream with a short seasonal variation between the base flow and maximum flow and **Figure 2-12** shows a river with more variation in flow during the year (Natural Resources Canada, 2004; BHA, 2005).

Distribution system pipelines will have flow-rating curves correlating with system demand. However, system demand will vary daily, weekly and monthly, depending on peak water-use times of system users.

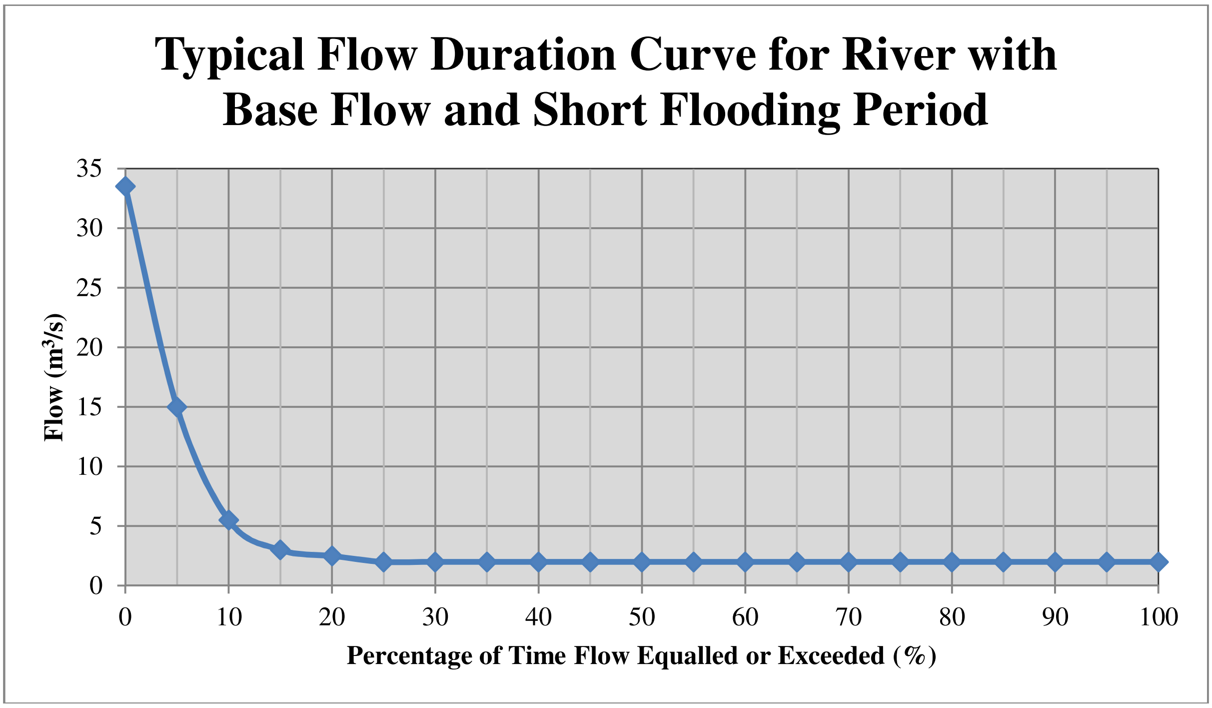


Figure 2-11: Flow-duration curve for river with base flow and short flooding period (Natural Resources Canada, 2004)

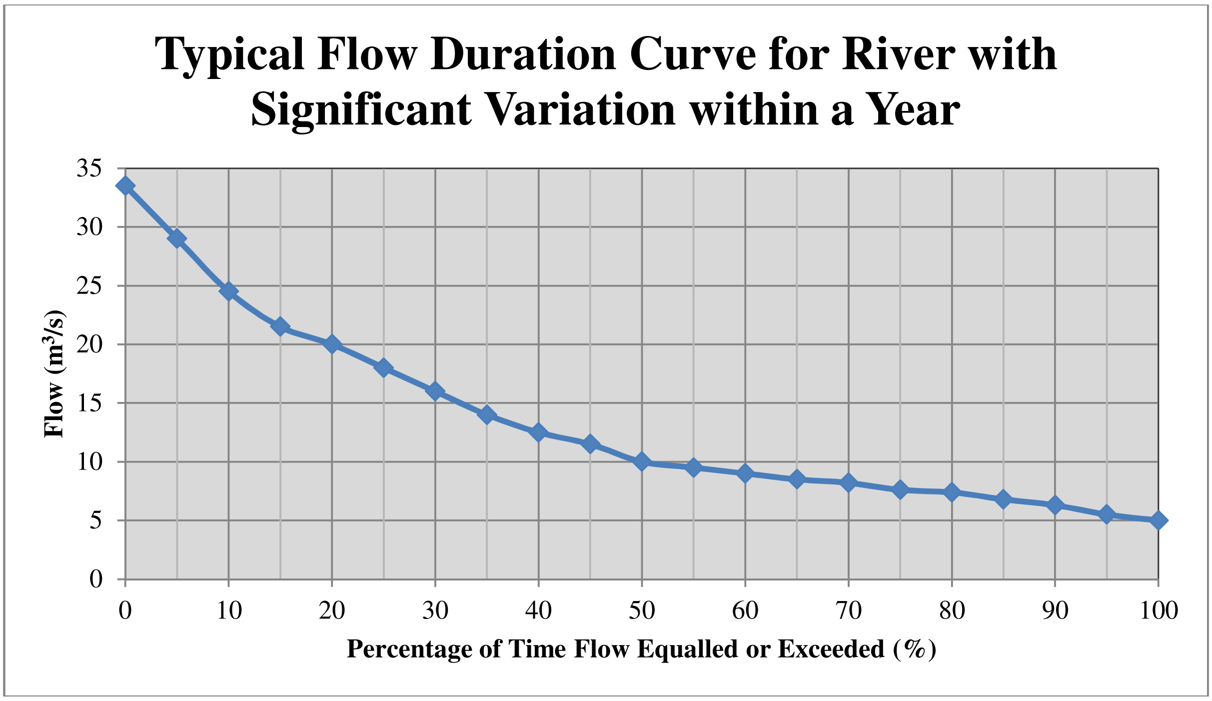


Figure 2-12: Flow-duration curve for low flow variation (Natural Resources Canada, 2004)

2.4.6 EFFICIENCY

The ratio between electricity output and input, at a specific time, is the electric power plant efficiency of a generator. The efficiency of a hydropower turbine can be calculated by comparing the actual power output with the theoretical output at 100% efficiency, as shown in **Equation 2-5:**

$$\eta = \frac{P_{actual}}{P_{theoretical}}$$ **Equation 2-5**

where:

η = hydraulic efficiency of the turbine (%)

P_{actual} = actual power output (W)

$P_{theoretical}$ = theoretical power output (W)

The actual electrical output of the turbine can be determined by multiplying the current of the electric flow by its potential difference:

$$P = IV$$ **Equation 2-6**

where:

P = electrical power output (W)

I = electrical current (A)

V = potential difference (V)

Harvey et al. (1993) proposes the following losses as typical system losses for a scheme operating at design flow (**Figure 2-13**).

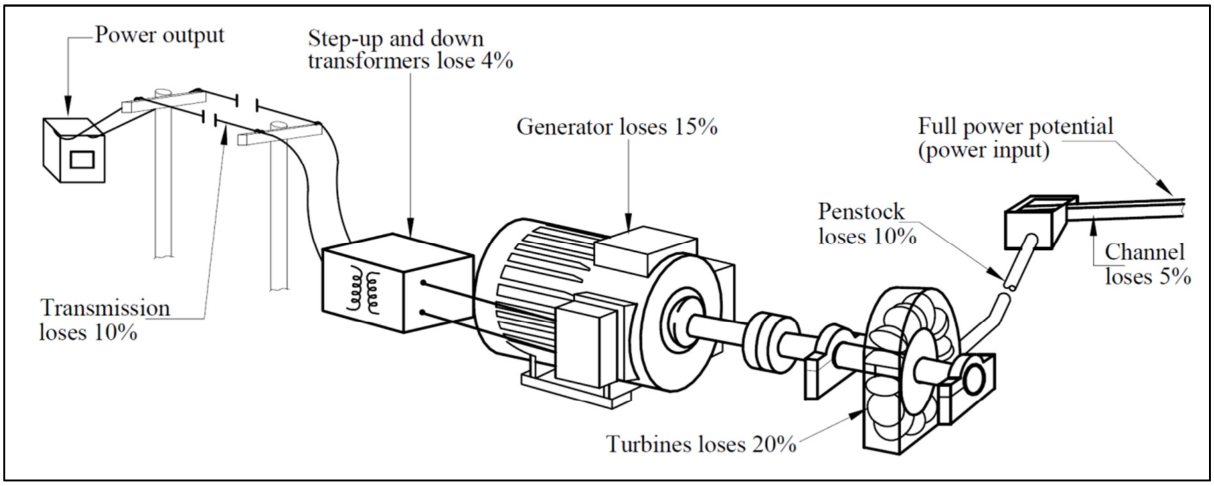


Figure 2-13: System losses (Harvey et al., 1993)

However, Natural Resources Canada (2004) proposes better efficiency ranges for turbines (**Table 2-8**) and ESHA (2004) proposes better efficiencies for small generators (**Table 2-9**). The BHA (2005) states that micro-hydro system efficiency tends to be between 60% and 80%, with 70% considered a typical efficiency.

Table 2-8: Typical efficiencies of turbines and water wheels (Natural Resources Canada, 2004)

Prime mover	Efficiency range (%)
Impulse turbines:	
Pelton	80-90
Turgo	80-95
Cross-flow	65-85
Reaction turbines:	
Francis	80-90
Pump-as-turbine	60-90
Propeller	80-95
Kaplan	80-90
Waterwheels:	
Undershot	25-45
Breastshot	35-65
Overshot	60-75

Table 2-9: Typical efficiencies of small generators (ESHA, 2004)

Rated power (kW)	Best efficiency (%)
10	91
50	94
100	95
250	95.5
500	96
1 000	97

2.4.7 ENVIRONMENTAL CONSIDERATIONS

The potential environmental impacts of a hydropower scheme need to be studied and mitigated. According to ESHA (2004), the process followed will consider the identification and mitigation of all possible impacts during construction and operation on site, as well as downstream and upstream of the site and due to the transmission lines.

Van Vuuren et al. (2011) conducted an extensive investigation into the potential impacts of retrofitted hydropower. Considered aspects included: land-use and construction impact; temporary and permanent river-diversion impact; the impact of the type of power generation on releases; the impact on aquatic biodiversity; noise impact during construction as well as operation; visual impacts; and social impacts. All other impacts considered, 'there is one major positive environmental consequence in the form of greenhouse gas emission reductions which indirectly affects wildlife, nature and the general public' (Van Vuuren et al., 2011).

The expectations of the public with regard to environmental and social impacts of hydropower have grown significantly over time and are therefore becoming increasingly important (Klimpt et al., 2002). The general areas of consideration in terms of social aspects are:

- The cultural heritage of the site.
- Potential public health threats resulting from changes in downstream flow regimes or changes in the water quality.
- Public acceptance by the community and affected parties to increase buy-in and reduce vandalism.
- Impacts on downstream agricultural activities.
- The balance between community upliftment and the preservation of traditional ways of life.

2.4.8 LEGISLATION AND LICENSING

2.4.8.1 NERSA licensing

According to Section 8 of the Energy Regulation Act (Act 4 of 2006), a licence is required for:

a) 'operat[ion] of any generation, transmission or distribution facility;
b) import or export [of] any electricity; or
c) involve[ment] in trading [of electricity].'

However, Schedule II of this Act exempts certain parties from holding a licence. Exemption is granted to:

1. 'Any generation plant constructed and operated for demonstration purposes only and not connected to an inter connected power supply
2. Any generation plant constructed and operated for own use
3. Non-grid connected supply of electricity except for commercial use.'

The National Energy Regulator of South Africa (NERSA) is responsible for granting energy generation licences in terms of the Energy Regulation Act (Act 4 of 2006). The application form consists of 12 sections that include: the applicant's information; desired commencement date of the licence; details of the generation station; details of arrangements with primary energy suppliers; maintenance programmes and decommissioning costs; customer particulars; financial overview; human resource particulars; other relevant regulatory permits; information on the Broad-Based Black Economic Empowerment (BBBEE) status of the project; any additional relevant information; and a declaration of accuracy. An example of the application form can be viewed in **Appendix A** (NERSA, 2006).

A similar application form exists for energy distribution licences in terms of the Energy Regulation Act (Act 4 of 2006). This application form consists of 11 sections that include: the applicant's information; desired commencement date of the licence; area of operation under the licence; details of the distribution system; maintenance programmes; customer particulars; financial overview; human resource particulars; other relevant regulatory permits; information on the Broad-Based Black Economic Empowerment (BBBEE) status of the project; and any additional relevant information (NERSA, 2007). An example of the application form can also be viewed in **Appendix A.**

2.4.8.2 Eskom grid connection

In addition to NERSA licensing requirements, permission should be granted by Eskom if the generator will be synchronised with an Eskom grid. To obtain permission, the applicant should complete the relevant application form (Eskom, 2011b) (attached in **Appendix A**) and comply with Eskom's interconnection standard (Eskom, 2008b) (which can also be viewed in **Appendix A**). The process can be summarised as follows (the complete Eskom *Guide for IPP Grid Application Process* is given in **Appendix A**) (Eskom, 2011c):

1. Complete the application form
2. Submit the application form
3. Obtain a quotation from Eskom
4. Accept the budget quote and sign the connection and use of system agreement
5. Connect and use the system

2.4.8.3 REFIT and REBID

In March 2009 NERSA announced the South African Renewable Energy Feed-in Tariff (REFIT) Programme. The primary objective of this programme was to cover generation costs with allowance for a profit potential that is sufficiently attractive to stimulate investment (NERSA, 2009).

In December 2009, the Department of Energy (DoE) with the endorsement from NERSA introduced the Integrated Electricity Resource Plan (IRP) for South Africa 2010 – 2030. The IRP 2010 was subjected to public scrutiny and comments and eventually the entire process resulted in a Final Policy Adjusted IRP 2010: New-Build Technology Mix (Viljoen and Wilson, 2011).

However, in August 2011 Government abandoned the REFIT process in favour of REBID, a competitive bidding process where tariff caps are applied for specific generation technologies. On 3 August 2011, the DoE issued the first order of the renewable energy capacity of 3 725 MW allocated entirely to independent power providers (IPPs) under the new competitive bidding procurement programme intended to be implemented in several phases (DoE, 2011).

Between 2011 and 2012 the DoE received 79 project proposals during the first and second bidding windows which closed in March 2012. The total renewable energy capacity potential amounted to more than 3 200 MW. From a rather large number of proposals only 19 preferred bidders were selected to develop a potential capacity of a 1 044 MW. Among the preferred projects were one concetrated solar power (CSP), nine solar photovoltaic (PV) projects, seven onshore wind projects, and two small scale hydropower projects. The preferred small scale hydropower projects included Stortmelk Hydro Project with proposed capacity of 4.3 MW situated on the Ash River in the Free State province and the Neusberg Hydro-electric Project to install 10 MW hydropower capacity on the Orange River in the Northern Cape province (DoE, 2013).

2.4.8.4 Water-use licensing

According to the National Water Act (Act 36 of 1998), water-use licensing is required in various cases. The cases that may be applicable to hydropower generation include:

a) 'taking water from a water resource;
b) storing water;
c) impeding or diverting the flow of water in a watercourse;' (Section 21)
d) 'a power generation activity which alters the flow regime of a water resource;' (Section 37) and
e) 'disposing of waste in a manner of water which contains waste from, or which has been heated in, any industrial or power generation process.' (Section 21)

But, Section 22 states *inter alia* that water may be used without a licence 'if that water use is permissible as a continuation of an existing lawful use'. Municipalities and water boards should have existing water-use licences and therefore Section 22 will apply to conduit hydropower in their distribution systems.

2.4.8.5 Environmental impact assessments

According to the National Environmental Management Act (Act 107 of 1998), an environmental impact assessment (EIA) and scoping report are needed before specific construction activities may commence and a basic assessment (BA) is a requirement for other specific construction activities. The main difference between the two assessment methods is that the scoping and EIA process is more detailed and time-consuming than the BA process. Therefore, an EIA is normally required for larger or more environmentally sensitive projects than a BA.

The regulations were studied and the activities possibly related to the construction of a conduit hydropower plant are listed in **Table 2-10**. It should be noted that additional provincial regulations or by-laws are applicable that have not been listed.

It is anticipated that most conduit hydropower installations in distribution systems in South Africa will fall below both EIA and BA requirements, although these regulations, as well as provincial regulations and by-laws should be studied when project feasibility is determined.

Table 2-10: Extract from Environmental Impact Assessment Regulations, 2010

Activities that require basic assessment		Activities that require scoping and EIA	
Activities listed in Government Notice 544 of 18 June 2010		**Activities listed in Government Notice 545 of 18 June 2010)**	
1	The construction of facilities or infrastructure for the generation of electricity where: i. The electricity output is more than 10 megawatts but less than 20 megawatts; or ii. The output is 10 megawatts or less but the total extent of the facility covers an area in excess of 1 hectare.	1	The construction of facilities or infrastructure for the generation of electricity where the electricity output is 20 megawatts or more.
9	The construction of facilities or infrastructure exceeding 1000 meters in length for the bulk transportation of water, sewage or storm water – i. With an internal diameter of 0.36 meters or more; or ii. With a peak throughput of 120 litres per second or more, Excluding where: a. Such facilities or infrastructure are for bulk transportation of water, sewage or storm water or storm water drainage inside a road reserve; or b. Where such construction will occur within urban areas but further than 32 meters from a watercourse, measured from the edge of the watercourse		
10	The construction of facilities or infrastructure for the transmission and distribution of electricity – i. Outside urban areas or industrial complexes with a capacity of more than 33 but less than 275 kilovolts; or ii. Inside urban areas or industrial complexes with a capacity of 275 kilovolts or more.	8	The construction of facilities or infrastructure for the transmission and distribution of electricity with a capacity of 275 kilovolts or more, outside an urban area or industrial complex.

12	The construction of facilities or infrastructure for the off-stream storage of water, including dams and reservoirs, with a combined capacity of 50 000 cubic metres or more, unless such a storage falls within the ambit of activity 19 of Notice 545 of 2010.		
23	The transformation of undeveloped, vacant or derelict land to – i. Residential, retail, commercial, recreational, industrial or institutional use, inside an urban area, and where the total area to be transformed is 5 hectares or more, but less than 20 hectares; or ii. Residential, retail, commercial, recreational, industrial or institutional use, outside an urban area and where the total area to be transformed is bigger than 1 hectare, but less than 20 hectares; - Except where such transformation takes place for linear activities.		
24	The transformation of land bigger than 1000 square meters in size, to residential, retail, commercial, industrial or institutional use, where, at the time of the coming into effect of the Schedule such land was zoned for open space, conservation or had an equivalent zoning.		
29	The expansion of facilities for the generation of electricity where: i. The electricity output will be increased by 10 megawatts or more, excluding where such expansion takes place on the original development footprint; or ii. Regardless the increased output of the facility, the development footprint will be expanded by 1 hectare or more.		

37	The expansion of facilities or infrastructure for the bulk transportation of water, sewage or storm water where: i. The facility or infrastructure is expanded by more than 1000 meters in length; or ii. Where the throughput capacity of the facility or infrastructure will be increased by 10% or more – Excluding where such expansion: a. Relates to transportation of water, sewage or storm water within a road reserve; or b. Where such expansion will occur within urban areas but further than 32 metres from a watercourse, measured from the edge of the watercourse.		
41	The expansion of facilities or infrastructure for the off-stream storage of water, including dams and reservoirs, where the combined capacity will be increased by 50 000 cubic metres or more.		
52	The expansion of facilities or infrastructure for the transfer of water from and to or between any combination of the following: i. Water catchments ii. Water treatment works; or iii. Impoundments Where the capacity will be increased by 50 000 cubic metres or more per day, but excluding water treatment works where water is treated for drinking purposes.	10	The construction of facilities or infrastructure for the transfer of 50 000 cubic metres or more water per day, from and to or between any combination of the following: i. Water catchments, ii. Water treatment works; or iii. Impoundments, Excluding treatment works where water is to be treated for drinking purposes.

2.4.8.6 Public participation process

According to the National Environmental Management Act (Act 107 of 1998), a public participation process must be conducted as part of an environmental impact assessment (EIA) or basic assessment (BA), before specific construction activities may commence. Additional municipal and provincial by-laws are also applicable. Government Notice 543 of 18 June 2010 explains the process and requirements.

2.4.9 ECONOMICS

According to Natural Resources Canada (2004), the cost for micro-hydropower schemes can be divided into two categories, namely initial and annual costs. Initial costs include all costs that are incurred before electricity is generated. This includes: feasibility study costs, equipment and construction costs and permitting costs. Annual costs include all operation and maintenance costs.

Another cost categorisation might be between fixed costs (like capital cost, insurance and some taxes), and variable costs, that include operation and maintenance expenses (ESHA, 2004).

Several aspects need to be taken into account when considering micro-hydropower plant implementation. Various tools can be used to evaluate this. One indicator would be to determine the cost per kilowatt of power generated. Another commonly used tool would be to determine the net present value (NPV) of the system (Natural Resources Canada, 2004).

It is important to take note that hydropower plants generally have greater initial investment cost per kilowatt generated than, for example, coal-fired plants. However, the operating costs of hydropower plants are significantly lower than those of coal-fired plants, mainly because there is no need to pay for fuel. Therefore it is important to consider the life-cycle costing of the scheme. The economics of hydropower schemes will be discussed in more detail in **Paragraph 2.8**(ESHA, 2004).

2.4.10 INSTALLATION, OPERATION AND MAINTENANCE

The installation phase is generally the most expensive phase in a conventional micro-hydropower system. Before this phase is commenced, all planning, licences, permits and detailed designs should be finalised. During installation effective project management is of the utmost importance. (Natural Resources Canada, 2004)

If operation and maintenance are carried out efficiently, this phase should not be associated with high cost and many man-hours used. 'It is good practice and cost-effective to perform preventive maintenance rather than wait for the system to fail. A well-maintained micro-hydropower system can provide an uninterrupted power supply for many years' (Natural Resources Canada, 2004).

Therefore, it is proposed that various documents be incorporated in an operation and maintenance manual that is provided to the system operator upon completion. This manual should include sections on: operation; components; installers' details and specifications; maintenance schedules; repair guidelines; log books; and training material (Harvey et al., 1993).

It is important that appropriate equipment be chosen that can be repaired easily and for which spare parts are readily available. This is especially true in rural installations (Harvey et al., 1993).

2.5 CONVENTIONAL HYDROPOWER SCHEME COMPONENTS

2.5.1 INTRODUCTION

Although the components of a conduit hydropower plant will differ, conventional hydropower was studied, as there are similarities. The similarities will be discussed in the summary at the end of the chapter. The components found in hydropower schemes can normally be grouped into two broad categories, namely civil work components and electrical and mechanical components. The following paragraphs will discuss these components in more detail.

2.5.2 CIVIL WORKS

Conventional hydropower schemes consist of a number of structures or combinations of structures, depending on the type and layout of the scheme. The following civil components will normally be found: diversion structure, including dams, spillways, fish passes and residual flow arrangements and conveyance systems, including intakes, canals, tunnels, penstocks and powerhouses (ESHA, 2004).

2.5.2.1 Dam

Dams or weirs are used to store and divert flow into the conveyance system and therefore to the turbine. Dams also ensure additional storage capacity and head. Dams can be constructed from a number of different materials and in a number of different forms. Site topography, environmental considerations, dam safety and budgetary constraints will be the main aspects to consider during dam design. Dams are associated with significant environmental impacts and are normally only constructed for large-scale projects, as dam construction makes small schemes economically unfeasible (ESHA, 2004).

2.5.2.2 Intake

A water intake must direct the required amount of water into a canal, with as little head loss as possible. It is carefully planned to ensure that the full design flow is diverted to the turbine (Natural Resources Canada, 2004). The handling of debris and sediment is an important, but challenging aspect to consider. During the design phase it is important to consider operation and maintenance of the structure.

In a run-of-river or storage system, the location of the intake will depend on various factors, including submergence, geotechnical conditions, environmental concerns, and sediment and debris exclusion. It should have a trash rack, sediment trap, gate and a spillway for the diversion of excess water (ESHA, 2004; BHA, 2005).

2.5.2.3 Trash rack and sediment trap

As the names imply, trash racks and sediment traps are structures to prevent debris and sediment from entering the turbine units. Traditionally trash screens consist of a combination of a floating boom placed across the flow path upstream of the intake to catch large debris and a panel with bars in front of the intake, with the bars spaced to allow raking of the screen. As the screen causes energy (head) loss, the bars should be installed with the maximum spacing to still prevent debris that could damage the turbine from passing through. Automatic cleaners can also be installed (BHA, 2005).

Although the trash rack will remove most of the large debris in the system, it will not eliminate sediment suspended in the water. Therefore, a sediment trap is installed downstream of the intake, to ensure that sedimentation does not occur in downstream structures or that the sediment does not damage the turbine. The sediment trap reduces the flow velocity and turbulence of the water and allows sedimentation to occur where it can be managed (ESHA, 2004).

2.5.2.4 Canals and tunnels

From the intake, water is conveyed to the penstock and ultimately the turbine using a system of canals or tunnels, or a combination. It is important to minimise the head losses in these conveyance structures, by providing smooth lining and regularly shaped conduits (ESHA, 2004).

2.5.2.5 Penstock

A penstock is the pipe that carries water from the conveyance system to the turbine. A variety of materials (like plastics, steel, iron, fibreglass or concrete) and installation techniques (above or below ground) can be used for penstocks. The selected materials are determined by site layout, pipe diameter, ground conditions, budgetary constraints etc. The penstock's diameter must be selected to minimise friction losses (which result in lost energy production). The pressure class should be taken to handle the maximum pressure, including possible surge pressures that might occur (ESHA, 2004).

2.5.2.6 Powerhouse

The purpose of the powerhouse is to support the turbines and electrical equipment, as well as to protect them from the weather. A powerhouse therefore has a substructure for support and a superstructure for protection. The superstructure contains all the operating equipment, including the turbines, generators, electrical control units, transformer and switching gear (Price and Probert, 1997). Powerhouses are normally constructed from concrete or other conventional building materials, but in the case of very small systems, might even be a prefabricated container. Space should be provided for easy maintenance and potential future expansion.

2.5.2.7 Tailrace

A tailrace is used to convey the water from the turbine back to the river (Price and Probert, 1997). It is important to ensure that the tailrace is properly protected against erosion, and also that the tailrace will not allow water to rise into, and interfere with, the turbine runner (in the case of an impulse turbine) (ESHA, 2004).

2.5.3 TURBINE TYPES

A turbine uses the energy of moving water to generate electricity by converting the kinetic energy of the water into rotational energy used to power the generator (Paish, 2002).

Turbines can be classified according to their type of action as either impulse or reaction turbines. Impulse turbines are surrounded by air while reaction turbines are submerged in water (Paish, 2002). **Table 2-11** provides a summary of the classification of turbines.

Table 2-11: Groups of water turbines (Natural Resources Canada, 2004)

Turbine runner	High head	Medium head	Low head	Ultra-low head
	> 100 m	20 m - 100 m	5 m - 20 m	< 5m
Impulse	Pelton Turgo	Cross-flow Turgo Multi-jet Pelton	Cross-flow Multi-jet Turgo	Water wheel
Reaction	-	Francis Pump-as-Turbine	Propeller Kaplan	Propeller Kaplan

- Impulse turbines use runners that are rotated using water jets at high velocities. The three main types are the Pelton, Turgo and cross-flow (or Banki) turbines. Pelton turbines are used for pressure-head ranges of between 50 m and about 1 300 m, and usually have very good efficiencies (ESHA, 2004). Turgo turbines use smaller diameter runners to obtain similar results at heads of between 50 m and 250 m (Paish, 2002) and can operate at flows significantly lower than the design flow, giving them high flexibility. Cross-flow (or Banki-Michell) turbines can be used for pressure heads of between 5 m and 200 m, but have a lower efficiency than other turbines (ESHA, 2004).
- Reaction turbines use the flow of water to generate hydrodynamic force that in turn rotates the runner blades. The most used reaction turbines are the propeller (or Kaplan) and the Francis turbine (Paish, 2002). Kaplan turbines are used in applications where the pressure head is

between 2 m and 40 m. Francis turbines can be used for pressure heads of between 25 m and 300 m (ESHA, 2004).

The following paragraphs will briefly describe each of the mentioned turbines. An extensive list of a variety of turbine types from various manufacturers can be seen in **Appendix B**.

2.5.3.1 Pelton turbine

Pelton turbines function by directing one or more jets of water tangentially onto a runner with split buckets, as shown in **Figure 2-14**. The jet of water causes a force on the buckets, causing the buckets to rotate, resulting in torque on its shaft (Paish, 2002). After propelling the buckets, the water falls into the tailrace, ideally with almost zero remaining energy.

Figure 2-21 shows that a Pelton turbine performs relatively well at flow rates well below design flow.

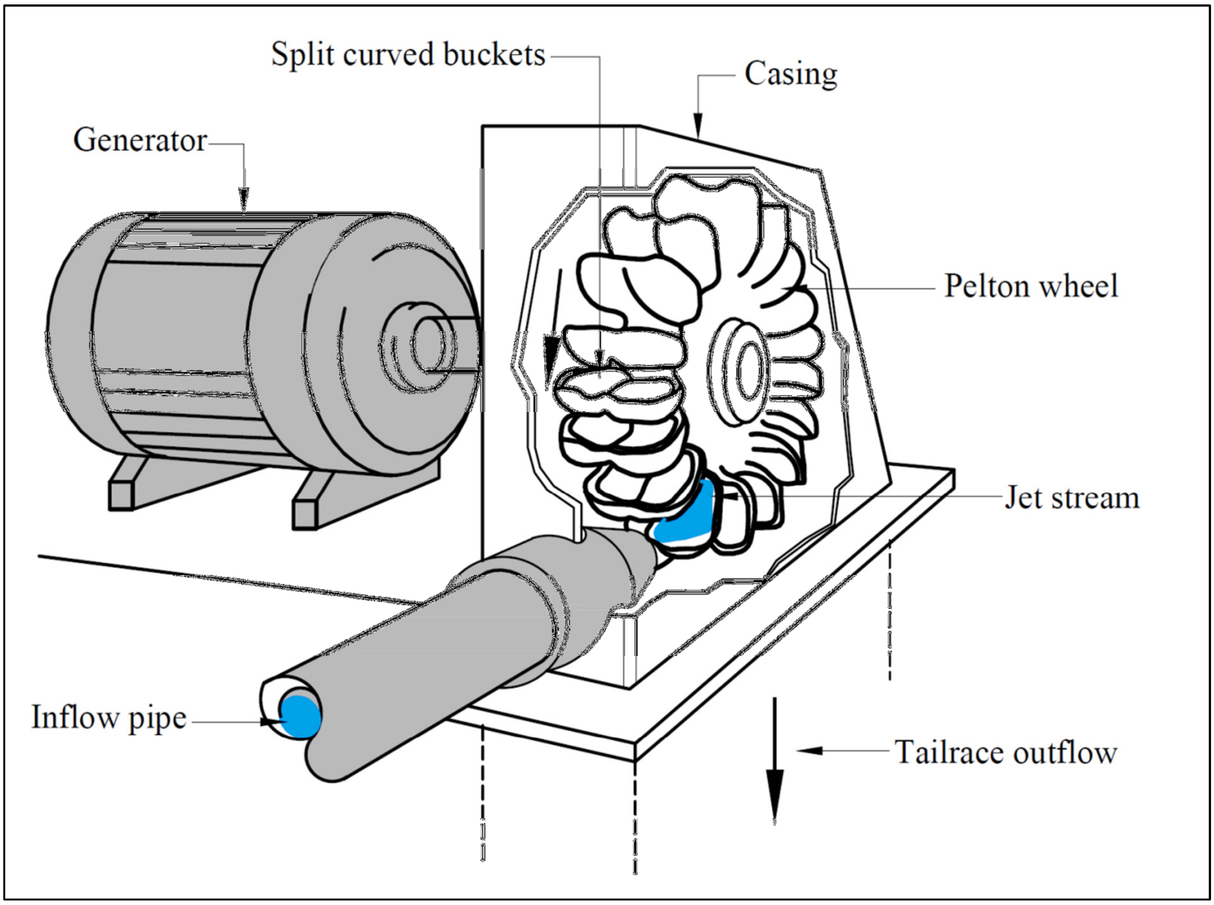


Figure 2-14: Typical Pelton turbine (Paish, 2002)

2.5.3.2 Turgo turbine

Turgo turbines and Pelton turbines function similarly, except that in the Turgo wheel the water jet is directed obliquely onto the buckets and hits several buckets at once (Gulliver and Arndt, 1991). A typical Turgo turbine is shown in **Figure 2-15**.

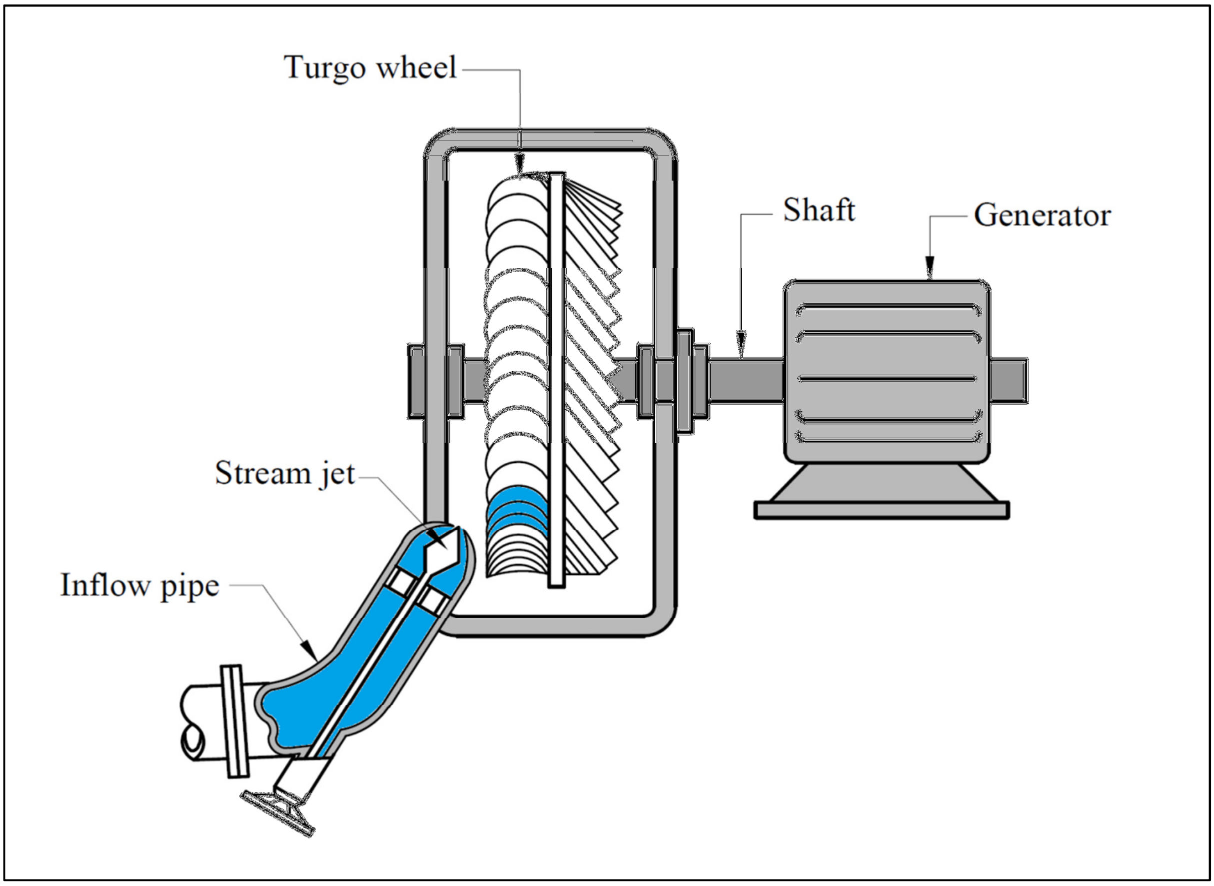


Figure 2-15: Typical Turgo turbine (Paish, 2002)

2.5.3.3 Cross-flow turbine

Cross-flow turbines are constructed with two disks joined together using inclined blades. Water enters the turbine from the top and passes through the blades twice, as shown in **Figure 2-16**. After hitting the blades twice, the water ideally has almost no residual energy and falls into the tailrace (Paish, 2002). Thornbloom et al. (1997) consider an accurately designed cross-flow runner as one in which 'the water impinges on the top blade, is turned by the blade, and flows through the runner, just missing any shaft in the centre and impinges on a lower blade before exiting to the tailrace.'

Figure 2-21 shows that the efficiency of a cross-flow turbine does not drop much when flow rates change. Therefore, cross-flow turbines are regularly used when large flow-rate variations are anticipated (Razak et al., 2010).

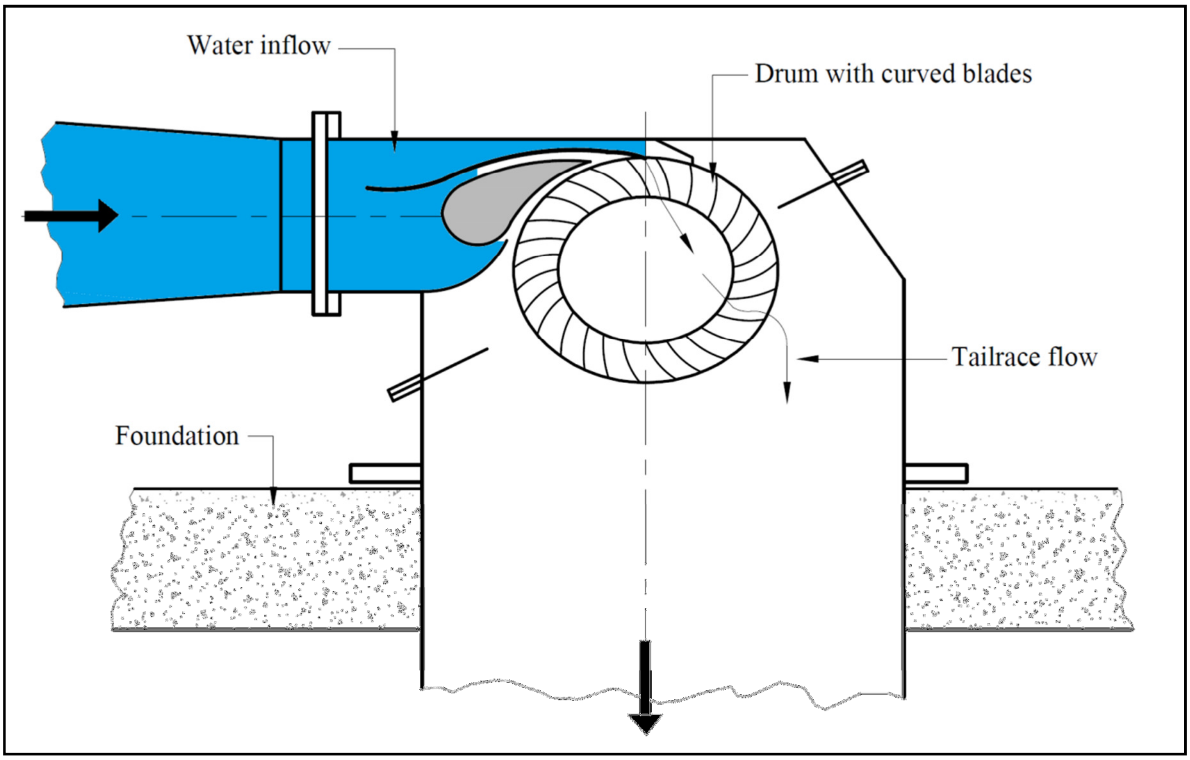


Figure 2-16: Typical cross-flow turbine (Paish, 2002)

2.5.3.4 Kaplan and propeller turbines

Kaplan and propeller turbines use the axial flow of water to develop hydrodynamic forces that rotate the runner blades (Paish, 2002). Unlike with impulse turbines, the Kaplan turbine is completely submerged inside the conduit, as shown in **Figure 2-17**. Guide vanes are installed upstream of the turbine to create inlet swirl, as this ensures better efficiency.

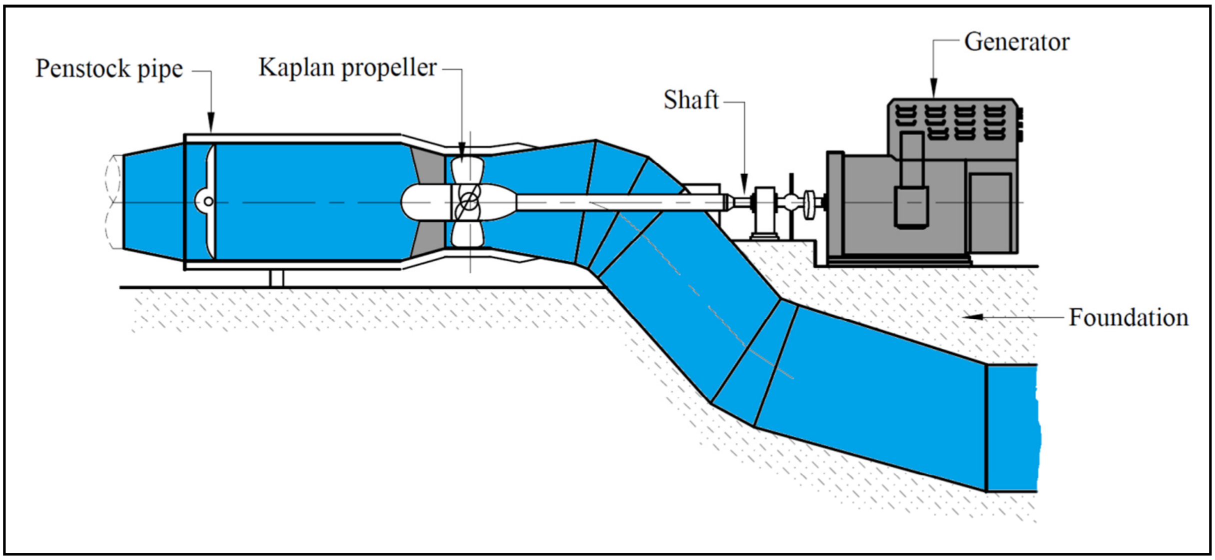


Figure 2-17: Typical Kaplan turbine (Paish, 2002)

2.5.3.5 Francis turbine

A Francis turbine has radial runners that guide the water to exit at a different radius than the inlet radius. Francis turbines force the water to flow radially inwards into the runner and turned to emerge axially at the outlet, as shown in **Figure 2-18** (Paish, 2002).

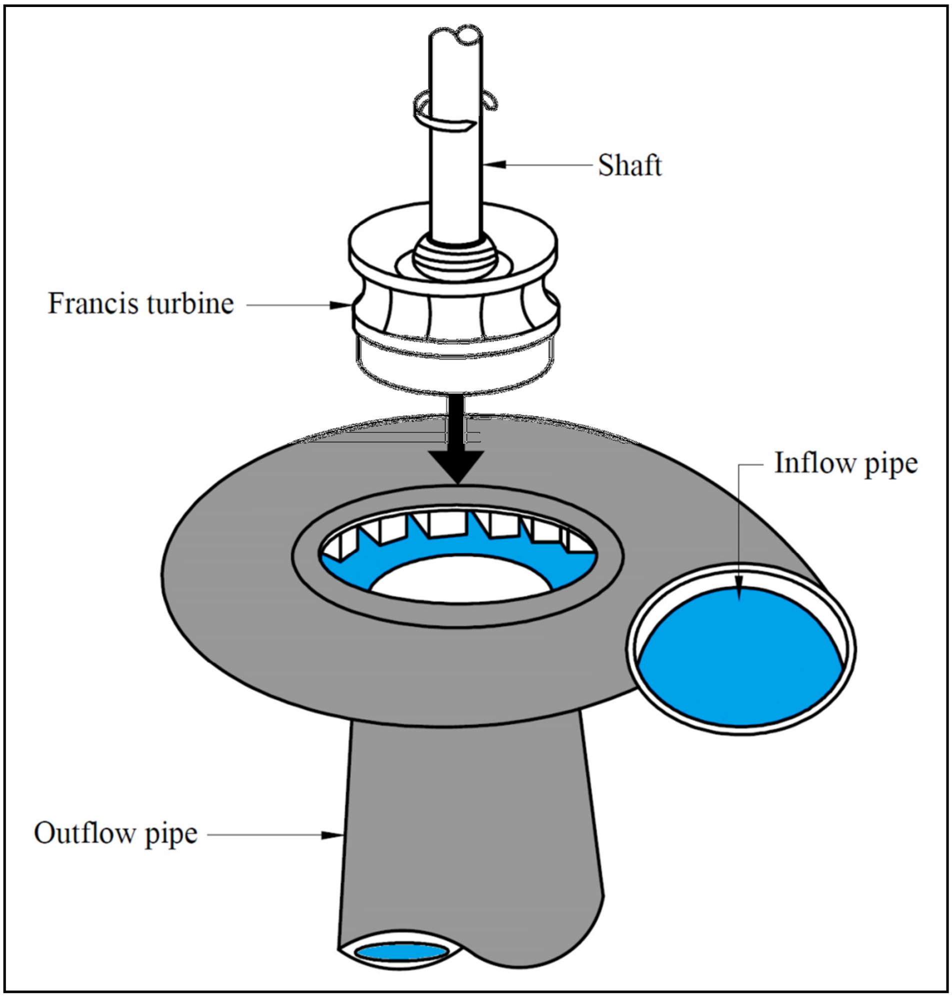


Figure 2-18: Francis turbine (Paish, 2002)

2.5.3.6 Pump as turbine (PAT)

Much research has been done recently on the use of reverse-engineered pumps that can be used as hydraulic turbines. A standard centrifugal pump is run in reverse to act as a turbine; this is an attractive option, especially in developing countries, because pumps are mass-produced, and therefore more readily available and cheaper than turbines (Williams, 2003).

However, PATs generally operate at lower efficiencies than conventional turbines, especially at partial flows. PATs can be operated most efficiently at heads of between 13 m and 75 m. 'The higher the head, the less expensive the cost per kilowatt; this is generally the case with all turbines.' (Natural Resources Canada, 2004).

2.5.3.7 Other turbine types

Water wheels have for many years been the traditional method of generating hydropower in small quantities. Although they are less efficient than turbines, they can still be a practical option in certain cases, as they are simple to control, easy to construct and maintain and are aesthetically pleasing (Natural Resources Canada, 2004).

Hydrokinetic turbines generate electricity using the kinetic energy of the water in low head applications, instead of the potential energy due to hydraulic head, as in high pressure applications. These devices therefore capture energy from moving water, without requiring dams or diversions (Kumar et al., 2011).

Recently the use of inline turbines has increased. These turbines include spherical and ring turbines (**Figure 2-19**) and are installed directly in the primary conduit of a pressurised system; they do not need to be installed in a bypass. These turbines can typically generate between 1 kW and 100 kW and are therefore applicable to pico- and micro-hydropower installations (Kanagy, 2011; International Energy Agency, 2010).

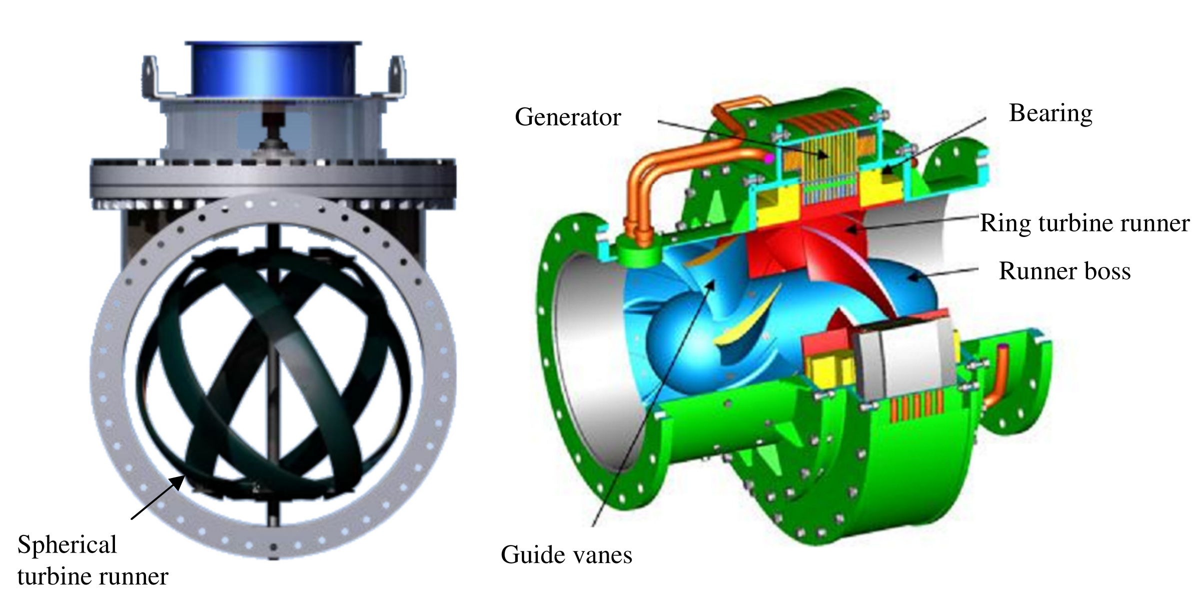


Figure 2-19: Examples of inline turbines (Kanagy, 2011; International Energy Agency, 2010)

Screw-type turbines are based on the principle of an Archimedes screw pump in reverse that operates by utilising the hydrostatic pressure difference across the blades (Williamson et al., 2012). These turbines are used in low-head, high-flow applications and can generate up to 300 kW (International Energy Agency, 2010).

2.5.4 TURBINE SELECTION

The key factors to consider in turbine selection and design are the net available head or effective pressure head across the turbine and the range of flow values which the turbine must be able to handle. These values are plotted on operational charts which give envelopes of limiting operational conditions for each type of turbine. Other factors to consider in turbine selection include specific speed, cavitation and efficiency (ESHA, 2004). A summary of the applicability of each type of turbine is given in **Table 2-12** and **Figure 2-20**.

Table 2-12: Operational ranges of different turbines (ESHA, 2004)

Type of turbine	Head range (m)	Acceptance of flow variation	Acceptance of head variation	Maximum efficiency (%)
Kaplan/propeller	2 - 40	High	Low	91 - 93
Francis	25 - 350	Medium	Low	94
Pelton	50 – 1 300	High	High	90
Cross-flow	2 – 200	High	Medium	86
Turgo	50 - 250	Low	Low	85

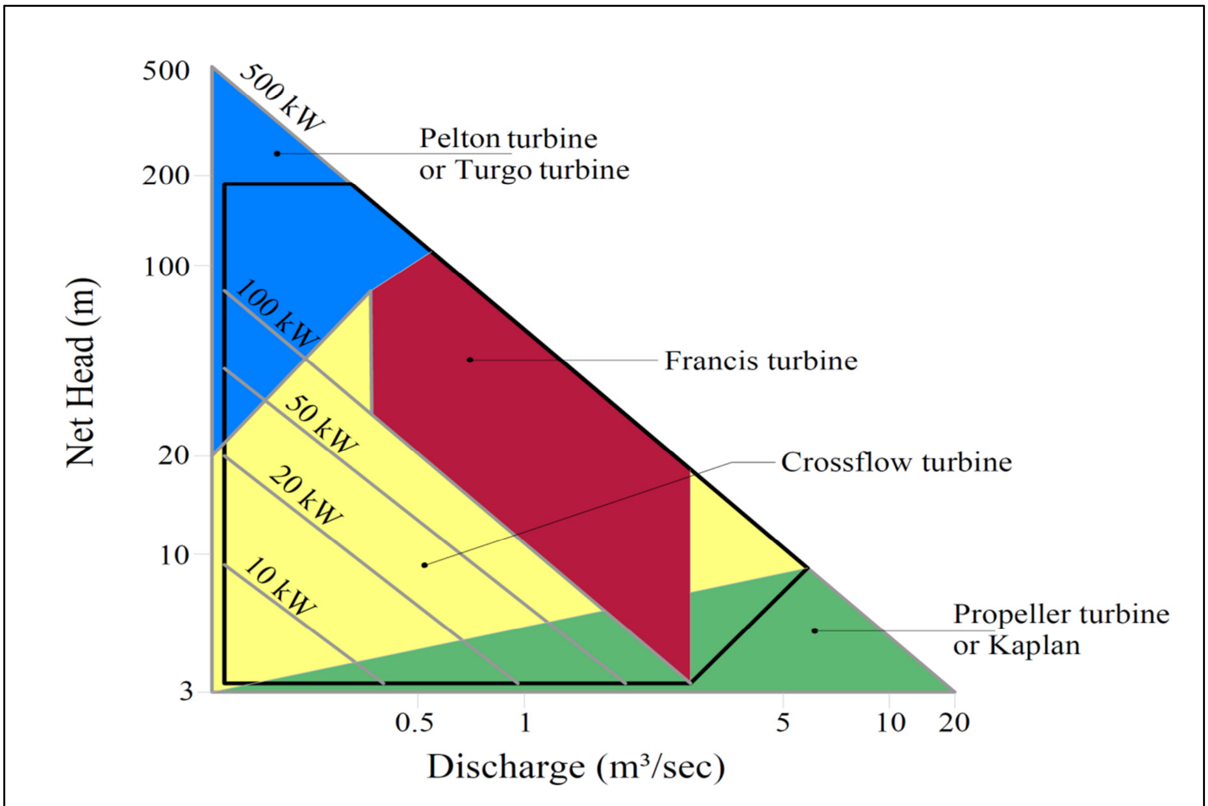


Figure 2-20: Head-flow ranges of hydro-turbines (Paish, 2002)

Another important factor to consider is flow-rate variation, as turbine efficiency might be severely impacted if high variation is experienced. For example, Francis and propeller-type turbines have high efficiencies at design flow, but very low efficiencies for other flow rates. On the other hand cross-flow and Pelton turbines can sustain high efficiencies over a wide range of flow rates. **Figure 2-21** shows the efficiencies of the most common turbine types.

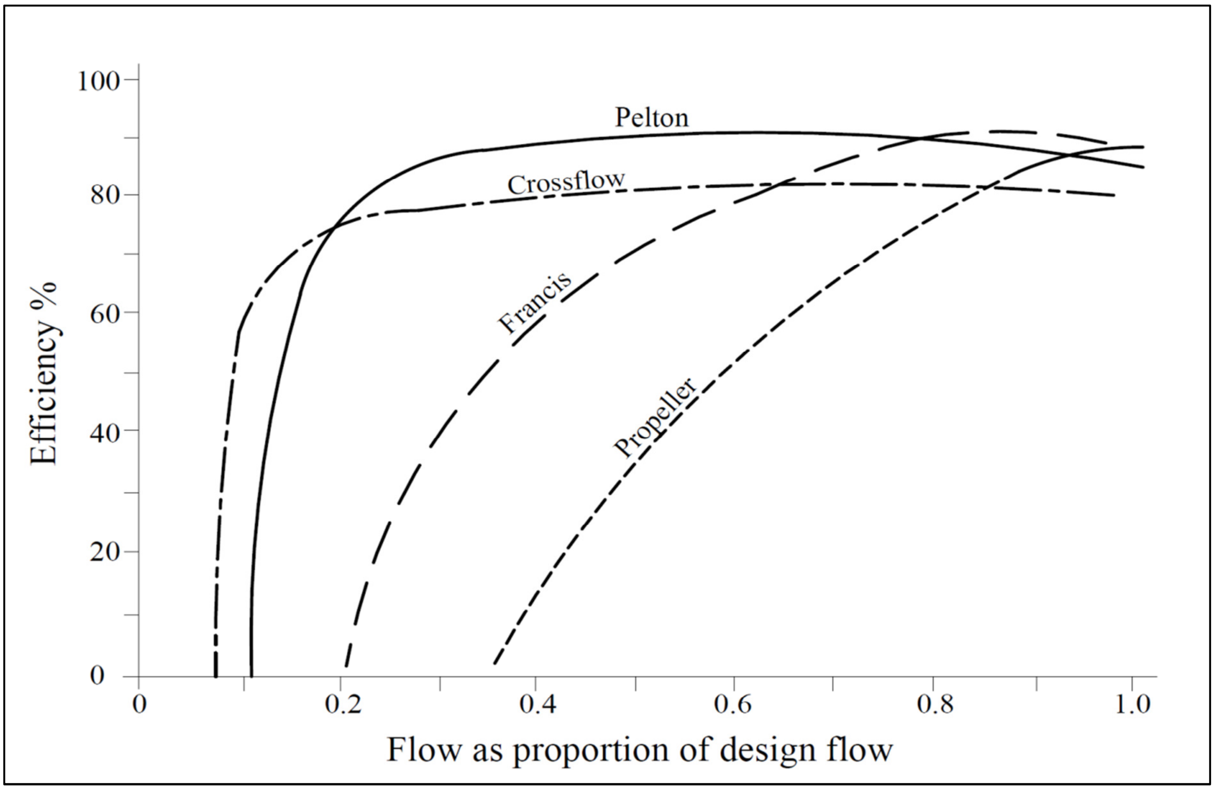


Figure 2-21: Part-flow efficiencies of different turbines (Paish, 2002)

2.5.5 OTHER ELECTRICAL AND MECHANICAL EQUIPMENT

2.5.5.1 Generators

The function of a generator is to convert the mechanical energy produced by the water flowing through the turbine to electrical energy. This is done by inducing a voltage in a coil of wire when the wire is moved through a magnetic field.

Generators can be grouped into two types: synchronous – and asynchronous generators. Synchronous generators are used in most power plants (Natural Resources Canada, 2004). They can run isolated from the grid (ESHA, 2004). Asynchronous (or induction) generators are usually applied in smaller systems, as they are more robust and less expensive than synchronous systems (Natural Resources Canada, 2004). However, they cannot generate high quality electricity if disconnected from the grid, as they cannot provide their own excitation current (ESHA, 2004). Therefore, asynchronous generators are generally connected to the grid.

2.5.5.2 Drivers

A drive system is needed in a hydropower system to ensure that electrical power is generated at a stable voltage and frequency. Therefore, it has to transmit power from the turbine to the generator shaft at the right speed and in the right direction. Typical drive systems include: direct drives; belts and pulleys; and gearboxes (Natural Resources Canada, 2004).

2.5.5.3 Turbine control

Although turbines are designed for a certain net head and discharge, deviations in both flow and head occur and must be compensated for. This is done by opening or closing control devices in the system to ensure that either the outlet power, the head in the system or the flow through the turbine remains constant (ESHA, 2004).

The two most common controls are speed governors and electronic load controllers. Speed governors regulate the speed of the generator by controlling the flow through the turbine. This is accomplished by extending or retracting the servo-motor's rod to the required position. Electronic load controllers manage decreased loads by switching to a pre-set resistance to maintain system frequency (ESHA, 2004).

2.5.5.4 Transmission

Electricity is transported from the powerhouse to the users via electric cables (either overhead or underground). The size and type of the cables are determined by the amount of power to be transmitted and the distance between the plant and the users. For small systems, single-phase electricity may be sufficient. In larger systems a transformer or three-phase electricity is required to minimise losses (Natural Resources Canada, 2004).

2.6 CONDUIT HYDROPOWER

2.6.1 HYDROPOWER POTENTIAL AT PRESSURE-REDUCING VALVES (PRVs)

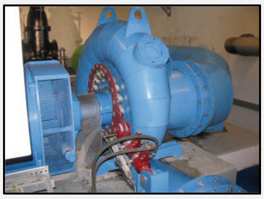
Sometimes excess energy is available in pressurised conduits (pumping or gravity), due to demand patterns and certain restrictions in the selection of component sizes in conduits. Pressure-reducing valves (PRVs) are installed to dissipate excess energy at specific points along a conduit, including just upstream of water-treatment plants and reservoirs (ESHA, 2004).

According to Giugni et al. (2009) PRVs are 'variable closure devices that reduce the conveyance capacity of the pipe by increasing the pressure losses.' This potential energy can be transformed into hydroelectricity by installing a turbine in the conduit. Therefore, by installing a turbine in parallel with the PRV, the flow and head are utilised to generate hydroelectric power (Ramos et al., 2010)

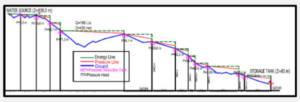
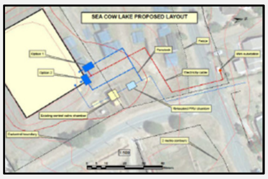
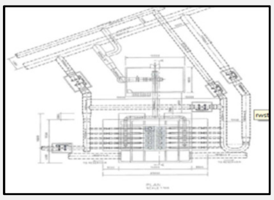
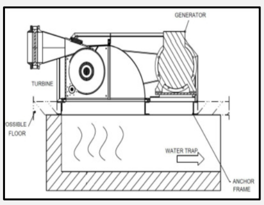
2.6.2 EXAMPLES OF CONDUIT HYDROPOWER

During recent years the focus on conduit hydropower in distribution systems has increased and many stakeholders have started to develop these sites. **Table 2-13** provides a summary of some existing and planned conduit hydropower facilities.

Table 2-13: Examples of existing and planned conduit hydropower installations

Project name	Location	Capacity (kW)	Photo	Year completed	Source
La Zour	Savièse, Switzerland	465 total		2004	ESHA (2009)
Schreyerbach	Aldrans - Innsbruck, Austria	63		2006	ESHA (2009)
Mühlau	Innsbruck, Austria	5 750		1952	ESHA (2009)
Poggio Cuculo	Arezzo, Italy	44		2010	ESHA (2009)
Vienna Mauer	Vienna, Austria	500		2006	ESHA (2009)

Project name	Location	Capacity (kW)	Photo	Year completed	Source
Armary Power Plant	Aubonne, Switzerland	68		2006	ESHA (2009)
Tordera	Blanes, Spain	2 880 total		2002	ESHA (2009)
Sangüesa	Sangüesa, Navarra, Spain	75		2006	ESHA (2009)
Lomza	Lomza, Poland	20		1997	ESHA (2009)
Rancho Peñasquitos	San Diego, USA	4 500		2007	NHA (2013)
Keene	New Hampshire, USA	55		2010	Rentricity (2010a)
Westmorland	Pennsylvania, USA	30		2010	Rentricity (2010b)

Project name	Location	Capacity (kW)	Photo	Year completed	Source
Pierre van Ryneveld	Gauteng, South Africa	14.9		2011	Van Dijk et al. (2012b)
Faure	Cape Town, South Africa	1 475		1994	Jonker Klunne (2012b)
Blackheath	Cape Town, South Africa	700		1982	Jonker Klunne (2012c)
Tshwane	Gauteng, South Africa	4 000 total		Planning	Van Vuuren (2010)
Edremit	Edremit, Turkey	559 total		Planning	Kucukali (2011)
Ethekwini	Ethekwini, South Africa	590 total		Planning	Dyer (2012)
Rand Water	Gauteng, South Africa	13 000 total		Planning	Jonker Klunne (2013b)
Brandkop	Bloemfontein, South Africa	96		Planning	Jonker Klunne (2013c)

2.7 DECISION SUPPORT SYSTEMS (DSS)

2.7.1 INTRODUCTION

According to Shim et al. (2002), '[d]ecision support systems (DSS) are computer technology solutions that can be used to support complex decision making and problem solving.' Typical DSS tools include one or more of the following:

- Database management capabilities;
- Modelling functions; and
- User-friendly interface designs allowing interactive 'queries, reporting and graphing' capability.

(Shim et al., 2002)

2.7.2 EXISTING HYDROPOWER DSS

Various models have been developed to determine power potential or estimated cost of conventional hydropower installations. However, none of these apply to conduit hydropower potential or economics. They were nonetheless reviewed, as there are correlations between the design and economics of conventional hydropower and conduit hydropower.

2.7.2.1 RETScreen

The RETScreen Clean Energy Project Analysis Software is freeware distributed by the Government of Canada as part of the country's drive to reduce pollution in an integrated manner. RETScreen can be used worldwide to determine the cost savings of various renewable energy options (Leng, 2000). 'RETScreen allows decision-makers and professionals to determine whether or not a proposed renewable energy, energy efficiency, or cogeneration project makes financial sense.' (RETScreen, 2011)

The use of RETScreen can significantly reduce the costs (both financial and time) that are normally spent during identification and the assessment of potential energy projects (Leng, 2000). The tool is designed to analyse most clean energy projects (including solar, wind, wave, hydro, geothermal, biomass and others). Analysis options include: power analysis, energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. The model includes a database with hydrology and climate information for many locations around the world. Of important relevance is the power analysis capability, displayed in **Figure 2-22** (RETscreen, 2011).

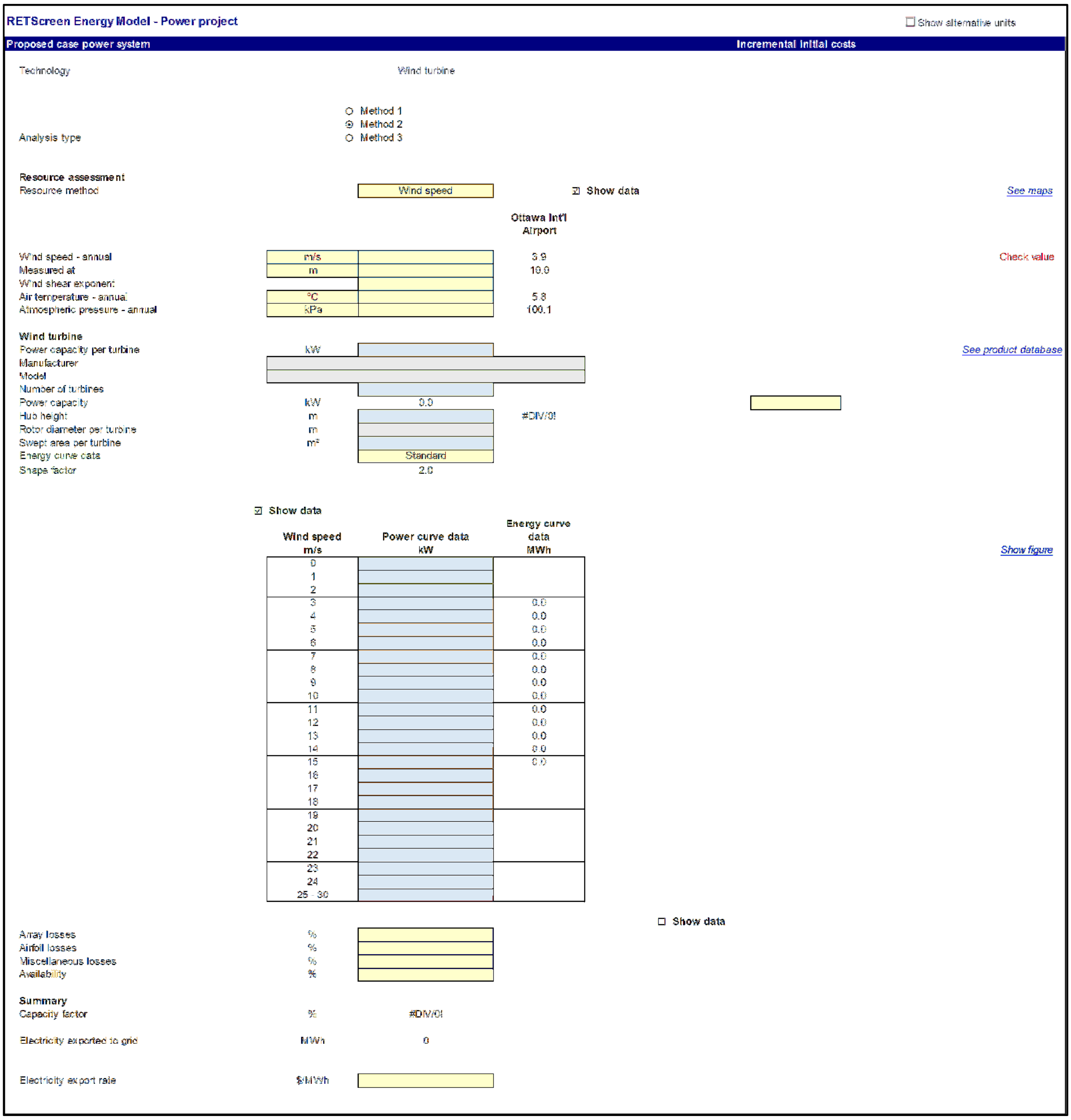


Figure 2-22: Typical RETScreen screenshot (RETScreen, 2011)

2.7.2.2 Hydrohelp

Hydrohelp is a tool that assists designers in choosing suitable turbines for conventional hydropower installations, as well as providing an initial cost estimate from related infrastructure. It uses data provided by manufacturers of 28 different types of turbines from 1 MW upwards. The program requires the input of 12 items describing the site characteristics, as shown in **Figure 2-23** (Hydrohelp, 2010).

HydroHelp 1- Turbine selection - CLOVA issue, January 2010.		
CLOVA FALLS	Enter data in blue cells only. Comment.	
Project input data. Date of estimate --- >		05-Jan-09
Headpond full supply level, m.	877.00	
Headpond low supply level, m.	875.00	
Head loss to turbine, % of gross head, at full load.	4.50	Comment
Normal tailwater level, m.	440.00	Comment
Flood tailwater level, m.	445.00	Comment
Design powerplant flow, cubic meters per second.	10.00	
Desired number of units.	2	
Summer water temperature, degrees Celsius.	15	
System frequency, Hz.	60	
Generator power factor.	0.90	
Maximum allowable gearbox power, MW.	2	Comment
Design standard & generator quality, industrial = 0, utility = 1.	0	Comment
Inflation ratio since 2008	1.01	
Program output - turbine heads and flow.	**Reaction unit.**	**Impulse unit.**
Maximum gross head FSL to normal and flood TWL, m.	437.00	432.00
Rated net head 1/3 drawdown to normal and flood TWL, m.	416.70	409.42
Rated flow per unit, cubic meters per second.	5.00	5.00
Recommended type of reaction turbine.		If no suitable turbines, change number of units.
No suitable reaction turbine, select impulse unit.		
Recommended type of impulse turbine.		
Vertical axis, 4 jet, 1 runner impulse turbine.		
Generating equipment details.	**Reaction unit.**	**Impulse unit.**
Turbine runner speed, rpm.	0.0	600.0
Reaction turb. runner throat, impulse turb. outside diameter, m.	0.000	1.713
Required powerhouse crane capacity, tonnes. **Comment.**	0.0	36.2
Not applicable, no suitable reaction unit.	0.00	------------------
Impulse turbine runner centerline elevation.	------------------	448.43
Generating unit capacity, MW.	0.00	17.58
Powerplant capacity, MW.	**0.00**	**35.17**

Figure 2-23: Typical Hydrohelp screenshot (Hydrohelp, 2010)

2.7.2.3 Hydropower Evaluation Software (HES)

The Hydropower Evaluation Software (HES) is a computer model that was developed by the Idaho National Engineering Laboratory for the United States Department of Energy to estimate the undeveloped hydropower potential in the US (Conner et al., 1996).

'The software was developed and tested using hydropower information and data provided by the Southwestern Power Administration' (Conner et al., 1996). HES allows the user to 'assign environmental attributes to potential hydropower sites, calculate development suitability factors for each site based on the environmental attributes present, and generate reports based on these suitability factors' (Conner et al., 1996). **Figure 2-24** shows a typical screenshot of the program, with all the known information about a specific dam.

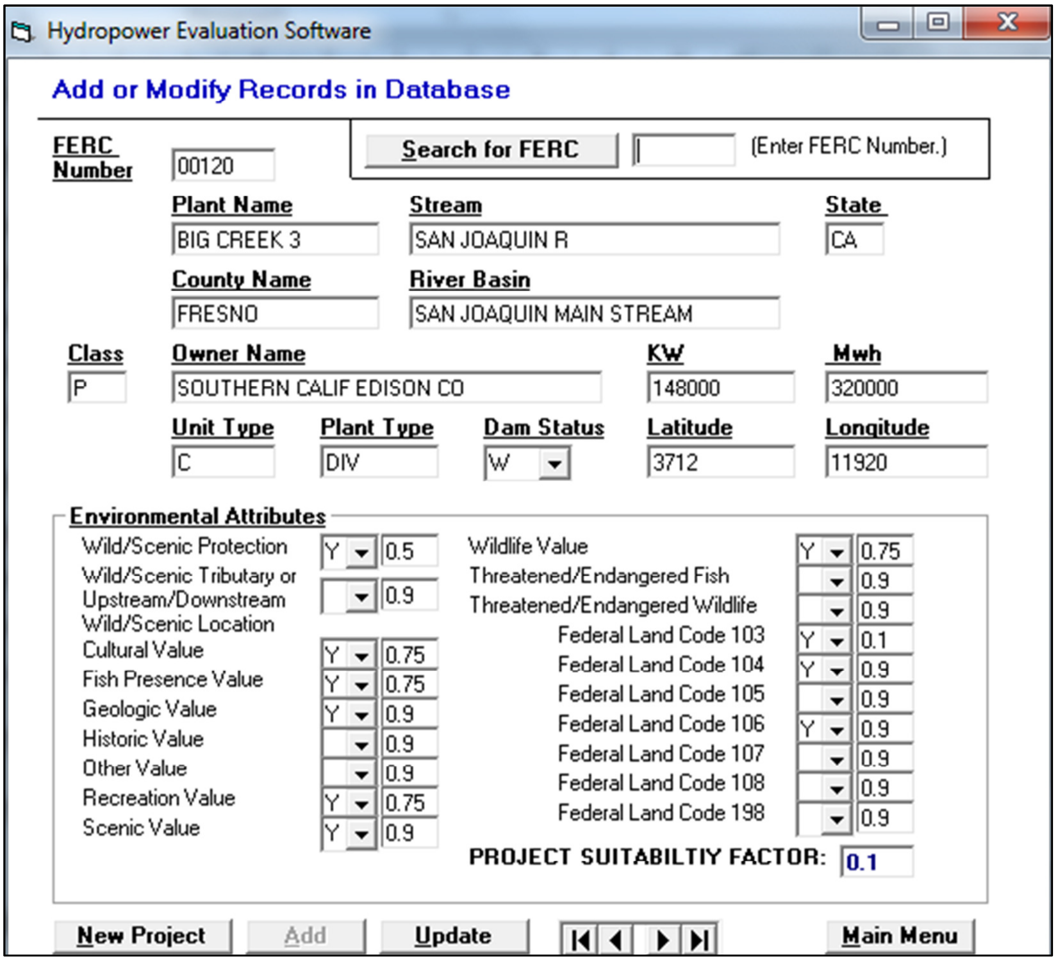


Figure 2-24: Typical HES screenshot (Hydropower Evaluation Software, 2002)

2.7.2.4 USBR Hydropower Assessment Tool

The United States Bureau of Reclamation (USBR) developed a tool for conventional hydropower assessment at its facilities (**Figure 2-25**). This tool can be used when evaluating a potential hydropower site that has at least the following known information: continuous flow; defined head and tail water levels; and distance to a transmission line. This tool is used for preliminary hydropower-potential evaluation and has a cost function based on USA prices in 2010. These cost functions may be used to determine the benefit/cost ratio and internal rate of return of a project, or the user may manually import known costs into the tool (USBR, 2011a).

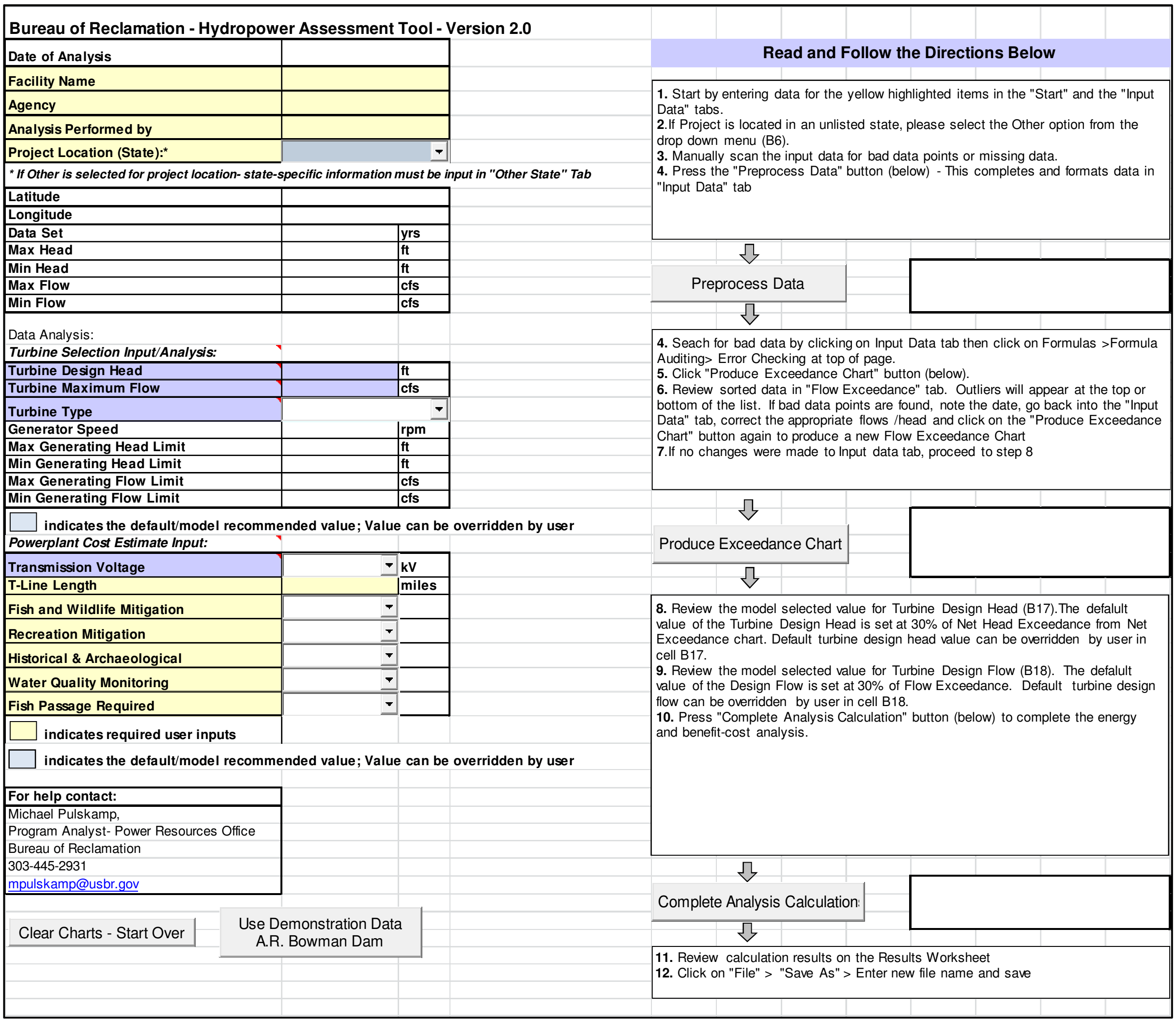


Figure 2-25: Typical USBR Hydropower Assessment Tool screen (USBR, 2011b)

2.7.2.5 Plant Cost Estimator

This model was developed by the Idaho National Engineering and Environmental Laboratory and funded by the U.S. Department of Energy. The model uses Microsoft Excel-based tools (**Figure 2-26**) for cost estimation of the development, operation and maintenance of hydropower plants in the USA. These tools were compiled using regression curves based on historical data in the USA at a 2002 time basis for various types of conventional hydropower installations. This included the development of new sites, existing dams without hydropower and the expansion of hydropower plant at dams with existing hydropower capacity (Hall et al., 2003).

Undeveloped Site		**Generic Hydro Plant**		
Site Information				
Installed Capacity (MW)	0.000	0.000	0.000	0.000
Annual production (KWH)	0	0	0	0
APR Finance Rate	**5.0%**	**6.0%**	**7.0%**	**8.0%**
Finance Period (yrs)	30	30	30	30
Annual Revenue		0	0	0
Construction Year	2 006			
Development Costs				
Cost Escalation factor from 2002	10.38%			
Licensing Cost	$0	$0	$0	$0
Construction Cost	$0	$0	$0	$0
Fish & Wildlife Mitigation	$0	$0	$0	$0
Recreation Mitigation	$0	$0	$0	$0
Historical & Archiological	$0	$0	$0	$0
Water Quality Monitoring	$0	$0	$0	$0
Fish Passage	$0	$0	$0	$0
Other (define)	$0	$0	$0	$0
Other (define)	$0	$0	$0	$0
Plant Construction Cost	$0	$0	$0	$0
Cost / KW	$0	$0	$0	$0
Annual Debt Service	$0	$0	$0	$0
Annual O&M				
Fixed Annual O&M	$0	$0	$0	$0
Variable O&M	$0	$0	$0	$0
FERC Charges	$0	$0	$0	$0
Annual Debt Service	$0	$0	$0	$0
Transmission / Interconnection	$10 000	$10 000	$10 000	$10 000
Insurance	$0	$0	$0	$0
Taxes	$0	$0	$0	$0
Management / Office / Overhead	$0	$0	$0	$0
Major Repairs Fund	$0	$0	$0	$0
Reclamation / Federal Admin	$10 000	$10 000	$10 000	$10 000
Other (define)	$0	$0	$0	$0
Other (define)	$0	$0	$0	$0
Other (define)	$0	$0	$0	$0
Annual O&M Expense	$20 000	$20 000	$20 000	$20 000
Cost of Production ($/KWH)	$0.0000	$0.0000	$0.0000	$0.0000
Grayed out areas are calculated by the spreadsheet				
Calculations are based upon *Estimation of Economic Parameters of U.S. Hydropower Resources*				
INEEL - June 2003				
Spreadsheet developed for Section 1834 Studies				

Figure 2-26: Typical Plant Cost Estimator screenshot (Plant Cost Estimator, 2003)

2.8 ECONOMIC ANALYSIS

2.8.1 INTRODUCTION

While the accurate identification of the technical potential of a possible hydropower site is crucial, the key to its successful development is accurate economic analysis. This is necessary to determine whether the costs incurred for the development of a site can be recovered (ESHA, 2004).

The development of any hydropower scheme will include a number of expenses, both initial and throughout the project life, and returns distributed throughout the same period. The expenses include fixed costs (like capital cost) and variable costs (like operation and maintenance (O&M) expenses) (ESHA, 2004).

It is necessary to compare the costs and returns to determine whether a project is deemed to be economically feasible. The various methods of performing this comparison include the calculation of the net present value (NPV), benefit-cost ratio, internal rate of return (IRR), as well as determining the payback period of a project (Natural Resources Canada, 2004).

While static methods, like the payback period, may be easier to calculate, it is valuable to consider the time value of money and therefore use dynamic methods to determine economic feasibility. The following sections investigate the parameters used in various static and dynamic analysis methods.

2.8.2 STATIC METHODS OF ANALYSIS

2.8.2.1 Payback period

The payback method is used to calculate the time required for the initial investment to be offset by the resulting revenue of the scheme. The required time is called the payback, recovery or break-even period. The formula used for the calculation is (ESHA, 2004):

$$\textit{Payback period} = \frac{\textit{investment cost}}{\textit{net annual revenue}} \qquad \textbf{Equation 2-7}$$

Equation 2-7 does not incorporate the time value of money and only considers the life of the project until the payback point has been reached. However, other literature suggests that inflation may be included and that the payback period would then be the time taken to equate initial capital outlay and the present value of net annual cash flow (Blank and Tarquin, 2004).

Both sources agree that the payback period should not be used as the deciding factor in project selection. It should only be used as a tool for initial screening to supplement other methods, as it does not give sufficient information to stand alone as an evaluation tool (ESHA, 2004; Blank and Tarquin, 2004).

2.8.2.2 Return on investment (ROI)

This method calculates the net annual benefit (income minus costs) as a percentage of the original cost of the investment. The formula used for the calculation is:

$$ROI=\frac{net\ annual\ revenue\text{-}depreciation}{investment\ cost}\times 100 \qquad \textbf{Equation 2-8}$$

With depreciation calculated using the straight-line method:

$$Depreciation=\frac{cost\text{-}salvage\ value}{operational\ life} \qquad \textbf{Equation 2-9}$$

The ROI can be used as a quick estimate of a project's profitability, but, as it does not consider the time value of money or cash flow over the design life, dynamic analysis methods are preferred (ESHA, 2004).

2.8.3 DYNAMIC METHODS OF ANALYSIS

Various methods for dynamic economic evaluations exist. According to SANRAL (2013), the most frequently used techniques are:

- 'Present worth of cost (PWOC) technique;
- Net present value (NPV) technique;
- Benefit/cost ratio (B/C) technique; and
- Internal rate of return (IRR) technique.'

These methods will be discussed in the following sections.

2.8.3.1 Present worth of cost (PWOC)

This technique is used find the lowest cost alternative between various mutually exclusive projects. All costs, including the cost of provision, management, maintenance and use of each of the alternatives are discounted to their present worth. The alternative with the lowest PWOC is the most cost-effective alternative. This method can be expressed as follows (**Equation 2-10**) (from SANRAL, 2013):

'$$PWOC=C_A+PW(M+U) \qquad \textbf{Equation 2-10}$$

where:

$PWOC$	=	present worth of cost
C_A	=	all costs incurred in establishing a facility (i.e. the opportunity cost of the investment)
$PW(M+U)$	=	present worth of all facility maintenance costs and user costs.'

2.8.3.2 Net present value (NPV)

According to SANRAL (2013), this method is used to:

- 'select the best alternative among the mutually exclusive projects; and
- to help establish an overall economic viability of independent projects.'

The net present value (NPV) of a project is determined by subtracting the present worth of investment cost from all future benefits. A positive NPV would indicate an economically feasible project, with a higher value more advantageous than a lower value. The formula used for this method is (**Equation 2-11**) (from SANRAL, 2013):

'$$NPV=PW(M_0+U_0)-PW(M_A+U_A)+PW(CS_A)-C_A \quad \textbf{Equation 2-11}$$

where:

NPV	=	net present value of benefits
$PW(M_0+U_0)$	=	the present worth of facility maintenance costs and user costs of the null alternative
$PW(M_A + U_A)$	=	the present worth of facility maintenance costs and user costs of a proposed alternative
$PW(CS_A)$	=	consumer surplus gained through additional usage induced by the proposed alternative. This is equal to one-half of the benefit accruing to each existing journey multiplied by the number of induced trips.
C_A	=	investment (capital) cost that is required to implement the alternative *A*'

BENEFIT/COST RATIO

This method gives an economic viability measure using the ratio between the present worth of future benefits and costs. It is used to select the most advantageous among independent projects. Future benefits include annual savings relative to the null alternative, plus income gained through usage of the facility.

The benefit/cost ratio is calculated by dividing the sum of all income and savings by the costs. Any project with a B/C ratio greater than one is deemed feasible, with a higher value indicating a more viable project. The formula used for this method is given in **Equation 2-12** (from SANRAL, 2013):

'$B/C = \frac{PW(M_0+U_0)-PW(M_A+U_A)+PW(CS_A)}{C_A}$ **Equation 2-12**

where:

B/C	=	benefit/cost ratio
$PW(M_0+U_0)$	=	the present worth of facility maintenance costs and user costs of the null alternative
$PW(M_A + U_A)$	=	the present worth of facility maintenance costs and user costs of a proposed alternative
$PW(CS_A)$	=	consumer surplus gained through additional usage induced by the proposed alternative. This is equal to one-half of the benefit accruing to each existing journey multiplied by the number of induced trips.
C_A	=	investment (capital) cost that is required to implement the alternative *A*'

2.8.3.3 Internal rate of return (IRR)

This method can also be used to find the most viable between independent projects. The distinguishing feature of this method is that it shows the discount rate at which the project would break even. Future benefits and costs are calculated in the same way as for the NPV or B/C methods and discounted to the present using different rates until a rate is found where the returns and costs are equal. This rate is the internal rate of return. The higher the IRR, the more advantageous the project will be. The formula used for this method is (**Equation 2-13**, from SANRAL, 2013):

'$IRR = r$ When $PW(M_0+U_0)-PW(M_A+U_A)+PW(CS_A) = C_A$ **Equation 2-13**

where:

IRR	=	internal rate of return
r	=	rate at which the left-hand and right-hand sides of the equation are equal, resulting in an NPV of zero.
$PW(M_0+U_0)$	=	the present worth of facility maintenance costs and user costs of the null alternative
$PW(M_A + U_A)$	=	the present worth of facility maintenance costs and user costs of a proposed alternative
$PW(CS_A)$	=	consumer surplus gained through additional usage induced by the proposed alternative.
C_A	=	investment (capital) cost that is required to implement the alternative'

2.8.4 COSTS

A number of expenses are incurred throughout the project life of any hydropower scheme development. These include fixed costs (like capital cost) and variable costs (like operation and maintenance expenses) (ESHA, 2004). Barta (2011) proposes that costs be defined in the following categories: initial planning cost; capital cost; operation and maintenance cost; and retirement/disposal costs. These categories are discussed in the following sections.

2.8.4.1 Initial planning cost

Initial planning costs essentially consist of the costs related to conceptual designs, site investigations and regulatory compliance costs. According to Barta (2011) this can be summarised using the following (**Equation 2-14** and **Table 2-14**):

$$\textit{Initial planning cost (IPC)} = C_{investigation} + C_{enviroment\ \&\ social} + C_{legal\ \&\ regulatory} \qquad \textbf{Equation 2-14}$$

Table 2-14: Prerequisite cost components of initial planning costs (IPC) (Barta, 2011)

Initial planning cost (IPC)		
Costs of investigation ($C_{investigation}$)	**Costs of environmental and social assessment ($C_{E\&S}$)**	**Costs of legal and regulatory requirements ($C_{L\&R}$)**
Project inception note/ terms of reference (C_{TOR}) **Project formulation/baseline or inception report (C_{PB})** • Desk review of previous work • Site(s) field visit(s) • Main project parameters • Conceptual design • Layout and programme of field surveys (e.g. geology, hydrology, asset status, etc.)	**Environmental impacts scoping (C_{ES})** • Environmental scope • Base line data • Potential impacts • Mitigation and institutional measures **Social benefits/dis-benefits evaluation(C_{SE})** Social local/regional benefits/ dis-benefits • Stakeholders sentiments • Target market(s) • Risks assessment	**Legal and regulatory package report (C_{LR})** • Water-use permit requirements • National Environmental Management Act (1996) • National Energy Regulator (NERSA) licence • Power Purchase Agreement (PPA) Guidelines • REFIT/REBID costs and requirements **Application and follow-up costs(C_{LF})**

According to Barta (2011) **Equation 2-14** can be re-written as follows (**Equation 2-15**):

$$IPC = C_{TOR} + C_{PB} + C_{ES} + C_{SE} + C_{LR} + C_{LF}$$ **Equation 2-15**

where:

C_{TOR} = *Terms of reference cost*: depending on the type of hydropower project and magnitude, the ToR is normally issued by national government, local government authority or parastatal entity through tenders. The private developer normally issues an inception note to the invited consultancy. The costs incurred are carried by the issuing agency.

C_{PB}= *Project formulation baseline report costs*: the developer usually carries the costs of time and resources used by the consultant in the compilation of the baseline (inception) report.

C_{ES} = *Environmental impacts scoping*: the developer usually pays for investigation and reporting of a project's ecological effects. A specialised consultancy is normally employed for the evaluation of the scope of proposed project impacts. The environmental impacts scoping is a first step towards a full environment impacts assessment (EIA).

C_{SE} = *Social benefits/dis-benefit evaluation*: the developer usually carries the time and resource costs incurred by the consultant for investigation and reporting of the project's social impacts.

C_{LR} = *Legal and regulatory package report*: the developer typically pays all costs relevant to this aspect. The lengthy time requirements (permits) and regulations could have a significant impact on the feasibility of a project.

C_{LF} = *Application and follow-up costs*: the developer usually carries these costs also.

2.8.4.2 Capital cost

A major aspect in any civil engineering project is the capital cost of the solution.

Capital expenditure typically includes: design costs, the purchase cost of equipment, installation cost, initial training and a start-up commissioning costs. These costs occur only once. According to Barta (2011) capital expenditure in conventional hydropower projects generally consists of the following (**Equation 2-16** and **Table 2-15**):

$$\text{Capital expenditure cost (CEC)} = C_{design} + C_{purchase} + C_{installation} + C_{start\text{-}up}$$ **Equation 2-16**

Table 2-15: Prerequisite cost components of capital expenditure cost

Capital expenditure costs (CEC)			
Costs of design (C_D)	**Costs of purchase (C_P)**	**Costs of installation (C_I)**	**Costs of start-up (C_S)**
Civil engineering design costs (C_{CE}) • access • intake • diversion • headrace • surge chamber • penstock • housing & crane • tailrace **Mechanical & electrical design costs ($C_{M\&E}$)** • turbine/generator • valves • controls • transformer • transmission • stand-by **Project management costs (C_{PM})** • procurement, scheduling and controlling plans	**Manufacturing costs (C_{MC})** • turbine and generator • valves • penstock • crane or hoist **Quality control costs (C_{QC})** • engineering supervision • management supervision **Logistic support and controls (C_{SC})** • backup and sensor systems • operational software **Documentation costs (C_{DC})** • equipment O&M manuals	**Construction costs (C_{CC})** • civil engineering works • mechanical/ electrical works **Equipment transport costs (C_{TC})** • road • railway • boat • air **Mounting and connecting ($C_{M\&C}$)** • mechanical/electric al equipment • SCADA controls • security lighting	**Test and evaluation costs (C_{TE})** • training • testing • as-built drawings **Commissioning of plant (C_{CP})** • technical • administrative

where:

C_{design} = *System design costs*: these can be significant and can include detailed design, drawings, project management programme, system operation configuration, and custom designed software. Consulting fees are normally related to the guidelines set by the Engineering Council of South Africa (ECSA).

$C_{purchase}$ = *Purchase costs*: these include costs of materials and equipment. These costs can be obtained from local or international of turbine equipment. These costs have a high level of certainty.

$C_{installation}$ = *Installation costs*: this includes payment for casting, delivery and mounting of equipment within the civil works.

$C_{start-up}$ = *Start-up costs*: this aspect accounts mainly for the testing and commissioning of installed equipment.

2.8.4.3 Operation and maintenance cost

Operation and maintenance (O&M) costs should be carefully broken down into all aspects, including spare parts, training and wages and should allow contingencies of 50%. If untried or newly designed and manufactured equipment is used, a full replacement cost should be incorporated. If batteries are used, they should be replaced every three years. It is important to allow for inflation in the prices of spare parts, transport and wages. Management costs should also be included (Harvey et al., 1993).

Revenue cost is related to O&M of equipment. This aspect includes the costs of power, labour, spare parts and materials used for routine maintenance. According to Barta (2011), O&M costs can be divided into two broad categories (**Figure 2-27**):

- **fixed costs (FCs)** – these costs are independent of the output. The costs typically include: payments of loans, salaries, maintenance, etc. The FCs do not vary significantly from year to year during the time under consideration.
- **variable costs (VCs)** – these costs are associated with the size of an installation and include charges for grid usage and sales. The VCs are costs that change as output changes. Materials like lubricants and factors like energy usage generate costs that change with varying output.

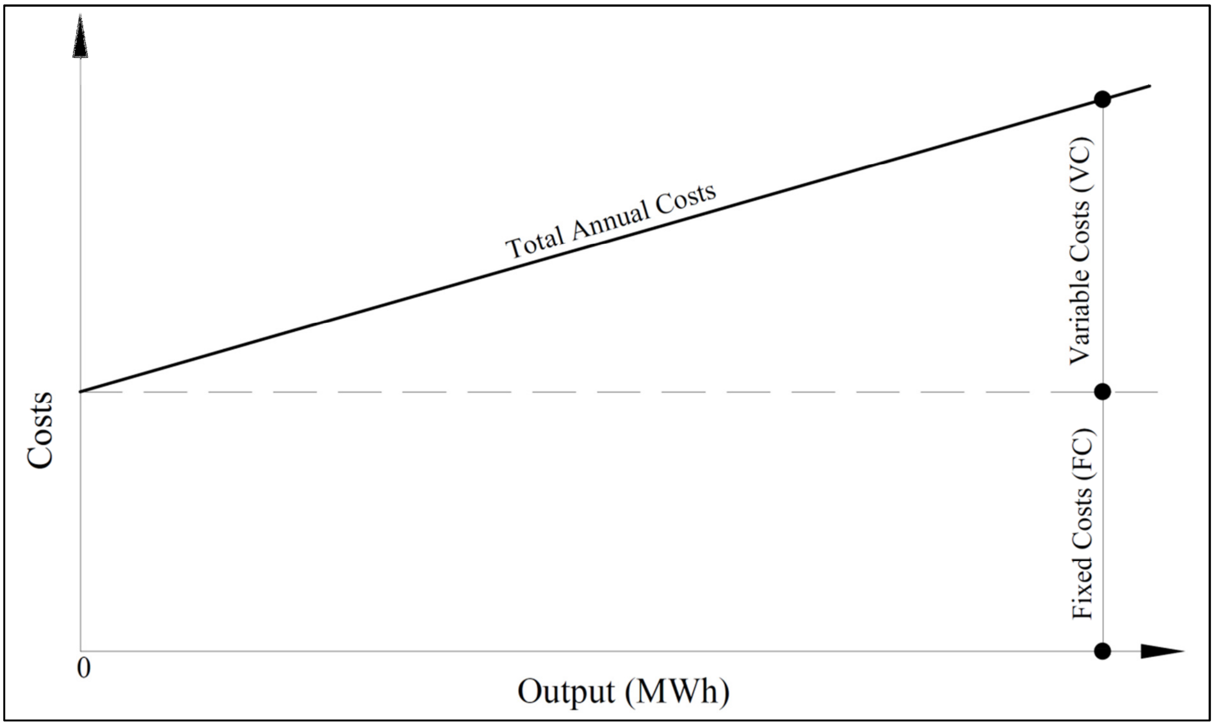


Figure 2-27: Simplified interpretation of total annual costs (Barta, 2011)

2.8.4.4 Refurbishment cost

These costs will be incurred when major renovations to the hydropower plant take place. According to Barta (2011), civil works will typically outlive electromechanical equipment by 20 years to 30 years. **Figure 2-28** illustrates the process of hydropower plant decline and the significance of refurbishment.

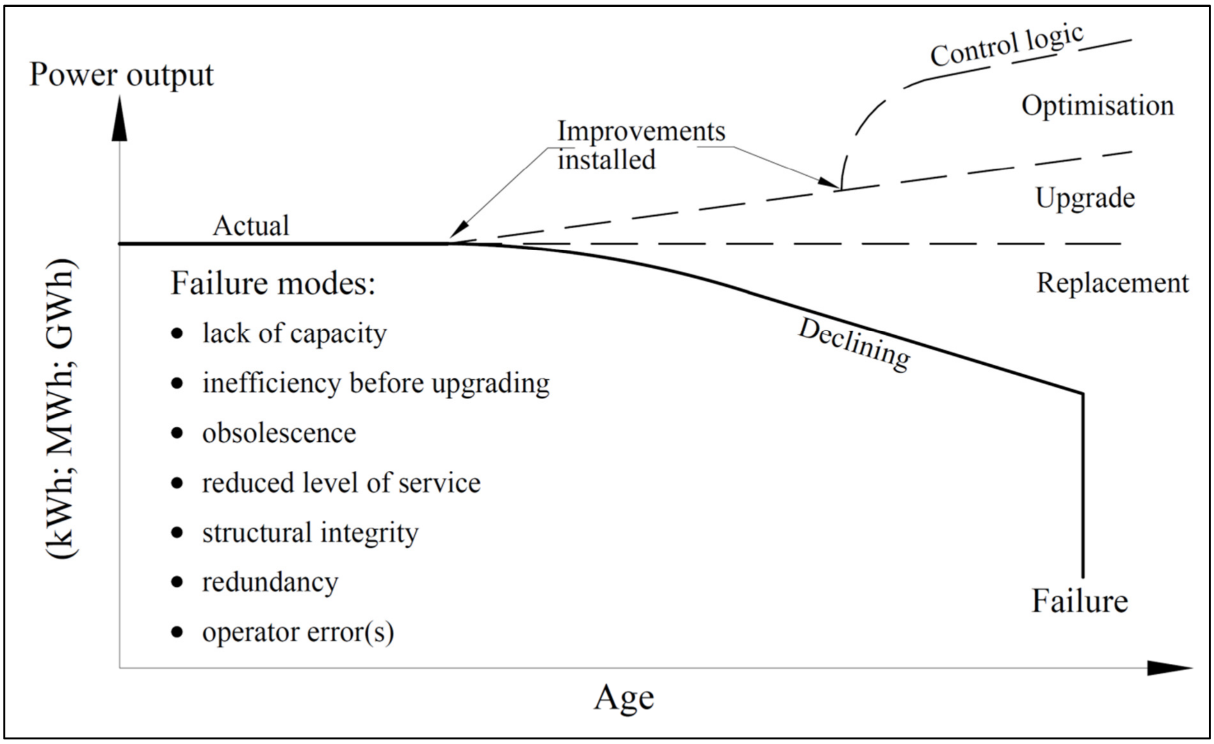


Figure 2-28: Possible status changes of a system component over its life cycle (Barta, 2011)

2.8.4.5 Retirement/disposal cost

These costs need to be included from planning stages to ensure that the logistics of system retirement, material recycling and, possibly, system replacement, are budgeted for. If environmental rehabilitation is required, the disposal cost will probably be negative (Barta, 2011).

2.8.5 LIFE-CYCLE COSTING

Normally engineering projects incur not only capital cost, but also various revenue costs, maintenance costs and ultimately replacement costs over their lifetimes (see **Figure 2-29**). Therefore it is important to consider the value of all the components allowing for the relationship between the value of money and time (Barta, 2011). The life-cycle cost (LCC) of a project includes all costs of constructing and operating a system over its full operating life (in present money value). The useful life of an overall hydropower facility is usually in the order of 30 years to 50 years. However, different plant components have different expected useful life (EUL) years.Table 2-17 shows typical useful lifetimes for different hydropower components). LCC provides valuable information that will enable the comparison of projects with different expenditure patterns (Barta, 2011).

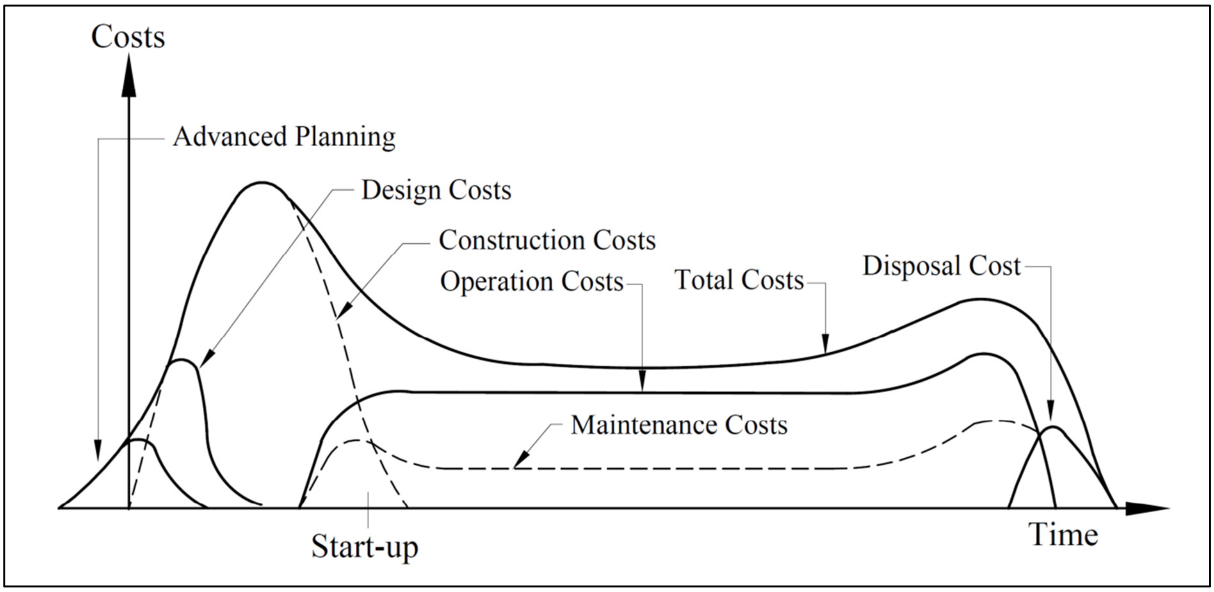


Figure 2-29: Representation of a hydroelectric system life-cycle profile (Barta, 2011)

LCC includes all costs associated with a system (or component) as applied over the defined life cycle. It is applicable to all phases of a system design, development, production, construction, operational use and logistics support. An LCC analysis is defined as a systematic analytical process of evaluating various designs or alternative courses of action with the objective of choosing the best way to employ scarce resources (Fabrycky and Blanchard, 1996). A typical table for the determination of the LCC of a project is proposed by Barta (2011) and shown in **Table 2-16**.

Table 2-16: Example of a life-cycle costing analysis (Barta, 2011)

Capital cost of alternative:					**Annual cost**
Interest/opportunity cost:	Capital @ annual interest (%) = C_1				
Depreciation of CC	**Cost value**		**EUL (years)**	**Rand/annum**	
Civil works					
Electrical Eq.					
Mechanical Eq.					
Controls					
Other					
				Subtotal: C_2	
Operating costs	**Quantity**	**Unit**	**Rate**	**Amount**	
Labour		h/week			
Materials		sum			
Power/energy	12	months			
Licences, etc.		sum			
Other		sum			
				Subtotal: C_3	
Maintenance costs	**Percentage (%) of capital**		**Capital**	**Amount**	
Civil items					
Electrical items					
Mechanical items					
Controls					
				Subtotal : C_4	
Rehabilitation funded from depreciation provision				C_5	
Decommissioning/demolition: **Estimated cost at the end of life cycle (years):**				C_6	
TOTAL ANNUAL LIFE-CYCLE COST:	$C_1 + C_2 + C_3 + C_4 + C_5 + C_6$				

Table 2-17: Expected useful life (EUL) of hydroelectric scheme assets (Barta, 2011)

Type of asset	Description	EUL (years)
Structures/roads	Dams/weirs/intakes/canals	50-100
	Buildings/houses	50
	Access roads (wearing surface)	20
Hydro-mechanical equipment	Turbines (small sizes)	25
	Valves and gates	45
	Penstocks (mainly steel)	50
Hydro-electrical equipment	Generators	20
	Transformers	20
	Transmission lines	30
Auxiliary equipment	Electrical controls	15
	Telemetry	15
	Security components	10
NB: Remaining useful life (RUL) is the difference in years between EUL and evaluation year		

2.8.5.1 Unit cost

When comparing the costs of hydropower plants of varying sizes, it is sensible to determine the unit cost of each plant and to compare these. According to Barta (2011), the unit cost of a micro-hydropower plant can be calculated using the following formula (**Equation 2-18**):

$$c_u = C_{LCC} / F_v * Dem * 365 \text{ (Rand/kWh)}$$ **Equation 2-17**

where:

c_u = unit cost

F_v = $(1+d_r)^n - 1/d_r(1+d_r)^n$

d_r = discount rate or escalation rate

n = number of years

Dem = system's daily demand (kWh or MWh)

C_{LCC} = life-cycle cost

2.8.6 FUNDING

Historically, funding for power-generation projects was provided by the public sector. However, privately financed and owned projects are increasing. According to IEA (2000), general financing alternatives include:

- The 'use of in-house funds', if the developer has accumulated reserves. This may be possible in very small projects, but larger projects will require a substantial initial investment.
- 'Ordinary bank loans', where a bank supplies the majority of the initial investment cost and secures the loan against assets of the developer.
- 'Co-development with a financially strong partner', where a partner is chosen either for his financial situation or for his expertise.
- 'Limited recourse project financing' in which the future cash flow of the project provides the security for the lender. This option is used when the developer does not have sufficient assets to provide as security, or when he wishes to split the risk involved in the development.
- Leasing of the hydropower plant can be used alternatively to ownership, although this is currently not often used for hydropower plants.
- In 'build-own-operate (BOO)' projects the water owner gives development rights to an independent power producer, who controls the development process and operation of the plant for a time, after which the owner resumes possession of the project.
- 'Pay-back using electricity or other goods' is an alternative method of repaying debt with electricity, rather than with cash.
- 'Supplier's credit' can be obtained from some equipment suppliers that link their purchase prices with financing terms.

In the case of small-scale conduit hydropower, municipalities and water boards will often be able to provide funds out of their own budgets. However, larger installations will require alternative funding. Funding for these projects may typically be acquired from the Development Bank of South Africa (DBSA), commercial banks or the South African National Energy Development Institute (SANEDI). (Van Dijk et al., 2012b; SANEDI, 2013)

2.8.7 RETURNS

In general terms, the energy services tariff can be defined as a set of norms and standards introduced by the authority. A tariff represents duties (or taxes) levied by the authority in order to raise revenue for energy services rendered. The national tariff norms and standards are usually provided by the government with guidelines indicating how local or specific tariffs are to be set out. The essential purpose of energy services tariffs is to serve as an important policy instrument to regulate the demand for energy services provision. The price of energy services to the end-user is priced on the tariff structure costs of local authorities and bulk suppliers. A representative energy services tariff should be based on both fixed and variable costs of services rendered (Barta, 2011).

In March 2009 NERSA announced the South African Renewable Energy Feed-in Tariff (REFIT) Programme. The primary objective of this programme was to cover electricity generation costs with allowance for a profit potential that is sufficiently attractive to stimulate investment of small hydropower plants (NERSA, 2009).

In December 2009, the Department of Energy (DoE) with the endorsement from NERSA introduced the Integrated Resource Plan (IRP) for Electricity for South Africa 2010 – 2030. The IRP 2010 has been subjected to public scrutiny and comments and eventually the entire process resulted in a Final Policy Adjusted IRP 2010: New-Build Technology Mix (Viljoen and Wilson, 2011).

However, in August 2011 the Government abandoned the REFIT process in favour of REBID, a competitive bidding process where tariff caps are applied for specific generation technologies. If a successful tender is submitted, a return of R1.20/kWh of electricity can be earned. However, only projects with a capacity of 1MW or more can qualify for REBID.

Therefore, Eskom has recently launched a Rebate Programme for Small-scale Renewable Energy Generation. This programme allows renewable energy projects with a capacity of less than 1MW to apply for an incentive of R1.20 per kWh generated for an initial contract period of 3 years. However, grid-connected applications do not qualify (Eskom, 2012d).

2.8.8 TYPICAL COST FUNCTIONS

According to Barta (2011) there is little information about hydropower development costs in South Africa, due to the small number of hydropower developments in this county during the past 30 years. Even in other countries it is difficult to accurately estimate the costs of hydropower plants during the early stages (Gunduz and Sahin, 2010).

However, various authors have developed cost functions to simplify early stage hydropower cost estimation. A study done be Aggidis et al. (2010), compared various cost functions written between 1978 and 2000 and combined the functions with obtained costs for sites in North West England. A summary of the resulting cost functions (all for British Pounds at a 2008 cost base, with P being power in kilowatts, H being available head in metres and Q being design flow in cubic metres per second) is shown in **Table 2-18**.

Table 2-18: British cost functions (Aggidis et al., 2010)

Description	Cost function (£, 2008)	Applicability
Overall project	$C_{Pr}=25\ 000\times(\frac{P}{H^{0.35}})^{0.65}$	2 m < H < 30 m
	$C_{Pr}=45\ 500\times(\frac{P}{H^{0.3}})^{0.6}$	30 m < H < 200 m
Electro-mechanical	$C_{EM}=12\ 000\times(\frac{P}{H^{0.2}})^{0.56}$	
Kaplan turbine	$C_{K1}=3\ 500\times(P)^{0.68}$	0.5 m^3/s < Q < 5 m^3/s
	$C_{K2}=14\ 000\times(P)^{0.35}$	5 m^3/s < Q < 30 m^3/s
Francis turbine	$C_{F1}=122\ 000\times(P\times H^{0.5})^{0.07}$	0.5 m^3/s < Q < 2.5 m^3/s
	$C_{F2}=223\ 000\times(\frac{P}{H^{0.5}})^{0.11}$	2.5 m^3/s < Q < 10 m^3/s
	$C_{F3}=16\ 500\times(\frac{P}{H^{0.5}})^{0.52}$	Q > 10 m^3/s
Pelton turbine	$C_{PEL}=2\ 600\times(P)^{0.54}$	

Ogayar and Vidal (2009) have developed cost functions for hydropower turbines using the installed capacity and net pressure head as variables. The derived equations were compared with costs of installed plants at various locations in Spain, with resulting correlation errors of between 20% and 24%. The resulting equations, for Euro at a 2007 cost base (with P being power in kilowatts and H being available head in metres), are shown in **Table 2-19**.

Table 2-19: European cost functions (Ogayar and Vidal, 2009)

Description	Cost function (€/kW)
Pelton turbine	$C_{PEL}=17\ 693\times P^{-0.3644725}\times H^{0.281735}$
Francis turbine	$C_{F1}=25\ 698\times P^{-0.560135}\times H^{-0.127243}$
Kaplan turbine	$C_{K1}=33\ 236\times P^{-0.58338}\times H^{-0.113901}$
Semi-Kaplan turbine	$C_{SK}=19\ 498\times P^{-0.583385}\times H^{-0.113901}$

Singal et al. (2010) conducted a study on small run-of-river hydropower projects in India, also using the installed capacity and net pressure head as variables. The derived equations were compared with costs of installed plants at various locations in India as well as installed plants in various other countries. The derived equations correlated well with actual costs in India and Brazil. China (-32%), Columbia (-64%) and Vietnam (-27%) had significantly lower installation costs, but European costs were 112% higher and Australian costs were 79% higher than those in India. **Table 2-20** shows the resulting equations, for Indian Rupees, at a 2007 cost base (with *P* being power in kilowatts and *H* being available head in metres).

Table 2-20: Indian cost functions (Singal et al., 2010)

Description	Cost function (Rs/kW)
Turbine with governing system	C_T=63 346×$P^{-0.1913}$×$H^{-0.2171}$
Generator with excitation system	C_G=78 661×$P^{-0.1855}$×$H^{-0.2083}$
Electrical and mechanical auxiliary	C_{EM}=40 860×$P^{-0.1892}$×$H^{-0.2118}$
Transformer and switchyard	C_{ST}=18 739×$P^{-0.1803}$×$H^{-0.2075}$

The USBR (2011b) proposes various cost functions (**Table 2-21**), for US Dollars at a 2010 cost base (with *P* being power in megawatts, *H* available head in feet and L_T transmission line length in miles).

Table 2-21: United States of America cost functions (USBR, 2011b)

Description	Cost function (US$, 2010)	Applicability
Kaplan turbine	C_{K1}=909 000×2.718$^{-0.0013×H}$×$P^{0.72}$	$H \leq 100$ ft
	C_{K2}=5 240 000×$H^{-0.38}$×$P^{0.72}$	$H > 100$ ft
Francis turbine	C_{F1}=760 000×2.718$^{-0.003×H}$×$P^{0.71}$	$H \leq 100$ ft
	C_{F2}=3 930 000×$H^{-0.42}$×$P^{0.71}$	$H > 100$ ft
Pelton turbine	C_{PEL}=0.8×3 930 000×$H^{-0.42}$×$P^{0.71}$	
Other turbines	C_{OT}=760 000×2.718$^{-0.003×H}$×$P^{0.71}$	
Generator	C_G=3 900 000×$P^{0.65}$×$N^{-0.38}$	
Balance of plant mechanical	C_M=0.2×C_T	
Balance of plant electrical	C_E=0.35×C_G	
Civil works	C_{Civil}=0.4×(C_T+C_G)	
Transformer	$C_{Trans}=25.403\times\left(P\times\frac{1000}{0.9}\right)-0.001\times\left(P\times\frac{1000}{9}\right)^2+14\,866$	
Transmission line	$C_{Transmission}$=L×160 000	KV < 69
	$C_{Transmission}$=L×320 000	69 < KV < 115
	$C_{Transmission}$=L×368 000	KV > 115
Contingency	$C_{Contingency}$=0.2×CEC	
Construction management	C_{CM}=0.15×(CEC+$C_{Contingency}$)	
Licensing	C_L=780 000×$P^{0.7}$	
Transmission line right of way	$C_{TransROW}$=58 180×L_T	
Fixed annual O&M	C_{FixOM}=26 000×$P^{0.75}$	
Variable O&M	C_{VarOM}=26 000×$P^{0.8}$	

RETScreen (2003) uses various cost functions for micro-hydropower project analysis (**Table 2-22**), (with P being power in megawatts, H available head in metres, Q design flow in cubic metres per second and N the number of turbines).

Table 2-22: RETScreen cost functions (RETScreen, 2003)

Description	Cost function (CAN$)	Applicability
Kaplan turbine	$C_{K1}=0.243N^{0.96}\times(0.482Q^{0.45})^{1.47}\times(1.17H^{0.12}+2)\times10^6$	$H \leq 25$ m
	$C_{K2}=0.267N^{0.96}\times(0.482Q^{0.45})^{1.47}\times(1.17H^{0.12}+2)\times10^6$	$H > 25$ m
Francis turbine	$C_{F1}=0.153N^{0.96}\times(0.482Q^{0.45})^{1.47}\times((13+0.01H)^{0.12}+3)\times10^6$	$H \leq 25$ m
	$C_{F2}=0.168N^{0.96}\times(0.482Q^{0.45})^{1.47}\times((13+0.01H)^{0.12}+3)\times10^6$	$H > 25$ m
Pelton/Turgo turbine	$C_{P/T}=3.47N^{0.96}\times(\frac{P}{H^{0.5}})^{0.44}\times10^6$	$\frac{P}{H^{0.5}} > 0.4$
	$C_{P/T} = 5.34N^{0.96} \times (\frac{P}{H^{0.5}})^{0.91} \times 10^6$	$\frac{P}{H^{0.5}} \leq 0.4$
Cross-flow turbine	$C_C=0.5\times C_{P/T}$	
Propeller turbine	$C_{Prop}=0.113n^{0.96}\times(0.482Q^{0.45})^{1.47}\times(1.17H^{0.12}+4)\times10^6$	$H \leq 25$ m
	$C_{Prop}=0.124n^{0.96}\times(0.482Q^{0.45})^{1.47}\times(1.17H^{0.12}+4)\times10^6$	$H > 25$ m
Transformer	$C_{Trans}=(0.0025N^{0.95}+0.002(N+1)\times(\frac{P}{0.95})^{0.9}\times V^{0.3}\times10^6$	

Various sources estimated component costs as percentages of investment or planning cost. These percentages are shown in **Table 2-23**.

Table 2-23: Comparison of component costs as percentages of total cost

Category	Cost Item	Percentage of total	Source
Initial planning	Regulatory	3% of IPC	Barta (2012)
	Environmental & social	27% of IPC	Barta (2012)
	Preliminary design	70% of IPC	Barta (2012)
Capital expenditure	Preliminary & general	20% of CEC	Barta (2012)
	Access to site	0.5% of CEC	Barta (2012)
	Intake structure/penstock	5% of CEC	Barta (2012)
	Power station housing & tailrace	15% of CEC	Barta (2012)
	Electro-mechanical	30% of CEC	Barta (2012)
	Electro-mechanical	34% of CEC	Aggidis et al. (2010)
	Transformer/transmission	10% of CEC	Barta (2012)
	Construction supervision	4.5% of CEC	Barta (2012)
	Contingencies	15% of CEC	Barta (2012)
Maintenance	Civil	0.25% of Civil CEC	Barta (2012)
	Civil	1% of CEC	Chutachindakate (2012)
	Mechanical	2.0% of Mech CEC	Barta (2012)
	Hydraulic equipment	2% of CEC	Chutachindakate (2012)
	Electrical	4.0% Electrical CEC	Barta (2012)
	Electro-mechanical	2.5% of CEC	Chutachindakate (2012)
	Transmission system	1% of CEC	Chutachindakate (2012)
Insurance	Civil	0.15% CEC	Barta (2012)
	Electro-mechanical	0.25% of CEC	Barta (2012)
	All	0.3% of CEC	USBR (2011b)
Overheads	All	0.5% of CEC	USBR (2011b)
Total O&M		1% of CEC	Barta (2012)

2.8.9 TYPICAL COST OF A SMALL HYDROPOWER PLANT

The unit cost of pico to small conduit hydropower installations vary significantly, as shown in **Table 2-24**. This can be attributed to various factors, including project location, infrastructure needed and inflation (note completion year in each case). This, combined with a shortage of available project costs, significantly complicates the development of a standardised cost function for conduit hydropower installations.

Table 2-24: Small hydropower unit cost comparison

Hydropower plant	Country	Year of completion	Capacity (kW)	Unit cost (currency/kW)	Source
Schreyerbach	Austria	2006	63	€ 6 350/kW	ESHA (2009)
Poggio Cuculo	Italy	2010	44	€ 4 550/kW	ESHA (2009)
Vienna Mauer	Austria	2006	500	€ 2 500/kW	ESHA (2009)
Armary	Switzerland	2006	68	€ 5 900/kW	ESHA (2009)
Sangüesa	Spain	2006	75	€ 4 000/kW	ESHA (2009)
Edremit	Turkey	Planning	559	€ 2 000/kW	Kucukali (2011)
Rancho Peñasquitos	USA	2007	4 500	$ 4 700/kW	NHA (2013)
Rand Water	South Africa	Planning	13 000 (total of 4 sites)	R 28 000/kW	Mbhele (2012)
Brandkop	South Africa	Planning	96	R 19 000/kW	Van Dijk (2013)

2.9 SUMMARY OF LITERATURE REVIEW

This Chapter focused on various aspects pertaining to hydropower, specifically small-scale and conduit hydropower. These aspects included: the fundamentals of hydropower potential evaluation and development; economic analysis methods; hydropower evaluation tools; and case studies. The Chapter also provided background information on the current and projected energy situations in South Africa, as well as regulatory requirements.

The information gathered in this Chapter will be utilised and applied specifically to conduit hydropower in **Chapters 3 to 5**.

3 PROCEDURAL METHOD DESCRIPTION

3.1 INTRODUCTION

The aim of this study was to develop a decision support system that can be used to identify conduit hydropower potential in South Africa, as well as to provide proper guidance for the development of identified sites.

A system of flow diagrams and tools has been compiled to identify and develop conduit hydropower sites. These diagrams and tools were tested at three sites in the City of Tshwane Metropolitan Municipality. During the analysis, shortcomings and variances in the system were identified and addressed, and a practical decision support system for conduit hydropower development in South Africa was produced.

3.2 SYSTEMATIC APPROACH

A systematic approach must be followed when assessing hydropower potential in a distribution network to ensure that all relevant factors are considered. The procedure for determining hydropower potential is illustrated through a series of flow diagrams, whilst a tool developed in Microsoft Excel facilitates calculation of all the factors that need consideration. **Chapters 4 and 5** will elaborate on the items in the flow diagrams. The development procedure has been divided into three phases:

- First Phase: Pre-Feasibility Investigation
- Second Phase: Feasibility Study
- Third Phase: Detailed Design

Each phase has its own process flow diagram linked to the Conduit Hydropower Development Tool (CHD Tool). Each item in the flow diagrams is also numbered and discussed in more detail in a paragraph with corresponding number in **Chapter 4**. Some of the aspects of the study will be required in two or more of the phases, but will be dealt with in increasing detail as the project progresses.

A fourth phase, dealing with operation and maintenance aspects, falls outside the scope of this document, but is also an important phase to consider when designing a conduit hydropower facility.

3.2.1 SCOPE OF WORKS

The total scope of works for the development and operation of conduit hydropower plants in South Africa is summarised in **Figure 3-1**. This document will focus on the potential identification and design processes, shown in the first five blocks of **Figure 3-1**.The other aspects fall outside the scope of this document, but are an integral part of the complete hydropower development process.

Figure 3-1: Conduit Hydropower Development Scope of Works

3.3 FLOW DIAGRAMS

3.3.1 PHASE 1 FLOW DIAGRAM

Phase 1 represents a pre-feasibility study and comprises various first-order analyses and studies. The purpose of this phase is to rapidly determine whether more in-depth studies will be worthwhile. **Figure 3-2** and **Figure 3-3** indicate the decision flow process for this phase.

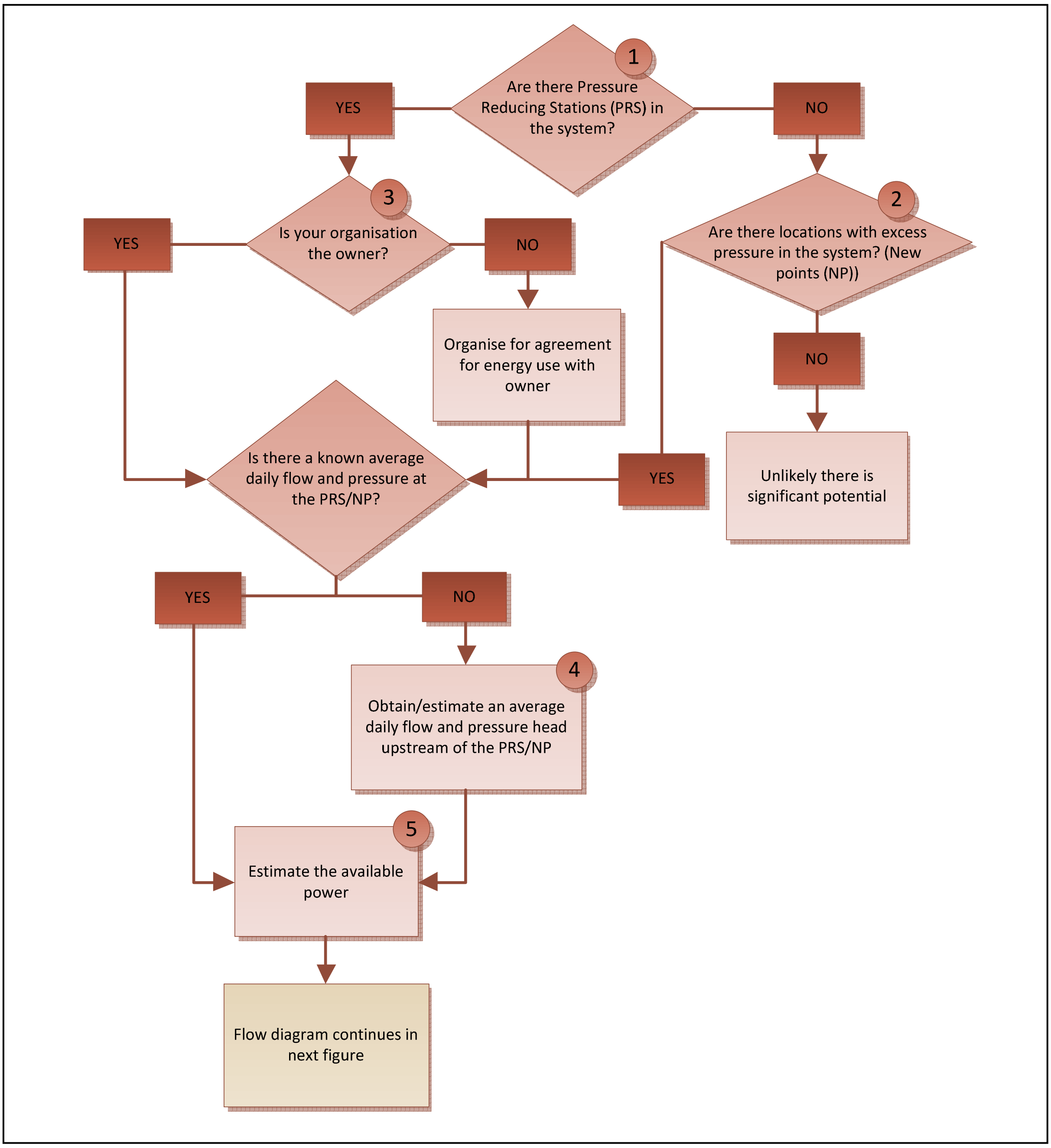


Figure 3-2: Phase 1 flow diagram Part A

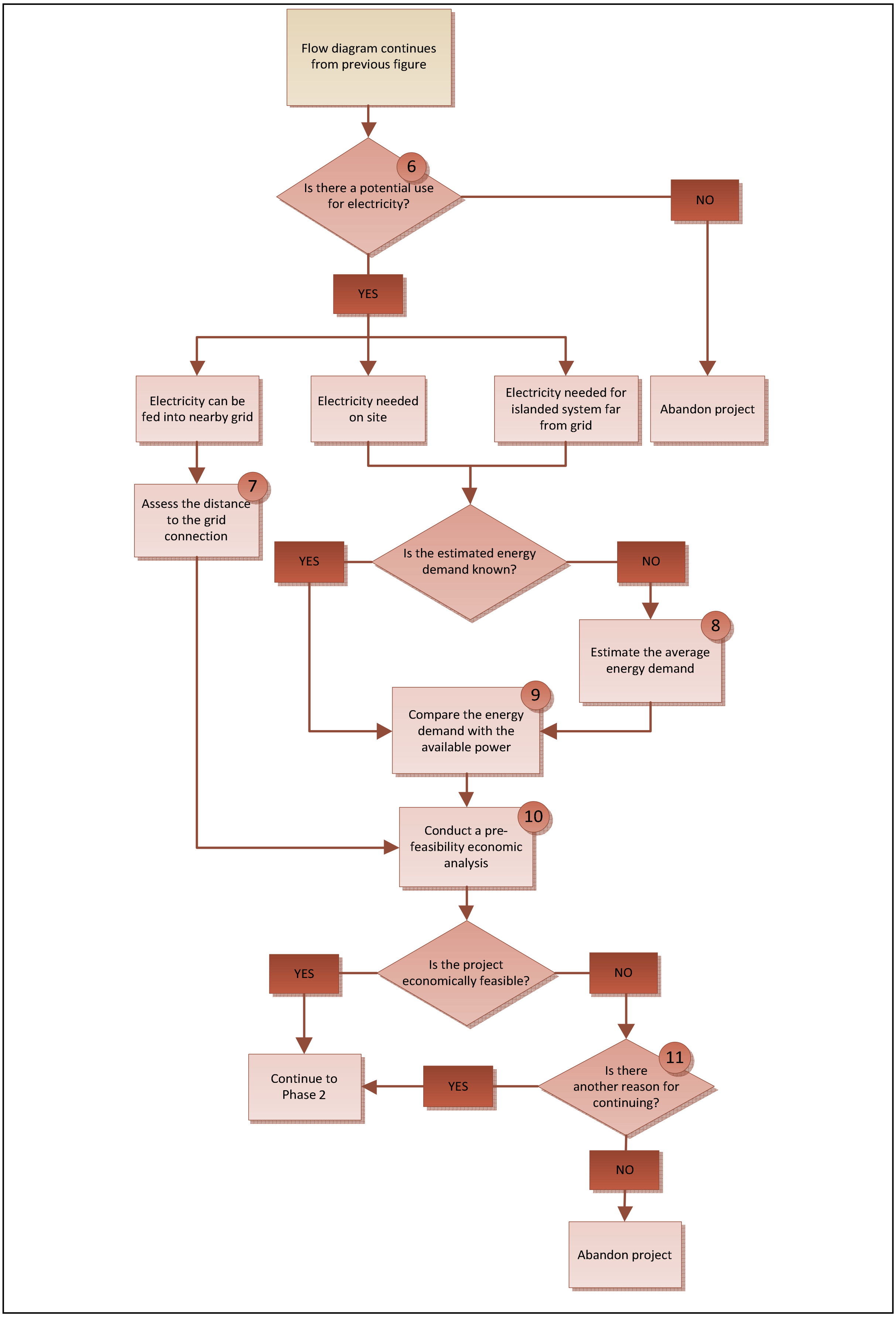


Figure 3-3: Phase 1 flow diagram Part B

3.3.2 PHASE 2 FLOW DIAGRAM

If Phase 1 indicates project viability, a more in-depth investigation can be done during the feasibility study of Phase 2. **Figure 3-4** and **Figure 3-5** illustrate the process to be followed during this stage.

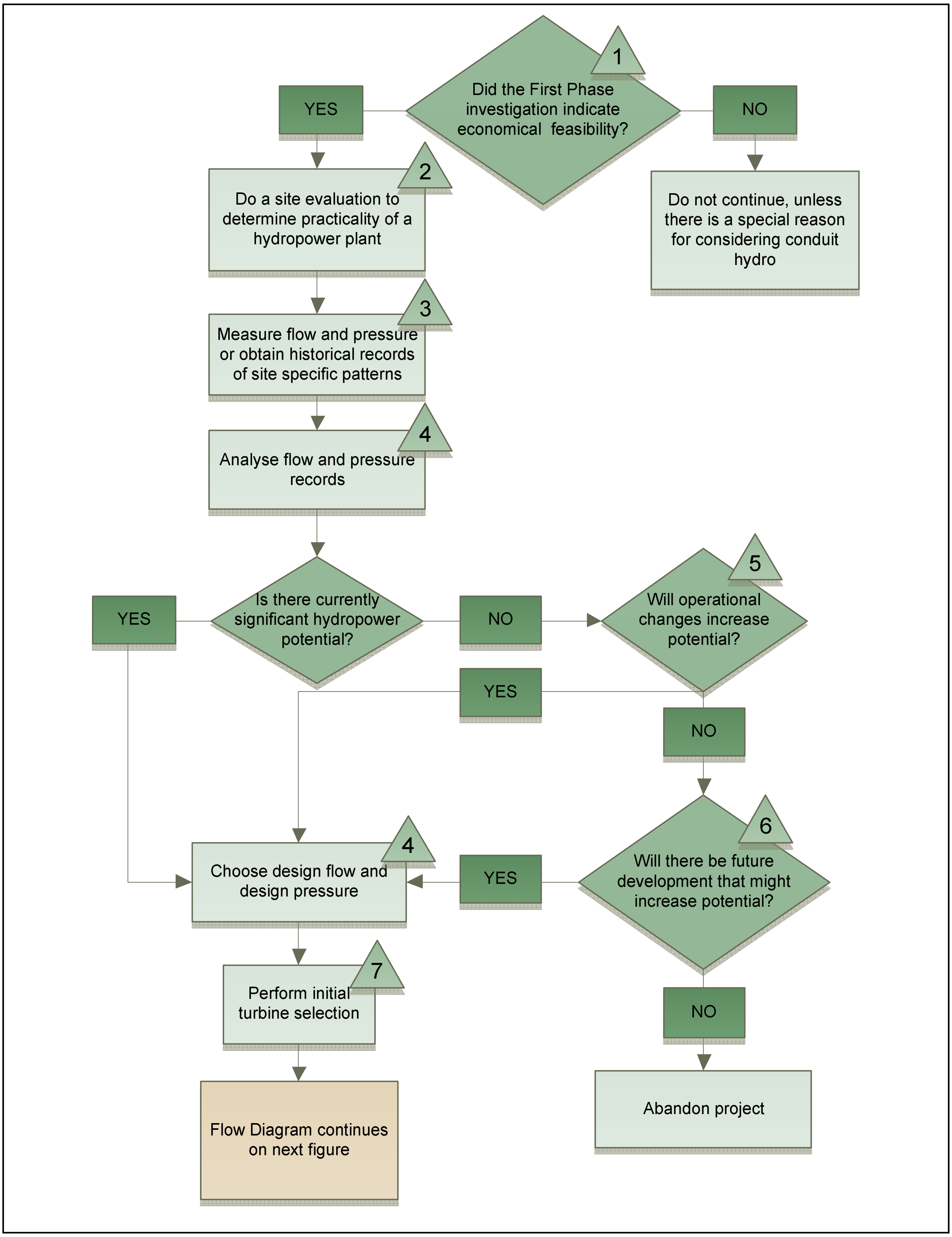


Figure 3-4: Phase 2 flow diagram Part A

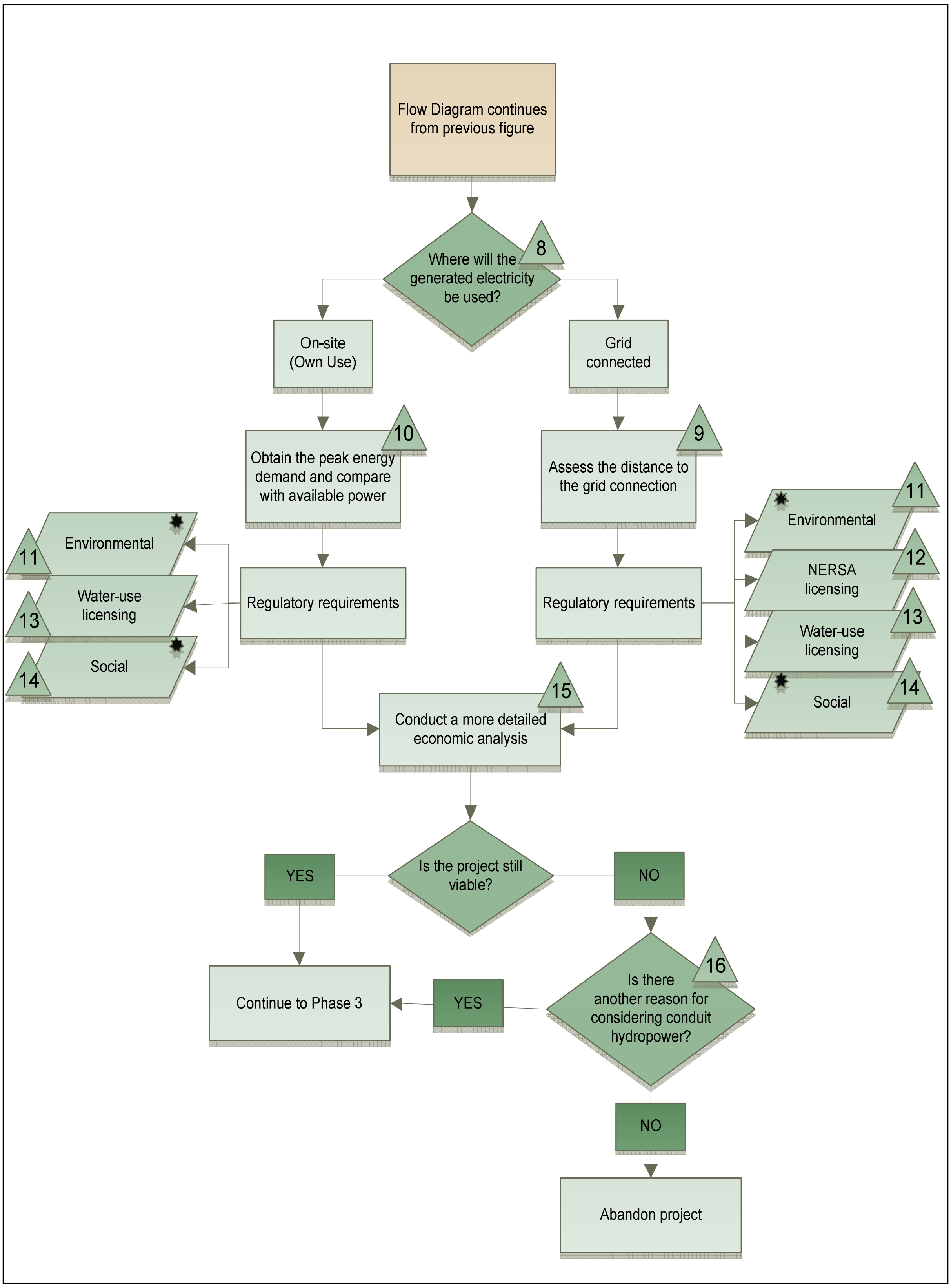


Figure 3-5: Phase 2 flow diagram Part B (✸ depicts specialist consultant input)

3.3.3 PHASE 3 FLOW DIAGRAM

If Phase 2 indicates project viability, a detailed design for the hydropower plant can be done during Phase 3. **Figure 3-6**, **Figure 3-7** and **Figure 3-8** depict the decision support process to be followed in developing the hydropower potential.

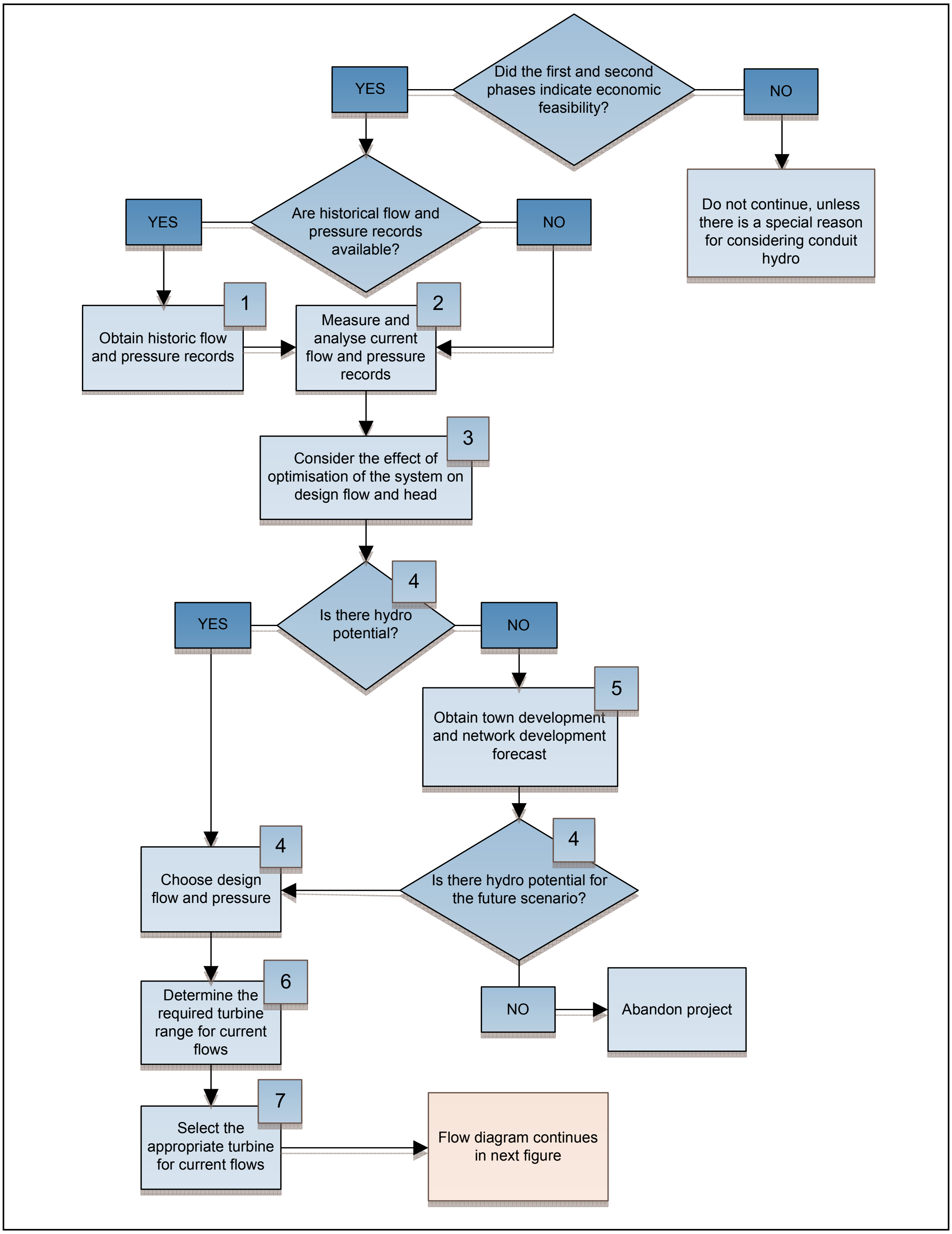


Figure 3-6: Phase 3 flow diagram Part A

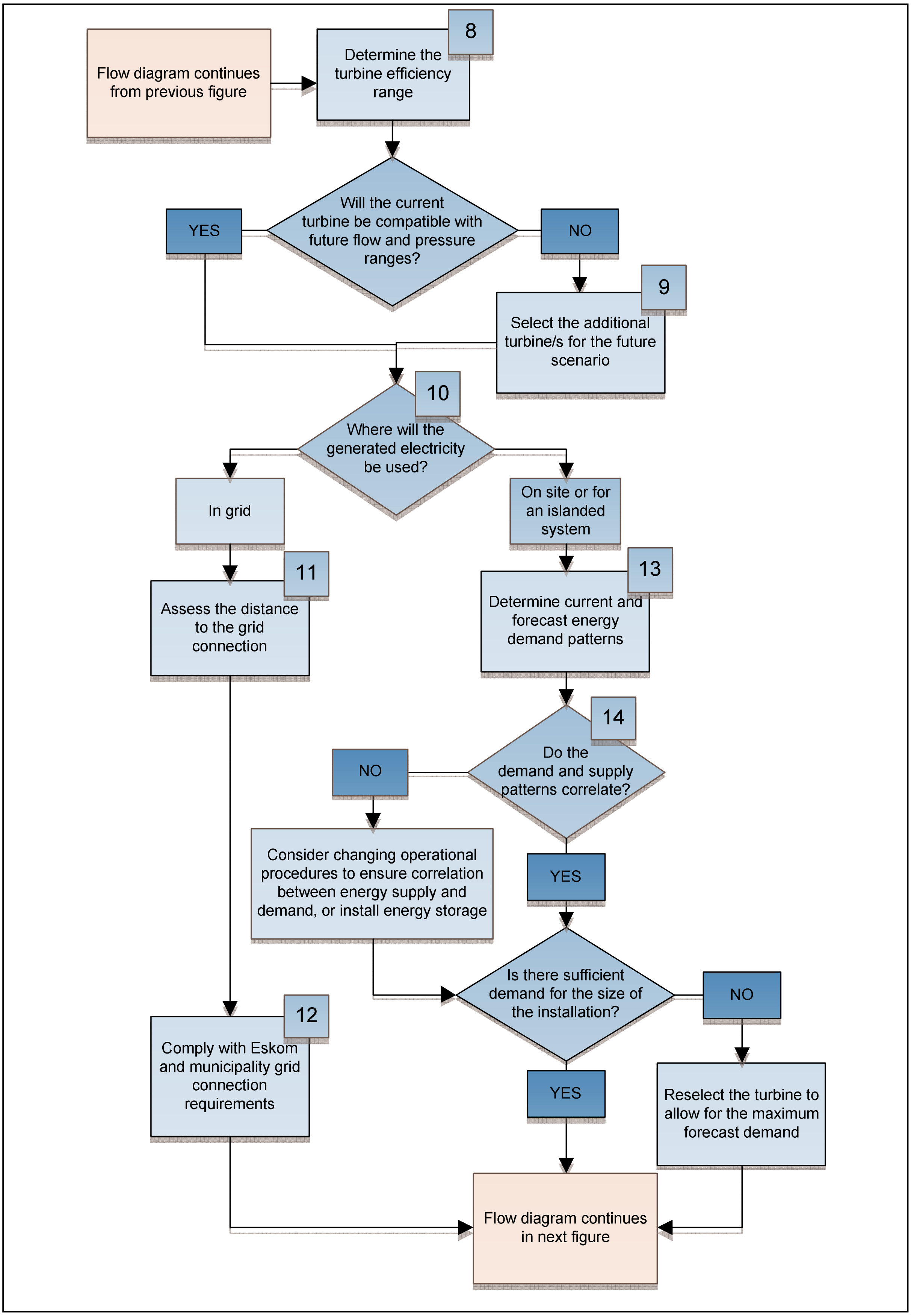


Figure 3-7: Phase 3 flow diagram Part B

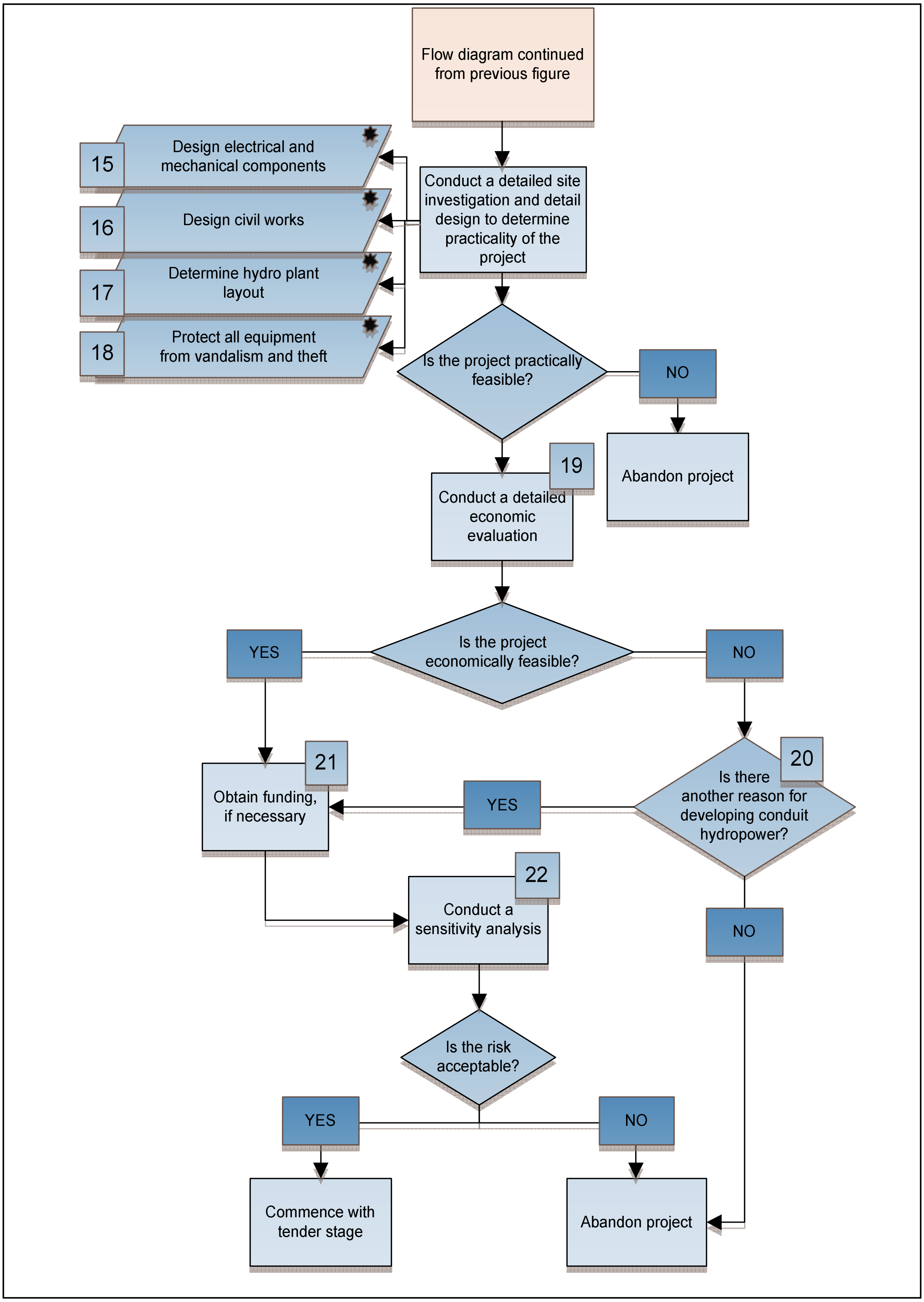


Figure 3-8: Phase 3 flow diagram Part C (✸ depicts specialist consultant input)

3.4 CONDUIT HYDROPOWER DEVELOPMENT TOOL (CHD TOOL)

The thought process and calculations of each phase are incorporated in a Conduit Hydropower Development Tool (CHD Tool). This tool is in the form of a Microsoft Excel spreadsheet and aims to guide designers through the process (Phases 1 to 3) of conduit hydropower design by including all the calculations in a user-friendly format. The tools for all the phases have colour-coded value blocks to visually differentiate between different phases, input and output, as well as user-entered and default values. The colour-coding system is explained in **Table 3-1**. The assumptions and derivations of default values are discussed in **Appendix C**.

Table 3-1: Colour-coding system for CHD Tool

Colour coding	Description
Tan	Phase 1
Green	Phase 2
Ice blue	Phase 3
Light yellow	User must enter values
Sky blue	User may edit default values if better information is available
Light purple	Results

3.4.1 PHASE 1 CHD TOOL

The CHD Tool for Phase 1 is divided into three sections, namely the Hydropower Potential Section, Economic Analysis Section and the Checklist Section.

The Hydropower Potential Section is shown in **Table 3-2**. The only input required in this section is the average daily flow, the average pressure head, if available, the static energy head (if the average head is not known) and, if applicable, the distance to the grid connection and power demand. The output in this section includes the theoretically available power and the ratio of the energy demand vs. available energy, in the case of on-site or islanded systems.

Table 3-2: Phase 1 potential analysis CHD Tool

PHASE 1 POTENTIAL ANALYSIS							
Power potential:							
Site name		Gars fontein					
Date of analysis		21/01/2013					
Annual average daily demand	(AADD)	85 475	kl/d				
Average daily flow	(Q)	0.989	m^3/s				
Average pressure head (if known)	(H)						
Static energy head (if average not known)	(H)	166	m				
Fluid density	(ρ)	1 000	kg/m^3				
Gravitational acceleration	(g)	9.81	m/s^2				
Efficiency	(η)	70	%				
Annual operational percentage		60	%				
Percentage of peak pressure head used		60	%				
Theoretical available power	(P_{av})	**676.6**	kW				
Annual operational time		5 256	h				
Potential annual power		**3 556**	MWh/a				
Energy usage:							
Grid connected					**Islanded/on-site**		
Distance to grid connection			km		Maximum power demand	500	kW
					P_{av}/Maximum power demand	135	%
					Distance to islanded grid		km

The Economic Analysis Section does not require any input, save the design life of the project, unless better information than the default values is available. The output from this section includes initial estimates of the net present value (NPV), internal rate of return (IRR) and payback period of the proposed project. It is important to note that the payback period was calculated considering inflation. **Table 3-3** provides an example of this section.

Table 3-3: Phase 1 economic analysis CHD Tool

PHASE 1 ECONOMIC ANALYSIS			
Power information			
Power rating		676.6	kW
Average daily flow	(Q)	0.989	m^3/s
Used pressure head	(H)	100	m
Design life		15	years
Cost			
Capital		13 234 668	R
Operation & maintenance percentage		1.00	% of capital cost
Annual operation & maintenance Cost		132 347	R
Annual operational percentage		60	%
Annual operational time		5 256	h
Planning		1 350	R/kW
Disposal percentage		1.00	% of capital cost
Disposal cost (present value)		132 347	R
Income			
Value of generated electricity		0.58	R/kWh
Revenue		0.00	R/kWh
Inflation			
Annual inflation of electricity		8.00	%
Annual inflation of O&M		6.00	%
Discount rate		6.00	%
Results			
Net present value of costs		-16 265 667	R
Net present value of income		36 048 301	R
Total NPV		**19 782 634**	**R**
Internal rate of return		**20**	**%**
Payback period		**7**	**years**

The Checklist Section (**Table 3-4**) also does not require any input, but serves as a reference for the user to determine whether all the steps for the first phase have been considered.

Table 3-4: Phase 1 checklist CHD Tool

PHASE 1 CHECKLIST	?
Are there pressure reducing stations in the system?	
Are there other locations with excess pressure in the system?	
Is there a utilization agreement with the owner?	
Have the average daily flow - and pressure records been obtained?	
Has the estimated available power been calculated?	
Has the electricity use destination been established?	
For grid tie-in: Has the distance to the grid connection been measured?	
For islanded/on-site systems: Has the energy demand been determined?	
For islanded/on-site systems: Is the energy demand less than the available power?	
Has a pre-feasibility economic analysis been conducted?	
Is the project economically feasible?	
If not, is there another reason for continuing?	

If Phase 1 indicates feasibility, the user should continue to Phase 2 of the CHD Tool.

3.4.2 PHASE 2 CHD TOOL

Phase 2 of the CHD Tool is divided into 15 sections. Current and Future scenarios can be included for: the Hydropower Potential; Flow-Rating Curves; Energy Delivered; Turbine Selection; Optimum Percentage Use Curves; and Flow vs. Head Curves. The final three sections (Regulatory; Economic Analysis; and Checklist Sections) are applicable to the entire project and therefore incorporate both current and future scenarios.

The Hydropower Potential Section can be seen in **Table 3-5**. The inputs required in this section are the measured values for flow and available head. The CHD Tool accepts data of up to 35 000 data points. The CHD Tool requires the data to be sorted from lowest to highest flow with corresponding pressure heads, with all data gaps removed. The number of used data points is also required.

Twenty-one data points corresponding to a 0% to 100% assurance of flow, (in 5% intervals) should be selected and entered into the allocated cells. If energy production is required for a specific percentage of time, this percentage (in multiples of 5%) should be entered into the 'Assurance of flow' cell to obtain the design flow. However, if the optimum flow, average flow or a user-defined flow is required, this cell should be left blank. If the average flow or a user-defined flow is required, it should be indicated by checking the applicable box.

Default values for fluid density, gravitational acceleration and turbine efficiency are provided, but if accurate values are known, they may be entered. The output values for this section are: an initial estimate of the design flow; design head; design power rating; and annual power generation.

Table 3-5: Phase 2 potential analysis CHD Tool

PHASE 2 POTENTIAL ANALYSIS

Flow rating curve	Load factor (%)	Flow (m^3/s)	Head available (m)	Time in use (h)	Power rating (kW)	Potential power (MWh/a)	Potential power for optimum use (MWh)
	100%	0	125	8592	0.0	0.000	0
	95%	0.000	123.4	8154	0.0	0.000	0
	90%	0.001	139.5	7716	0.7	5.257	0.146331973
	85%	0.059	143.9	7278	57.9	421.481	12.58574673
	80%	0.184	142.9	6840	180.5	1234.373	51.20306327
	75%	0.310	138.0	6402	293.8	1880.647	101.8631544
	70%	0.412	131.2	5964	371.2	2213.611	142.8251233
	65%	0.553	127.4	5526	483.7	2673.165	183.6336555
	60%	0.780	113.8	5088	609.8	3102.773	261.9793884
	55%	0.959	92.6	4650	609.9	2836.029	261.9793884
	50%	0.974	94.6	4212	632.5	2664.041	261.9793884
	45%	0.981	96.6	3774	651.0	2456.741	261.9793884
	40%	0.986	99.0	3336	670.6	2237.108	261.9793884
	35%	0.992	101.0	2898	688.3	1994.790	261.9793884
	30%	0.999	103.4	2460	709.2	1744.648	261.9793884
	25%	1.009	109.8	2022	760.6	1537.894	261.9793884
	20%	1.025	120.9	1584	851.4	1348.662	261.9793884
	15%	1.105	88.0	1146	667.8	765.326	261.9793884
	10%	1.194	97.1	708	795.7	563.354	261.9793884
	5%	1.372	85.8	270	808.2	218.204	261.9793884
	0%	1.456	82.6	0	825.4	0.000	261.9793884
Optimum flow	60%	0.780	113.8	5088.0	609.8		3897.989125
Average flow		0.767	111.6	8592	588.0	5052.294	
Chosen flow		0.037	50.4	8592	12.8	110.026	
Assurance of flow		0.000	0.0	0	0.0		
Design flow	**60%**	**0.780**	**113.8**	**5088**	**609.8**	**3898.0**	

General input				Energy usage			Islanded/on-site		
Fluid density	(ρ)	1000	kg/m^3	Grid connected			Islanded/on-site		
Gravitational acceleration	(g)	9.81	m/s^2	Distance	0.5	km	Max demand		kW
Efficiency	(η)	70	%				P_{av}/Max demand	0	%
Annual maintenance days		7	days				Distance to grid		km

PHASE 2 INPUT

Site name: Garsfontein

Data points	Load factor (%)	Date and time	Flow (m^3/s)	Head available (m)	Time in use (h)	Power rating (kW)	Potential power (MWh/a)
13929	100.0000%	2012/03/30 13:45	0	125	8760	0.0	0.0
13928	99.9928%	2012/03/30 14:30	0	122	8759.371096	0.0	0.0
13927	99.9856%	2012/03/30 14:45	0	123	8758.742193	0.0	0.0
13926	99.9785%	2012/03/31 16:15	0	127	8758.113289	0.0	0.0
1392[illegible]	99.9713%	2012/03/31 16:30	0	127	8757.484385	0.0	0.0

This section also generates various decision support graphs. These include a flow-rating curve (**Figure 3-9**), a potential energy curve (**Figure 3-10**), an initial turbine selection curve (**Figure 3-11**), an optimum percentage use curve (**Figure 3-12**) and a flow vs. head curve (**Figure 3-14**). These curves can be viewed in the four sections subsequent to the Hydropower Potential Section.

It should be noted that in a closed system (with one inflow), there will be a specific inverse relationship between flow and pressure head, with a flow rate always associated with the same pressure head, as per **Figure 3-13**. However, in a complex system with various independent inflow and outflow points, a specific correlation will not be found between flow rate and pressure head, as per **Figure 3-14**. It is therefore necessary to carefully choose the design pressure head in a complex system.

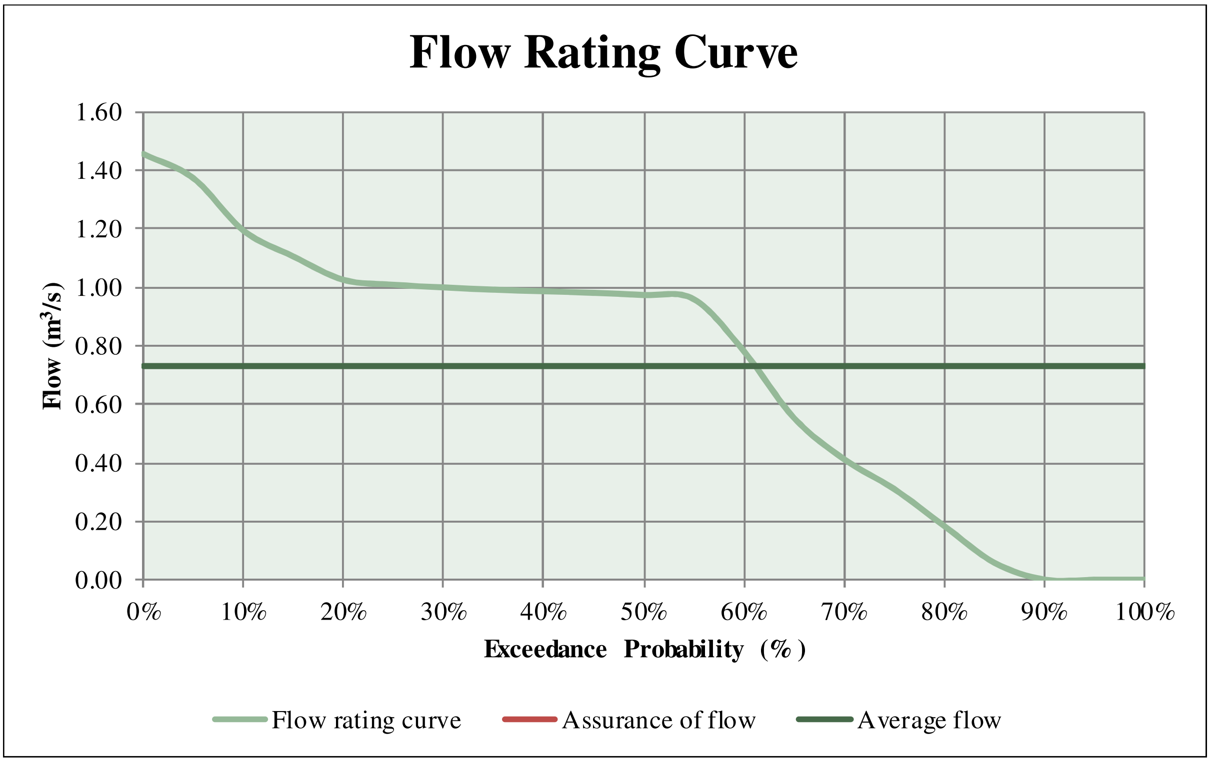


Figure 3-9: Phase 2 flow-rating curve CHD Tool

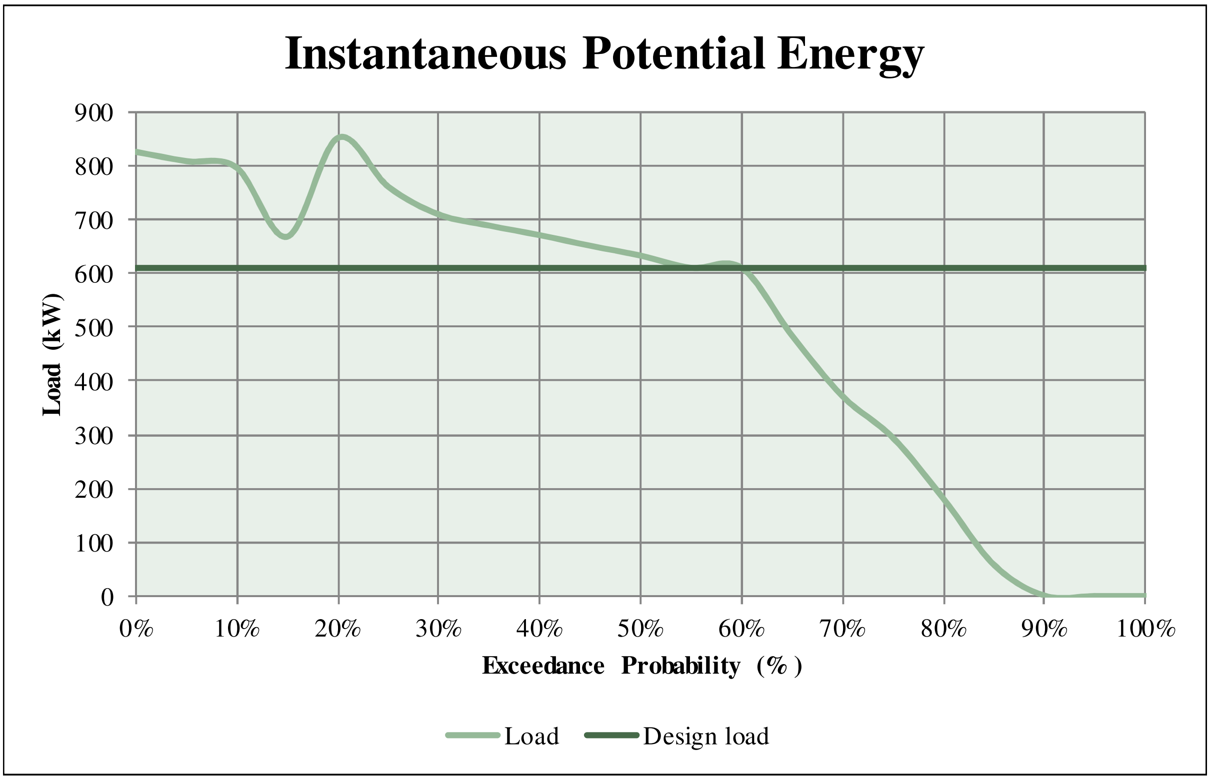


Figure 3-10: Phase 2 potential energy curve CHD Tool

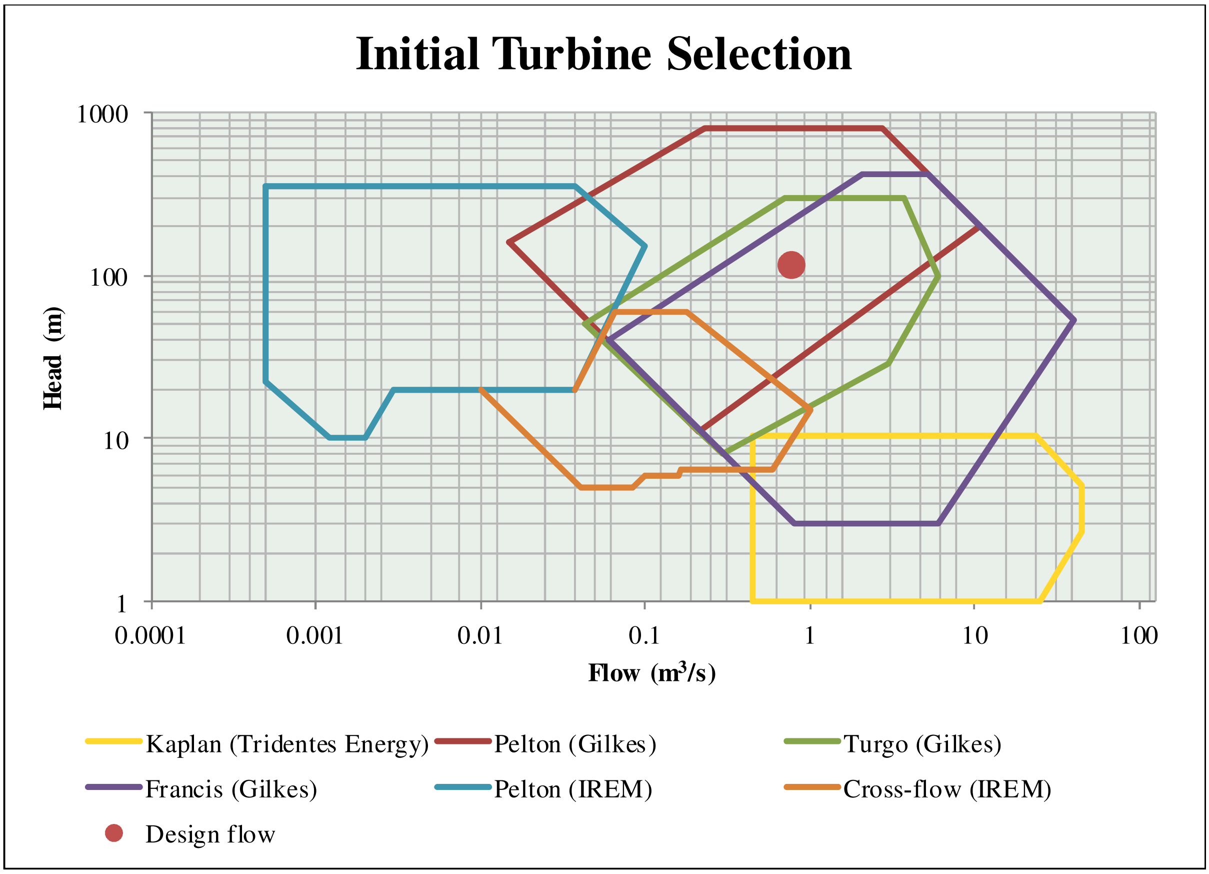


Figure 3-11: Phase 2 initial turbine selection CHD Tool

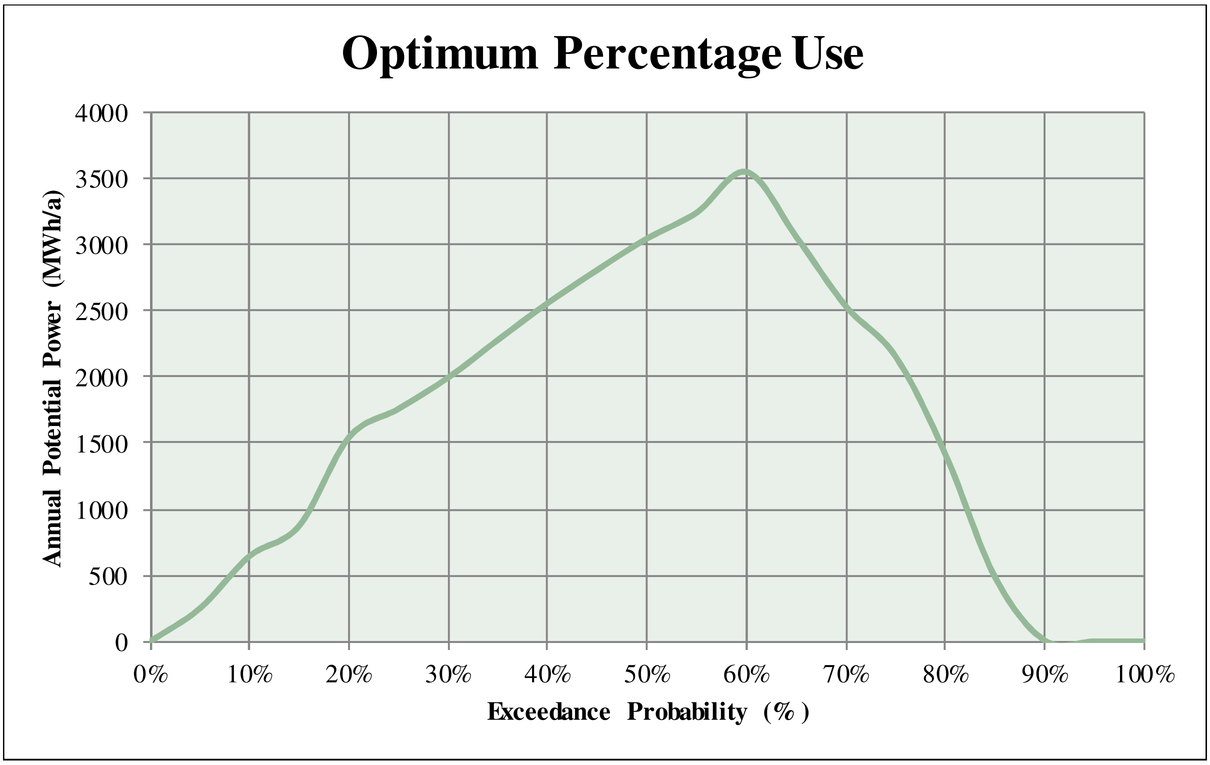


Figure 3-12: Phase 2 optimum percentage use curve CHD Tool

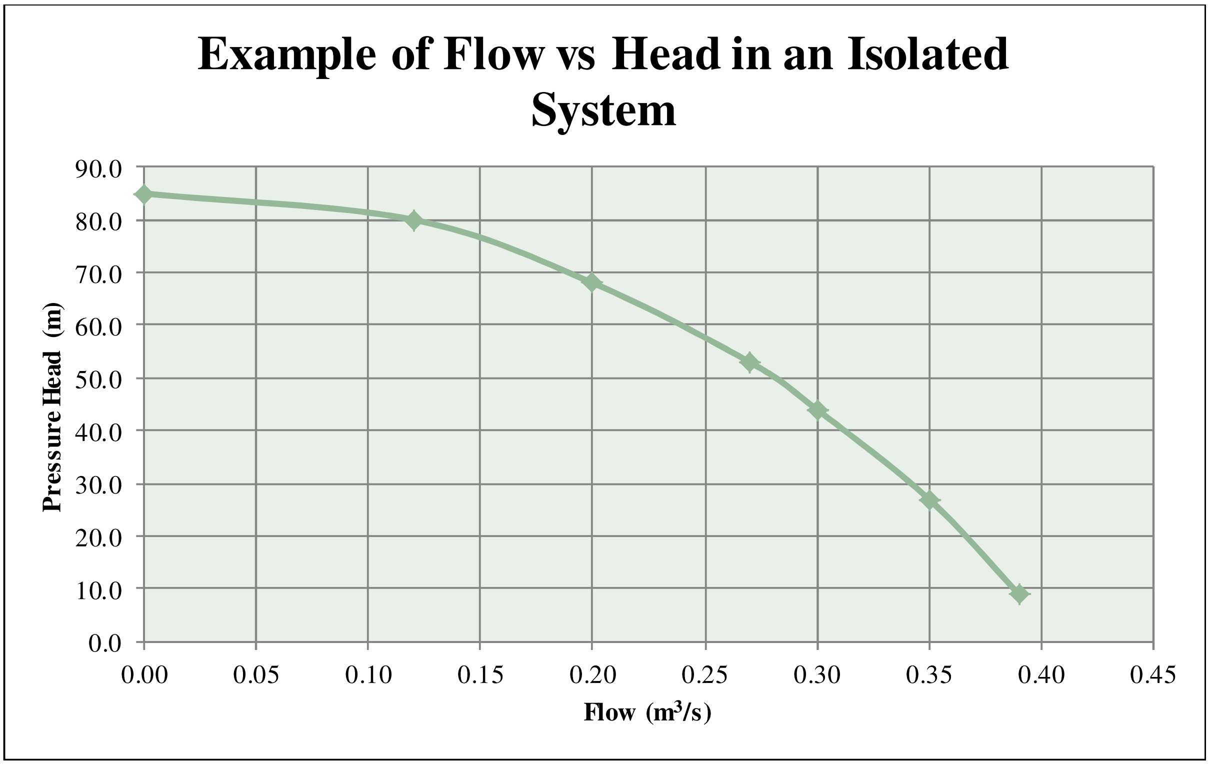


Figure 3-13: Example of flow vs. head in an isolated system

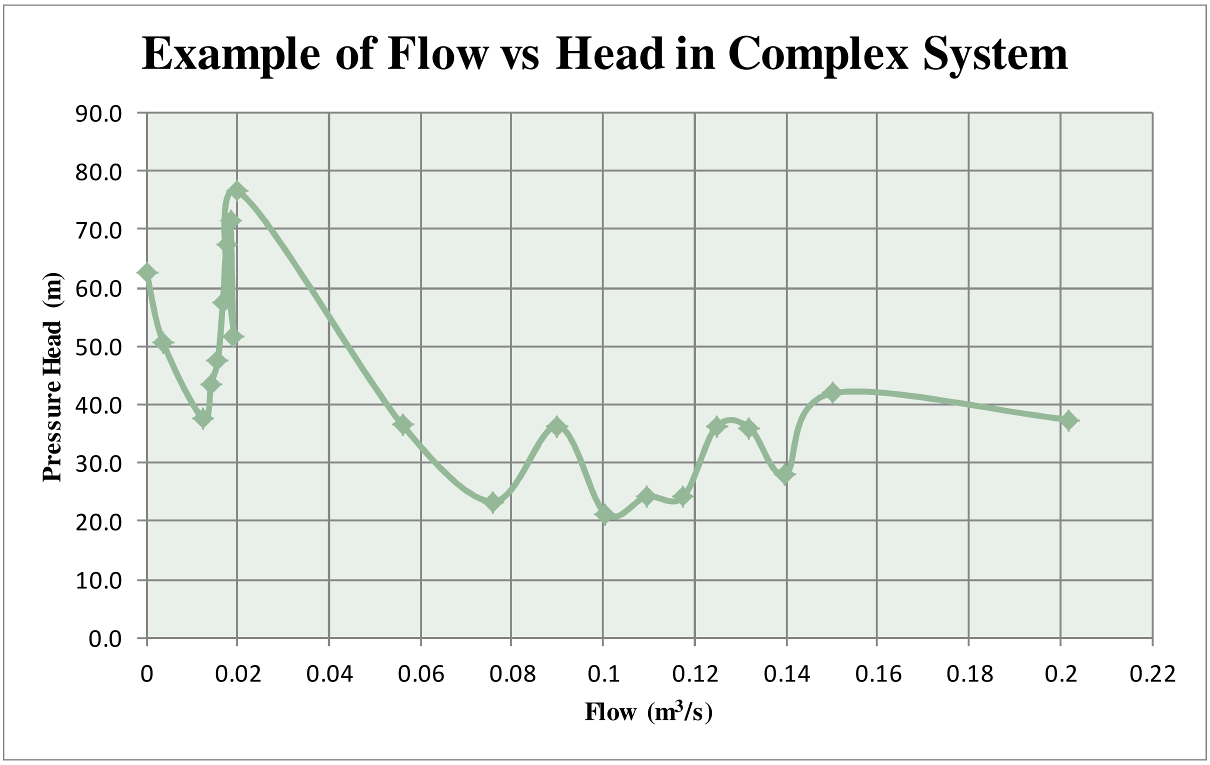


Figure 3-14: Example of flow vs. head in an open system

The Regulatory Section includes links to relevant websites, as well as applicable application forms for regulatory processes, pertaining to NERSA licensing and Eskom licensing.

The Economic Analysis Section has various default formulas (refer to **Appendix C** for derivation of formulas), but information like turbine type, updated overall costs, design life and inflation rates have to be entered into the Tool. Also, if better information than the default values is available, the values should be altered to reflect the most accurate costs. The output in this screen includes an estimated net present value (NPV), internal rate of return (IRR) and payback period of the proposed project.

Table 3-6: Phase 2 economic analysis CHD Tool

PHASE 2 ECONOMIC ANALYSIS			
Power information for current scenario			
Power rating		609.8	kW
Design flow	(Q)	0.780	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		3 898	MWh/a
Turbine type		Turgo	
Total Power information for future scenario			
Power rating		1 220	kW
Design flow	(Q)	1.561	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		7 796	MWh/a
Turbine type		Turgo	
Design life		15	years
Cost			
Initial planning cost (IPC)	% of total IPC		
Planning cost per MW installed (2012)		R 1 350 000	
Planning year		2013	
Planning cost per MW installed		R 1 350 000	
Legal and regulatory	3.0%	R 24 698	
Environmental and social assessment	27.0%	R 222 280	
Investigation and preliminary design	70.0%	R 576 281	
Subtotal	100.0%	**R 823 259**	
Capital expenditure (CEC)	% of total CEC		
Turbine		R 6 708 193	
Capital cost per MW installed (excl turbine) (2012)		R 13 300 000	
Construction year		2014	
Capital cost per MW installed (excl turbine)		R 13 300 000	
Preliminary and general	24.5%	R 1 987 104	
Access to site	0.5%	R 40 553	
Pipework and valves	6.5%	R 527 191	
Power station housing and tailrace	20.0%	R 1 622 126	
Electromechanical and controls	12.0%	R 973 275	
Transformer/transmission	12.5%	R 1 013 829	
Construction supervision	5.5%	R 446 085	
Contingencies	17.5%	R 1 419 360	
Disposal (present value (PV))	1.0%	R 81 106	
Subtotal	100.0%	**R 14 818 821**	
Additional capital expenditure due to expansion (PV)		R 6 708 193	
Year of expansion		2029	
Annual operation and maintenance cost (OMC)	% of CEC for component		
Civil items	0.25%	R 5 373	
Electrical and mechanical items	2.00%	R 153 629	
Transmission	0.80%	R 8 111	
Operation	0.40%	R 59 275	
Insurance	0.30%	R 44 456	
Subtotal (PV)		**R 270 845**	
Income			
Annual income for current scenario	R/kWh		
Average value of generated electricity	0.58	R 2 260 834	
Revenue		R 0	
Subtotal (PV)		**R 2 260 834**	
Annual income for future scenario	R/kWh		
Average value of generated electricity	0.58	R 4 521 667	
Revenue		R 0	
Subtotal (PV)		**R 4 521 667**	
Results			
Net present value of costs	-R 19 266 797		
Net present value of income	R 41 090 195		
Total NPV	**R 21 823 398**		
Internal rate of return	**19.74%**		
Payback period	**8**	years	

Inflation and maintenance factors over design life					
Year	**Annual Inflation**				**Maintenance factors**
	Electricity	**Operation**	**Maintenance**	**General**	
0	8.0%	5.3%	5.3%	5.3%	0.8
1	8.0%	5.1%	5.1%	5.1%	0.8
2	8.0%	6.0%	6.0%	6.0%	0.8
3	8.0%	6.0%	6.0%	6.0%	0.8
4	8.0%	6.0%	6.0%	6.0%	0.8
5	10.0%	6.0%	6.0%	6.0%	1
6	10.0%	6.0%	6.0%	6.0%	1
7	10.0%	6.0%	6.0%	6.0%	1
8	10.0%	6.0%	6.0%	6.0%	1
9	10.0%	6.0%	6.0%	6.0%	1
10	10.0%	6.0%	6.0%	6.0%	1
11	10.0%	6.0%	6.0%	6.0%	1
12	10.0%	6.0%	6.0%	6.0%	1
13	10.0%	6.0%	6.0%	6.0%	1
14	10.0%	6.0%	6.0%	6.0%	1
15	6.0%	6.0%	6.0%	6.0%	1.2
16	6.0%	6.0%	6.0%	6.0%	1.2
17	6.0%	6.0%	6.0%	6.0%	1.2
18	6.0%	6.0%	6.0%	6.0%	1.2
19	6.0%	6.0%	6.0%	6.0%	1.2
20	6.0%	6.0%	6.0%	6.0%	1.25
21	6.0%	6.0%	6.0%	6.0%	1.25
22	6.0%	6.0%	6.0%	6.0%	1.25
23	6.0%	6.0%	6.0%	6.0%	1.25
24	6.0%	6.0%	6.0%	6.0%	1.25
25	6.0%	6.0%	6.0%	6.0%	1.25
26	6.0%	6.0%	6.0%	6.0%	1.25
27	6.0%	6.0%	6.0%	6.0%	1.25
28	6.0%	6.0%	6.0%	6.0%	1.25
29	6.0%	6.0%	6.0%	6.0%	1.25
30	6.0%	6.0%	6.0%	6.0%	1.5
31	6.0%	6.0%	6.0%	6.0%	1.5
32	6.0%	6.0%	6.0%	6.0%	1.5
33	6.0%	6.0%	6.0%	6.0%	1.5
34	6.0%	6.0%	6.0%	6.0%	1.5
35	6.0%	6.0%	6.0%	6.0%	1.5
36	6.0%	6.0%	6.0%	6.0%	1.5
37	6.0%	6.0%	6.0%	6.0%	1.5
38	6.0%	6.0%	6.0%	6.0%	1.5
39	6.0%	6.0%	6.0%	6.0%	1.5
40	6.0%	6.0%	6.0%	6.0%	1.5
41	6.0%	6.0%	6.0%	6.0%	1.5
42	6.0%	6.0%	6.0%	6.0%	1.5
43	6.0%	6.0%	6.0%	6.0%	1.5
44	6.0%	6.0%	6.0%	6.0%	1.5
45	6.0%	6.0%	6.0%	6.0%	1.5
46	6.0%	6.0%	6.0%	6.0%	1.5
47	6.0%	6.0%	6.0%	6.0%	1.5
48	6.0%	6.0%	6.0%	6.0%	1.5
49	6.0%	6.0%	6.0%	6.0%	1.5
50	6.0%	6.0%	6.0%	6.0%	1.5

The Checklist Section (**Table 3-7**) for this phase does not require any input, but serves as a reference for the user to determine whether all the steps for the second phase have been considered.

Table 3-7: Phase 2 checklist CHD Tool

PHASE 2 CHECKLIST	
Did the first phase indicate economic feasibility?	
If not, is there another reason for considering conduit hydro?	
Did the site evaluation show feasibility?	
Were flow - and pressure records measured/obtained?	
Were all gaps discarded?	
Were the values ranked from small to large flow with corresponding pressures?	
Was a percentage assigned to each flow (100% exceedance for min flow to 0% exceedance for max flow?	
Has the flow rating curve been populated?	
Has the hydropower potential been analysed?	
Is there currently significant potential?	
If not, will there be future develoment that might increase potential?	
Has a design flow and pressure been chosen?	
Has a first order turbine selection been done?	
For grid tie-in: Have all environmental aspects been considered and permission been obtained?	
For grid tie-in: Have licensing requirements been satisfied?	
For grid tie-in: Have all water use aspects been considered and permission been obtained?	
For grid tie-in: Have all social issues been addressed?	
For islanded/on-site systems: Have all environmental aspects been considered and permission been obtained?	
For islanded/on-site systems: Have all water use aspects been considered and permission been obtained?	
For islanded/on-site systems: Have all social issues been addressed?	
Has a pre-feasibility economic analysis been conducted?	
Is the project economically feasible?	
If not, is there another reason for continuing?	

3.4.3 PHASE 3 CHD TOOL

Phase 3 of the CHD Tool has 14 sections. Current and Future Sections are available for: the Hydropower Potential; Required Turbine Range; Potential Income (for grid-connected applications); Power Potential vs. Income Graphs (for grid-connected applications); Power Potential vs. Demand (for on-site and islanded applications); and Daily Supply-and-Demand Graphs (for on-site and islanded applications). The Economic Analysis and Checklist Sections are applicable to the entire project and therefore incorporate both current and future scenarios.

As this phase includes detailed design, site-specific information needs to be sourced and generalised information cannot be used for this phase. The CHD Tool for this phase can therefore only provide a minimum amount of default information.

The Hydropower Potential section can be seen in **Table 3-8**. The inputs required in this section are the measured values for flow and available head. The screen accepts data for up to 35 000 data points.

The CHD Tool requires the data to be sorted from lowest to highest flow with corresponding pressure heads, with all data gaps removed. The number of used data points is also required.

Twenty-one data points corresponding to a 0% to 100% assurance of flow, (in 5% intervals) should be selected and entered into the allocated cells. If energy production is required for a certain percentage of time, this percentage (in multiples of 5%) should be entered into the applicable cell to obtain the design flow. However, if the optimum flow, average flow or a user-defined flow is required, this cell should be left blank. If the average flow or a user-defined flow is required, it should be indicated by checking the applicable box.

The first set of output values for this section includes: the design flow, design head and annual power generation. The design flow, as well as required minimum and maximum flows is entered into the Flow Range column in the section. A graph depicting the required turbine range (**Figure 3-15**) is produced from this information. This can be used when contacting turbine suppliers to obtain turbine information. It is important to note that turbines produced by different manufacturers will have different ranges of flow rate and operating heads applicable to the various turbine types and this graph is therefore only a guideline as far as turbine selection is concerned. The Required Turbine Range Section does have a column where user-defined turbine information may be entered. This is shown in **Table 3-9**.

Table 3-8: Phase 3 potential analysis CHD Tool

PHASE 3 POTENTIAL ANALYSIS

Flow rating curve	Load factor (%)	Flow (m^3/s)	Head available (m)	Efficiency (%)	Time in use (h)	Power rating (kW)	Potential power (MWh/a)	Potential power for optimum use (MWh)
	100	0	125	0%	8592	0.0	0.000	0.000
	95	0.000	123.4	0%	8154	0.0	0.000	0.000
	90	0.001	139.5	0%	7716	0.0	0.000	0.000
	85	0.059	143.9	22%	7278	18.2	132.465	5.681
	80	0.184	142.9	55%	6840	141.8	969.865	5.681
	75	0.310	138.0	80%	6402	335.7	2149.311	5.681
	70	0.412	131.2	83%	5964	440.1	2624.710	5.681
	65	0.553	127.4	84%	5526	577.0	3188.704	5.681
	60	0.780	113.8	84%	5088	727.4	3701.165	5.681
	55	0.959	92.6	84%	4650	727.5	3382.977	5.681
	50	0.974	94.6	84%	4212	754.5	3177.821	5.681
	45	0.981	96.6	84%	3774	776.5	2930.541	5.681
	40	0.986	99.0	84%	3336	799.9	2668.550	5.681
	35	0.992	101.0	84%	2898	821.1	2379.499	5.681
	30	0.999	103.4	84%	2460	846.0	2081.116	5.681
	25	1.009	109.8	84%	2022	907.3	1834.488	5.681
	20	1.025	120.9	84%	1584	1015.6	1608.761	5.681
	15	1.105	88.0	84%	1146	796.6	912.925	5.681
	10	1.194	97.1	84%	708	949.2	672.001	5.681
	5	1.372	85.8	84%	270	964.0	260.286	5.681
	0	1.456	82.6	84%	0	984.5	0.000	5.681
Optimum flow	60	0.780	113.8		5088	727.4	3701.165	102.259
Average flow		0.767	111.6	84%	8592	701.4	6026.665	
Chosen flow	USE	0.032	50.4	84%	8592	13.0	111.735	
Assurance of flow		0.000	0.0	84%	0	0.0	0.000	
Design flow	**Chosen**	**0.032**	**50.4**		**8592**	**13.0**	**111.7**	

Flow range

Minimum flow	55	0.959	92.6		727.5	3382.977
Design flow	60	0.0315	50.4		13.0	111.735
Maximum flow	55	0.959	92.6		727.5	3383.0

General input

Fluid density	(ρ)	1000	kg/m^3
Gravitational acceleration	(g)	9.81	m/s^2
Efficiency	(η)	80	%
Annual maintenance days		7	days

Energy usage

Grid connected

Distance	0.5	km

Islanded/on-site

Max demand		kW
Pav/Max demand	0	%
Distance to grid		km

PHASE 3 INPUT

Site name: Garsfontein

Data points	Load factor (%)	Date and time	Flow (m^3/s)	Head available (m)	Time in use (h)	Potential power (MWh/a)
13929	100.0000%	2012/03/30 13:45	0	125	8760	0.0
13928	99.9928%	2012/03/30 14:30	0	122	8759.371096	0.0
13927	99.9856%	2012/03/30 14:45	0	123	8758.742193	0.0
13926	99.9785%	2012/03/31 16:15	0	127	8758.113289	0.0
13925	99.9713%	2012/03/31 16:30	0	127	8757.484385	0.0
13924	99.9641%	2012/04/02 06:30	0	123	8756.855481	0.0
13923	99.9569%	2012/04/02 10:00	0	107	8756.226578	0.0
13922	99.9497%	2012/04/02 10:15	0	117	8755.597674	0.0
13921	99.9426%	2012/04/02 12:45	0	114	8754.96877	0.0
13920	99.9354%	2012/04/02 15:15	0	114	8754.339866	0.0
13919	99.9282%	2012/04/02 15:30	0	117	8753.710963	0.0
13918	99.9210%	2012/04/02 19:30	0	130	8753.082059	0.0
13917	99.9138%	2012/04/03 08:45	0	117	8752.453155	0.0
13916	99.9067%	2012/04/03 09:00	0	117	8751.824252	0.0
13915	99.8995%	2012/04/03 16:15	0	114	8751.195348	0.0
13914	99.8923%	2012/04/03 16:30	0	115	8750.566444	0.0

Table 3-9: Phase 3 user turbine input CHD Tool

PHASE 3 USER TURBINE INPUT	
Manufacturer	
Flow (m^3/s)	Corresponding head (m)

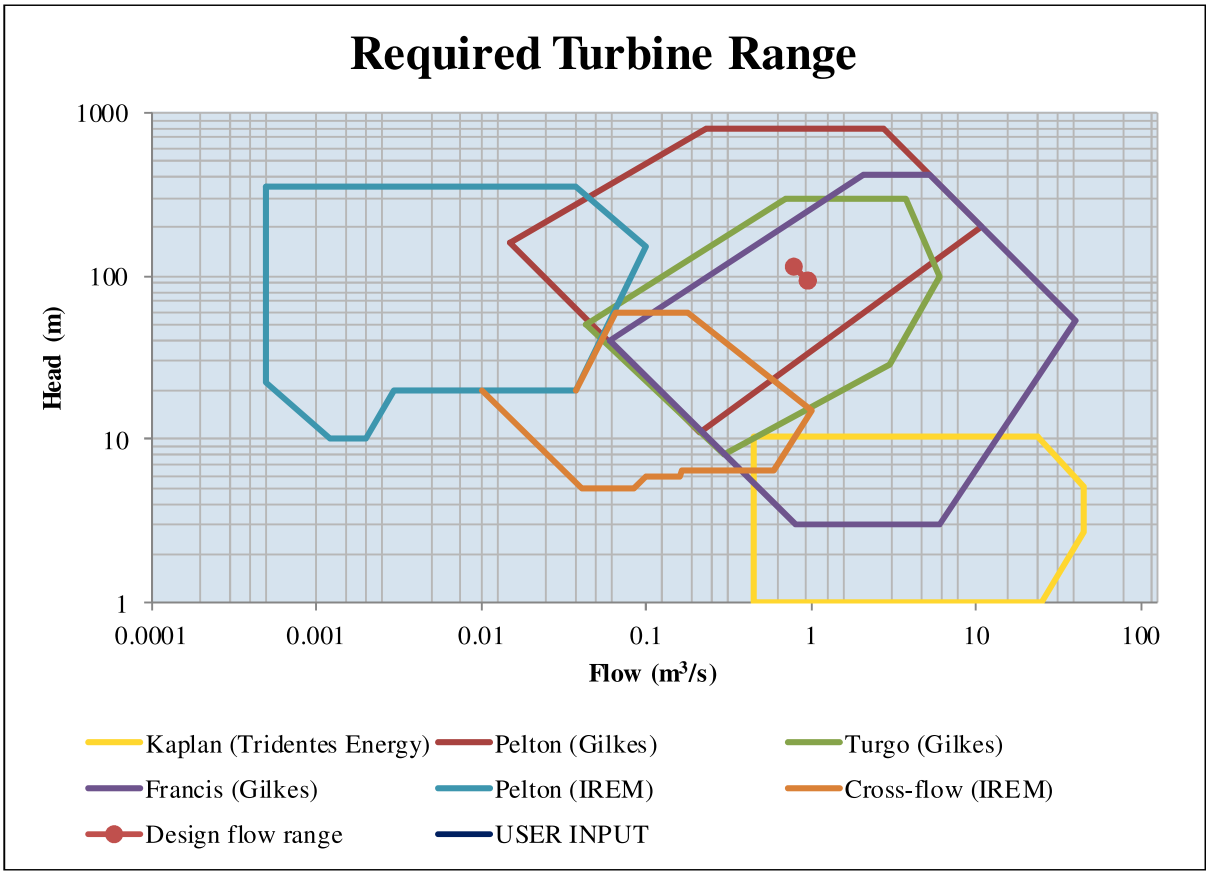


Figure 3-15: Phase 3 turbine selection CHD Tool

The next two sections are the Potential Income and Power Potential vs. Income Graph Sections and are applicable to grid-connected applications. The information entered into the Potential Income Section is depicted graphically in the Power Potential vs. Income Graphs Section.

The function of the Potential Income Section is to tabulate electricity tariffs and average hourly power potential throughout the day, for different seasons and days of the week (**Table 3-10**). This information is used to populate the Power Potential vs. Income Graphs (**Figure 3-16**), that clearly show the correlation between hours of high electricity value (peak times) and hours with high power potential. The purpose of this section is to indicate to the municipality a possible operational procedure for higher power production (to ensure a higher income), if it does not negatively affect water supply to users.

Table 3-10: Phase 3 potential income CHD Tool (for grid-connected applications)

PHASE 3: VALUE OF ELECTRICITY

Megaflex tariffs 2012-2013	Time of day	Winter (c/kWh)			Summer (c/kWh)		
		Weekdays	Saturday	Sunday	Weekdays	Saturday	Sunday
	00:00	41.79	41.79	41.79	36.99	36.99	36.99
	01:00	41.79	41.79	41.79	36.99	36.99	36.99
	02:00	41.79	41.79	41.79	36.99	36.99	36.99
	03:00	41.79	41.79	41.79	36.99	36.99	36.99
	04:00	41.79	41.79	41.79	36.99	36.99	36.99
	05:00	41.79	41.79	41.79	36.99	36.99	36.99
	06:00	71.74	41.79	41.79	49.73	36.99	36.99
	07:00	254.85	71.74	41.79	76.5	49.73	36.99
	08:00	254.85	71.74	41.79	76.5	49.73	36.99
	09:00	254.85	71.74	41.79	76.5	49.73	36.99
	10:00	71.74	71.74	41.79	49.73	49.73	36.99
	11:00	71.74	71.74	41.79	49.73	49.73	36.99
	12:00	71.74	41.79	41.79	49.73	36.99	36.99
	13:00	71.74	41.79	41.79	49.73	36.99	36.99
	14:00	71.74	41.79	41.79	49.73	36.99	36.99
	15:00	71.74	41.79	41.79	49.73	36.99	36.99
	16:00	71.74	41.79	41.79	49.73	36.99	36.99
	17:00	71.74	41.79	41.79	49.73	36.99	36.99
	18:00	254.85	71.74	41.79	76.5	49.73	36.99
	19:00	254.85	71.74	41.79	76.5	49.73	36.99
	20:00	71.74	41.79	41.79	49.73	36.99	36.99
	21:00	71.74	41.79	41.79	49.73	36.99	36.99
	22:00	41.79	41.79	41.79	36.99	36.99	36.99
	23:00	41.79	41.79	41.79	36.99	36.99	36.99
General input							
Fluid density	(ρ)	1000 kg/m³					
Gravitational acceleration	(g)	9.81 m/s²					

PHASE 3: POTENTIAL POWER

Time of day	Average hourly power in winter														
	Weekdays					Saturday					Sunday				
	Flow (m³/s)	Head (m)	Efficiency (η)	Average hourly power (kWh)	Value of power (c)	Flow (m³/s)	Head (m)	Efficiency (η)	Average hourly power (kWh)	Value of power (c)	Flow (m³/s)	Head (m)	Efficiency (η)	Average hourly power (kWh)	Value of power (c)
00:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
01:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
02:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
03:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
04:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
05:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
06:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
07:00	0.126	126	84.0%	130.93	33367	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
08:00	0.126	126	84.0%	130.93	33367	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
09:00	0.126	126	84.0%	130.93	33367	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
10:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
11:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
12:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
13:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
14:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
15:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
16:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
17:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
18:00	0.126	126	84.0%	130.93	33367	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
19:00	0.126	126	84.0%	130.93	33367	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471
20:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
21:00	0.126	126	84.0%	130.93	9993	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
22:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
23:00	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471	0.126	126	84.0%	130.93	5471
Total per hour	3.024			3142.28	313928				3142.28	159365				3142.28	131316
Total per year (kWh or c)	10886.4			204248.3343	20405344.74				43591.94696	2222311.55				40849.66627	1707107.57
Total per year (MWh or R)	[illegible]			204.2483343	204053.4474				43.59194696	22223.1155				40.84966627	17071.0757

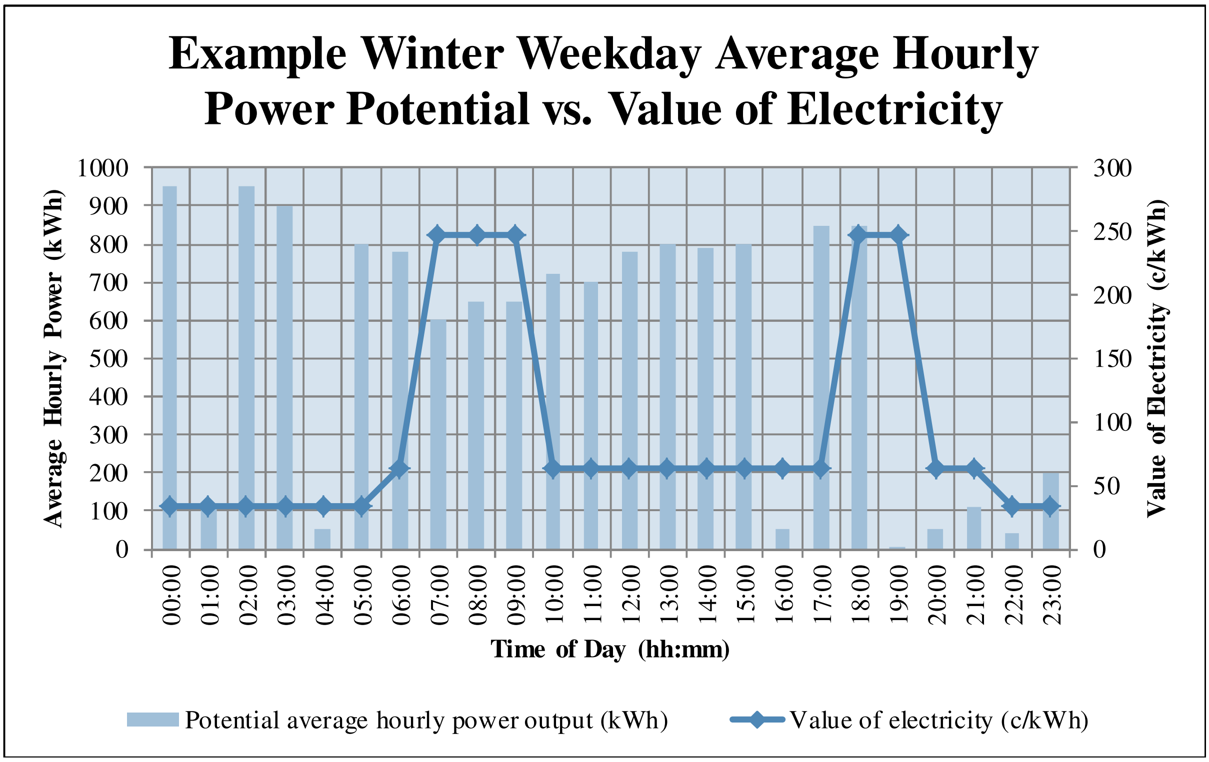


Figure 3-16: Phase 3 power potential vs. income graph (for grid-connected applications)

The next two sections are the Power Potential vs. Demand Section and the Power Potential vs. Demand Graph Section and are applicable to islanded or on-site applications. The information entered into the Power Potential vs. Demand Section is depicted graphically in the Power Potential vs. Demand Graph Section.

The function of the Power Potential vs. Demand Section is to tabulate daily and seasonal demand variation for energy usage. The table separates typical winter and summer power output, as well as winter and summer energy demands. The available energy is then compared with demand to obtain the surplus or deficit at a number of points (typically at 15 min intervals over a 24 h period). **Table 3-11** shows a shortened version of this section. This information is summarised in the Power Potential vs. Demand Graph Section, as shown in **Figure 3-17**.

These sections will clearly show how the operation needs to be adjusted if power is needed throughout the day and energy storage is not available.

Table 3-11: Phase 3 power potential vs. demand CHD Tool (for islanded and on-site applications)

PHASE 3 POWER SUPPLY DISTRIBUTION: SUMMER						
Example daily summer power potential						
Time (hh:mm)	**Flow (m^3/s)**	**Head available (m)**	**Efficiency (η)**	**Potential power (kW)**	**Power demand (kW)**	**Surplus/deficiency (kW)**
00:00	0.0333	50.4		13.2	12.5	0.7
00:15	0.0333	50.4		13.2	12.5	0.7
00:30	0.0333	50.4		13.2	12.5	0.7
00:45	0.0333	50.4		13.2	12.5	0.7
01:00	0.0333	50.4		13.2	12.5	0.7
01:15	0.0333	50.4		13.2	12.5	0.7
01:30	0.0333	50.4		13.2	12.5	0.7
01:45	0.0333	50.4		13.2	12.5	0.7
02:00	0.0333	50.4		13.2	12.5	0.7
02:15	0.0333	50.4		13.2	12.5	0.7
02:30	0.0333	50.4		13.2	12.5	0.7
02:45	0.0333	50.4		13.2	12.5	0.7
03:00	0.0333	50.4		13.2	12.5	0.7
03:15	0.0333	50.4		13.2	12.5	0.7
03:30	0.0333	50.4		13.2	12.5	0.7
03:45	0.0333	50.4		13.2	12.5	0.7
04:00	0.0333	50.4		13.2	12.5	0.7
04:15	0.0333	50.4		13.2	12.5	0.7
04:30	0.0333	50.4		13.2	12.5	0.7
04:45	0.0333	50.4		13.2	12.5	0.7
05:00	0.0333	50.4		13.2	12.5	0.7
05:15	0.0333	50.4		13.2	2.0	11.2
05:30	0.0333	50.4		13.2	2.0	11.2
05:45	0.0333	50.4		13.2	2.0	11.2
06:00	0.0333	50.4		13.2	2.0	11.2
06:15	0.0333	50.4		13.2	2.0	11.2
21:30	0.0333	50.4		13.2	12.5	0.7
21:45	0.0333	50.4		13.2	12.5	0.7
22:00	0.0333	50.4		13.2	12.5	0.7
22:15	0.0333	50.4		13.2	12.5	0.7
22:30	0.0333	50.4		13.2	12.5	0.7
22:45	0.0333	50.4		13.2	12.5	0.7
23:00	0.0333	50.4		13.2	12.5	0.7
23:15	0.0333	50.4		13.2	12.5	0.7
23:30	0.0333	50.4		13.2	12.5	0.7
23:45	0.0333	50.4		13.2	12.5	0.7
General input						
Fluid density	(ρ)	1000	kg/m^3			
Gravitational acceleration	(g)	9.81	m/s^2			
Efficiency	(η)	80	%			

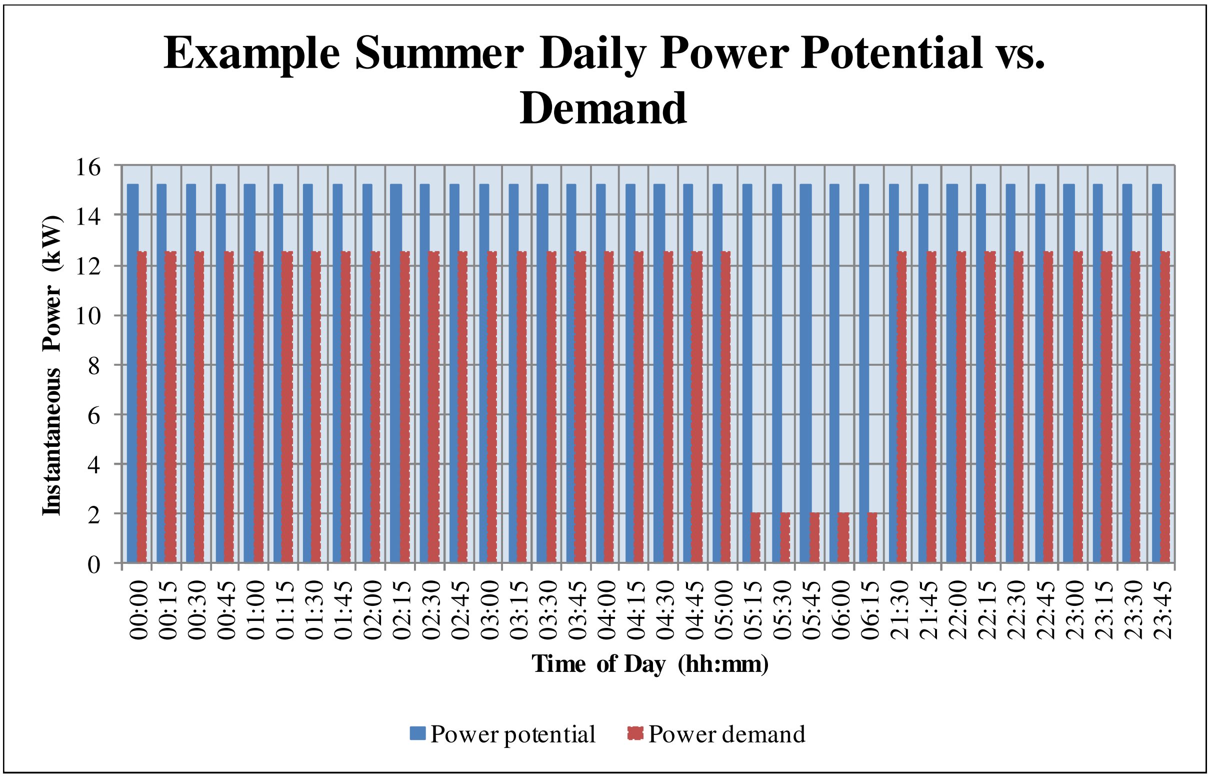


Figure 3-17: Phase 3 power potential vs. demand graph (for islanded and on-site applications)

The Economic Analysis Section is shown in **Table 3-12**. Input required for this section includes the broken down costs for initial planning and capital expenditure, as well as annual operation and maintenance expenses. It also requires the design life (maximum 50 years) of the plant, projected income and inflation rates for electricity, operation and maintenance and a general discount rate.

The output of this section includes an estimate of the net present value (NPV) and the internal rate of return (IRR) of the proposed project.

Table 3-12: Phase 3 Economic analysis CHD Tool

PHASE 3 ECONOMIC ANALYSIS			
Power information for current scenario			
Power rating		727	kW
Design flow	(Q)	0.780	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		4 666	MWh/a
Turbine type		Turgo	
Total power information for future scenario			
Power rating		727	kW
Design flow	(Q)	1.561	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		9 307	MWh/a
Turbine type		Turgo	
Design life		15	years
Cost			
Initial planning cost (IPC)			
Legal and regulatory		R 0	
Environmental and social assessment		R 0	
Investigation and preliminary design		R 1 200 000	
Subtotal		**R 1 200 000**	
Capital expenditure (CEC)			
Construction year		2014	
Turbine		R 7 404 665	
Preliminary and general		R 1 300 000	
Access to site		R 0	
Pipework and valves		R 1 100 000	
Power station housing and tailrace		R 1 600 000	
Electromechanical and controls		R 1 100 000	
Transformer/transmission		R 700 000	
Construction supervision		R 1 000 000	
Contingencies		R 1 300 000	
Other (Data logging)		R 20 000	
Disposal (Present value (PV))		R 0	
Subtotal		**R 15 524 665**	
Additional capital expenditure due to expansion (PV)		R 0	
Year of expansion		2029	
Annual operation and maintenance cost (OMC)	% of CEC for component		
Civil items	0.25%	R 6 750	
Electrical and mechanical items	2.00%	R 170 093.29	
Transmission	0.80%	R 5 600	
Operation	0.40%	R 62 099	
Insurance	0.30%	R 46 574	
Subtotal (PV)		**R 291 116**	
Income			
Annual income for current scenario	R/kWh		
Average value of generated electricity	0.58	R 2 706 251	
Revenue		R 0	
Subtotal (PV)		**R 2 706 251**	
Annual income for future scenario	R/kWh		
Average value of generated electricity	0.58	R 5 398 243	
Revenue		R 0	
Subtotal (PV)		**R 5 398 243**	
Results			
Net present value of costs	-R 20 617 844		
Net present value of income	R 49 185 573		
Total NPV	**R 28 567 728**		
Internal rate of return	**22.14%**		

Inflation and maintenance factors over design life					
Year	Annual Inflation				Maintenance factors
	Electricity	Operation	Maintenance	General	
0	8.0%	5.3%	5.3%	5.3%	0.8
1	8.0%	5.1%	5.1%	5.1%	0.8
2	8.0%	6.0%	6.0%	6.0%	0.8
3	8.0%	6.0%	6.0%	6.0%	0.8
4	8.0%	6.0%	6.0%	6.0%	0.8
5	10.0%	6.0%	6.0%	6.0%	1
6	10.0%	6.0%	6.0%	6.0%	1
7	10.0%	6.0%	6.0%	6.0%	1
8	10.0%	6.0%	6.0%	6.0%	1
9	10.0%	6.0%	6.0%	6.0%	1
10	10.0%	6.0%	6.0%	6.0%	1
11	10.0%	6.0%	6.0%	6.0%	1
12	10.0%	6.0%	6.0%	6.0%	1
13	10.0%	6.0%	6.0%	6.0%	1
14	10.0%	6.0%	6.0%	6.0%	1
15	6.0%	6.0%	6.0%	6.0%	1.2
16	6.0%	6.0%	6.0%	6.0%	1.2
17	6.0%	6.0%	6.0%	6.0%	1.2
18	6.0%	6.0%	6.0%	6.0%	1.2
19	6.0%	6.0%	6.0%	6.0%	1.2
20	6.0%	6.0%	6.0%	6.0%	1.25
21	6.0%	6.0%	6.0%	6.0%	1.25
22	6.0%	6.0%	6.0%	6.0%	1.25
23	6.0%	6.0%	6.0%	6.0%	1.25
24	6.0%	6.0%	6.0%	6.0%	1.25
25	6.0%	6.0%	6.0%	6.0%	1.25
26	6.0%	6.0%	6.0%	6.0%	1.25
27	6.0%	6.0%	6.0%	6.0%	1.25
28	6.0%	6.0%	6.0%	6.0%	1.25
29	6.0%	6.0%	6.0%	6.0%	1.25
30	6.0%	6.0%	6.0%	6.0%	1.5
31	6.0%	6.0%	6.0%	6.0%	1.5
32	6.0%	6.0%	6.0%	6.0%	1.5
33	6.0%	6.0%	6.0%	6.0%	1.5
34	6.0%	6.0%	6.0%	6.0%	1.5
35	6.0%	6.0%	6.0%	6.0%	1.5
36	6.0%	6.0%	6.0%	6.0%	1.5
37	6.0%	6.0%	6.0%	6.0%	1.5
38	6.0%	6.0%	6.0%	6.0%	1.5
39	6.0%	6.0%	6.0%	6.0%	1.5
40	6.0%	6.0%	6.0%	6.0%	1.5
41	6.0%	6.0%	6.0%	6.0%	1.5
42	6.0%	6.0%	6.0%	6.0%	1.5
43	6.0%	6.0%	6.0%	6.0%	1.5
44	6.0%	6.0%	6.0%	6.0%	1.5
45	6.0%	6.0%	6.0%	6.0%	1.5
46	6.0%	6.0%	6.0%	6.0%	1.5
47	6.0%	6.0%	6.0%	6.0%	1.5
48	6.0%	6.0%	6.0%	6.0%	1.5
49	6.0%	6.0%	6.0%	6.0%	1.5
50	6.0%	6.0%	6.0%	6.0%	1.5

As with the previous phases, the Checklist Section (**Table 3-13**) for this phase does not require any input, but serves as a reference for the user to determine whether all the steps for Phase 3 have been considered.

Table 3-13: Phase 3 checklist for CHD Tool

PHASE 3 CHECKLIST	?
Did the first two phases indicate economic feasibility?	
If not, is there another reason for considering conduit hydro?	
Has historical flow and pressure records been obtained?	
Were flow - and pressure records measured/obtained?	
Were all gaps discarded?	
Were the values ranked from small to large flow and large to small pressure?	
Was a percentage assigned to each flow (100% exceedance for min flow to 0% exceedance for max flow?	
Has the flow rating curve been populated?	
Has the hydropower potential been analysed?	
Is there currently significant potential?	
If not, will there be future develoment that might increase potential?	
Has a design flow and pressure been chosen?	
Has the effect of optimization been considered?	
Has the required turbine range been determined?	
Has the appropriate turbine been selected?	
Has the turbine efficiency been determined and included in the analysis?	
Are the future flow rate scenarios compatible with the turbine range?	
If not, have additional turbines been selected for for the future scenario?	
Has the electricity use destination been established?	
For grid tie-in: Has the distance to the grid been calculated?	
For grid tie-in: Does the connection comply with Eskom and Municipality requirements?	
For islanded/on-site systems: What are the current and future energy demands?	
For islanded/on-site systems: Do the demand and supply patterns correlate?	
For islanded/on-site systems: If not, can the operational procedure be changed or batteries installed to ensure reliability of supply?	
For islanded/on-site systems: Is there is sufficient demand for the size of the installation?	
For islanded/on-site systems: If not, has a smaller turbine been selected to allow for the maximum forecast demand?	
Have the electrical and mechanical components been designed?	
Have the civil works been designed?	
Has the plant setup been determined?	
Is all equipment protected from vandalism and theft?	
Is the system practically feasible?	
Has a detail design phase economic analysis been conducted?	
Is the project economically feasible?	
Has a sensitivity analysis been conducted?	
Is the risk acceptable?	
If not, is there another reason for continuing?	

4 A DECISION SUPPORT SYSYEM FOR CONDUIT HYDROPOWER DEVELOPMENT

This Chapter serves to elaborate on the steps illustrated in the process flow diagrams of **Chapter 3** and to discuss the Conduit Hydropower Decision Support System (CHDSS) in greater detail. It should be noted that each item in the flow diagrams of **Chapter 3** has been numbered and a corresponding number in this chapter indicates discussion of that particular item.

4.1 FIRST PHASE: PRE-FEASIBILITY INVESTIGATION

4.1.1 INTRODUCTION

A pre-feasibility study should be performed on all potential sites, as valuable information on hydropower potential can be gathered by doing systematic desktop studies. The following sections discuss each of the aspects that should be considered before a full feasibility study is performed.

4.1.2 POTENTIAL SITES

The first task would be to determine whether there are any points in the municipality's distribution network with excess energy. Excess energy will generally be available between points in the network with significant elevation differences. The easiest way to source this information is to obtain maps indicating the topography of the municipality and location of pressure-reducing stations (PRSs) and reservoirs in the distribution system.

Therefore three important aspects to consider at this stage include: firstly, whether there are any PRSs in the municipal distribution system; secondly whether any high pressure points exist that do not have PRSs installed; and thirdly, whether the identified reservoirs and PRSs are indeed the property of the municipality.

Pressure reducing stations (1)

In some cases the frictional and secondary losses along the length of the pipe are significantly lower than the total pressure head. To avoid unnecessary high-pressure class pipes and the increased risk of leakages in these pipes, one has to include a restriction that will dissipate the excess pressure at calculated points along the distribution line. These restrictions are particularly necessary upstream of reservoir intakes to prevent damage to the reservoir structure due to excessive pressures of piped water arriving at the reservoir.

Therefore, single or multiple PRSs are normally installed just before the inlet of a reservoir at the downstream end of a gravitational line. Pressure-reducing valves (PRVs) are commonly used. These valves ensure sufficiently low pressures to prevent damage to the reservoir and its connections and fittings. The size and number of PRVs at a reservoir inlet are directly related to the magnitude of the pressure head to be dissipated.

PRVs or other PRSs can also be installed in strategic points along the distribution line, to reduce excess pressures and ensure more cost-effective use of pipe sizes and diameters. These PRSs therefore indicate points with excess energy along the pipeline (or at reservoirs) and can be used as a first-order indicator of hydropower potential.

High pressure points 2

It is possible that not all the high pressure points in the network have PRSs. To determine if high pressure points exist at locations that do not have PRSs, a network analysis has to be run to find high pressure points. This can typically be done in EPANET. Möderl et al. (2012) provide a description of the process with a case study.

It should be noted during the analysis that high pressure points may in some cases be necessary to maintain a balance in the system. In these cases the energy may therefore not be dissipated.

Property of the municipality 3

If the reservoirs with PRSs and PRSs along the distribution line are not the property of the municipality or water board, or do not fall within municipal boundaries, permits for use should be obtained before effort is wasted on determining hydropower potential that cannot be used by the municipality.

4.1.3 HYDRAULIC ANALYSIS

A pre-feasibility hydraulic analysis is done to obtain a first-order estimate of hydropower potential at a site.

Flow and pressure 4

All available flow and pressure data should now be compiled to determine the design flow and head values, and estimates should be done where sufficient information is not readily available. At this stage, the annual average daily demand (AADD) can be used to calculate average flow and a percentage (typically 50%) of the static head may be used for a conservative pressure head, if other information is not known. More detailed studies and flow and pressure measurements during different times of the day and seasons will be done in subsequent phases, if the outcome of the First Phase is positive.

The average daily flow should be given in m^3/s and the pressure head given in metres (m). These values are used for the initial calculation of the power available at the specific point in the distribution system.

Power available 5

In order to obtain an initial estimate of the power potential at a specific site, the following formula (**Equation 4-1**), can be used:

$$P = \rho g Q H \eta \qquad \textbf{Equation 4-1}$$

where:

P = mechanical power output (W) (calculated)

η = hydraulic efficiency of the turbine (%) (use 70% in the First Phase)

ρ = density of water (kg/m^3) (use 1 000 kg/m^3)

g = gravitational acceleration (m/s^2) (use 9.81 m/s^2)

Q = flow rate through the turbine (m^3/s) (use the average flow in the First Phase)

H = effective pressure head across the turbine (m) (use average head or 60% of static head)

4.1.4 ENERGY USE CONSIDERATIONS

Use of energy 6

Potential uses for electricity should be identified. It is important to note whether there are any settlements close to the site, or, if no settlements exist, whether generated electricity will be used on site or requires a grid connection. Generated energy can be used for one, or a combination of, the following options:

- Feeding electricity into an existing grid;
- So-called islanded systems that are far from an electricity grid; and/or
- Reservoirs or other sites in the network that need local lighting, security and telemetry.

Distance of site to energy users 7

If the generated electricity is to be connected to the grid, it is important to know how far the hydropower plant would be from the connection point. If the plant is far away from a grid connection, it might have a significant impact on the economic feasibility of the project.

Energy demand 8

Once potential users or uses have been identified for the generated electricity, the expected demand should be established. This can be done by either assessing current energy usage through measurement or electricity bills and estimation of future use.

Demand vs. energy potential 9

The energy potential and energy demand should be compared to determine whether the project has the potential to be feasible and whether further investigation should be undertaken. This is especially true in the case of islanded systems or on-site usage, as insufficient hydropower potential would mean that additional sources of energy should also be utilised.

It is important to consider implementation of energy-efficiency measures to reduce demand. Energy efficiency may be increased by using low-energy lights and appliances and encouraging users to switch off unused or unnecessary lights and appliances.

4.1.5 PRE-FEASIBILITY ECONOMIC ANALYSIS 10

A pre-feasibility economic analysis is done using a life-cycle approach with roughly estimated values for both costs and income. It is proposed that at least the net present value (NPV) and internal rate of return (IRR) be calculated to estimate economic feasibility at this stage using the formulas as indicated in **Chapter** 2. The payback period may also be calculated, preferably considering inflation. However, it should not be used as the deciding factor in project selection. It should only be used as a tool for initial screening to supplement other methods, as it does not give sufficient information to stand alone as an evaluation tool. (ESHA, 2004; Blank and Tarquin, 2004)

4.1.6 OTHER REASONS FOR CONDUIT HYDROPOWER 11

In some cases, there might be reasons other than economic feasibility to justify the use of conduit hydropower. These reasons include:

- islanded systems which are not supplied from the national electricity grid.
- Reservoirs far from the grid that need local lighting, security and telemetry.
- Areas where cable theft may be a problem.
- Areas that need additional peak-time electricity.
- Political reasons for developing greener renewable energy sources.

It may also be that operational changes can have a positive impact on the economic feasibility of a project. If this might be the case, a Phase 2 analysis would also be recommended.

4.1.7 OUTCOME OF PHASE 1

This phase requires a minimal amount of input information by the user. The main function of this phase is to obtain an initial estimate of potential power and the economic feasibility of a conduit hydropower plant at a site. The outcome of this phase is a decision on the practicability of conducting a full feasibility study.

4.2 SECOND PHASE INVESTIGATION: FEASIBILITY

4.2.1 FIRST PHASE SUCCESSFUL 1

The first step during this phase is to critically consider the answers obtained during Phase 1. If Phase 1 indicates economic feasibility, or if there is another reason for considering hydropower at the site under investigation, the Second Phase study should commence.

4.2.2 SITE EVALUATION 2

After completing the desktop study and determining whether it would be theoretically possible to generate electricity at a given site, it would be necessary to visit the site and assess the practicability of a hydropower plant there.

Aspects to consider include space for the hydropower plant; safety of the turbine and other equipment from theft or vandalism; noise impact on the surroundings; and accessibility to the site during construction.

4.2.3 HYDRAULIC STUDY

Flow and pressure measurement 3

Flow meters (refer to **Table 2-5** for examples of typical flow meters) and pressure transducer (refer to **Table 2-7** for examples of typical pressure transducers) should be installed (or existing ones utilised) to determine the maximum and minimum flow rates and corresponding pressures at the site. At this stage, it would be unreasonable to expect long-term flow data, but longer record sets would lead to better estimation.

The data should be critically evaluated and all gaps should be discarded before continuing. Care should be taken not to discard zero values, unless it is known that faulty measuring equipment caused incorrect zero values to be recorded at certain times.

Design flow and associated power 4

Power estimation can be done during the Feasibility Phase, using the additional information gathered. The following formula (with values as indicated in **Equation 4-2**), can be used:

$$P = \rho g Q H \eta$$ **Equation 4-2**

where:

P = mechanical power output (W) (calculated)

η = hydraulic efficiency of the turbine (%) (use 70% in the Feasibility Phase)

ρ = density of water (kg/m^3)

g = gravitational acceleration (m/s^2)

Q = flow rate through the turbine (m^3/s) (use the design flow)

H = effective pressure head across the turbine (m) (use the design head)

The design flow and head can be calculated by generating a flow-rating curve (**Figure 4-1**) and calculating the available power for different combinations of flow and associated head. The design flow and head are calculated in different ways, depending on the application of the generated energy. This aspect may become quite complicated when operational procedures are incorporated in the design, but this will be dealt with in more detail in Phase 3. At this stage it should be decided whether the electricity generated by the hydropower plant should have a certain reliability of supply (for example, power should be reliable for 95% of the time), or whether the maximum possible annual amount of energy can be supplied to the grid.

If electricity should be supplied at a certain assurance level, the flow at that percentage may be used as the design flow, with its corresponding head. **Figure 4-1** shows an example of the flow for 80% reliability of supply. If the maximum potential is used, then the design flow and head will be the combination that generates the optimum potential annual power. **Table 4-1** is an example of a table used to obtain the optimum potential power and **Figure 4-2** is a graphical representation of the data. The annual potential power for a selected turbine capacity can be calculated by multiplying the potential power with the hours per year when that potential is available. The last column in **Table 4-1** is used to calculate this and **Figure 4-3** is a visual representation.

It should be noted that in a closed system (with one inflow), there will be a specific inverse relationship between flow and pressure head, with a flow rate always associated with the same head, as per **Figure 4-4**. However, in a complex system with various independent inflow and outflow points, a specific correlation will not be found between flow rate and pressure head, as per **Figure 4-5**. It is therefore necessary to carefully select the design pressure head in a complex system.

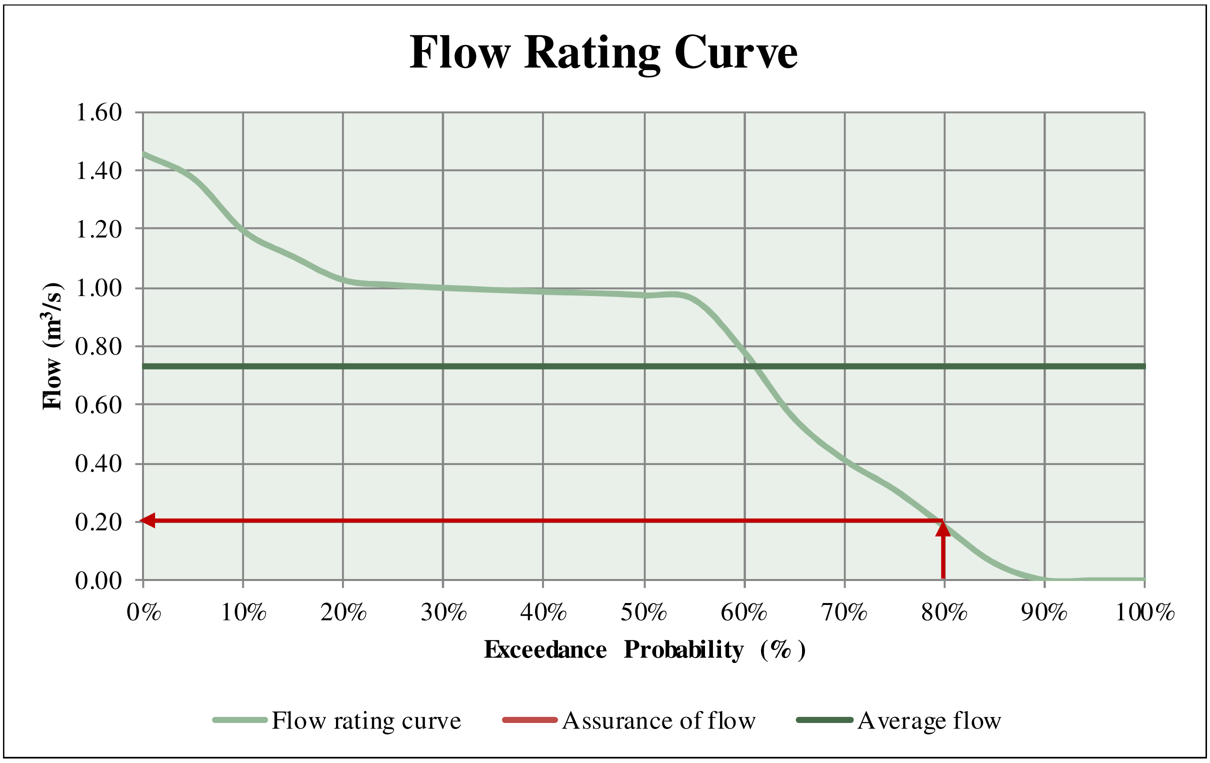


Figure 4-1: Example of a flow-rating curve with an 80% assurance of flow

Table 4-1: Example of a Phase 2 potential analysis

PHASE 2 POTENTIAL ANALYSIS							
Flow rating curve	Load factor (%)	Flow (m^3/s)	Head available (m)	Time in use (h)	Power rating (kW)	Potential power (MWh/a)	Potential power for optimum use (MWh)
	100%	0	125	8592	0.0	0.000	0
	95%	0.000	123.4	8154	0.0	0.000	0
	90%	0.001	139.5	7716	0.7	5.257	0.146331973
	85%	0.059	143.9	7278	57.9	421.481	12.58574673
	80%	0.184	142.9	6840	180.5	1234.373	51.20306327
	75%	0.310	138.0	6402	293.8	1880.647	101.8631544
	70%	0.412	131.2	5964	371.2	2213.611	142.8251233
	65%	0.553	127.4	5526	483.7	2673.165	183.6336555
	60%	0.780	113.8	5088	609.8	3102.773	261.9793884
	55%	0.959	92.6	4650	609.9	2836.029	261.9793884
	50%	0.974	94.6	4212	632.5	2664.041	261.9793884
	45%	0.981	96.6	3774	651.0	2456.741	261.9793884
	40%	0.986	99.0	3336	670.6	2237.108	261.9793884
	35%	0.992	101.0	2898	688.3	1994.790	261.9793884
	30%	0.999	103.4	2460	709.2	1744.648	261.9793884
	25%	1.009	109.8	2022	760.6	1537.894	261.9793884
	20%	1.025	120.9	1584	851.4	1348.662	261.9793884
	15%	1.105	88.0	1146	667.8	765.326	261.9793884
	10%	1.194	97.1	708	795.7	563.354	261.9793884
	5%	1.372	85.8	270	808.2	218.204	261.9793884
	0%	1.456	82.6	0	825.4	0.000	261.9793884
Optimum flow	60%	0.780	113.8	5088.0	609.8		3897.989125
Average flow		0.767	111.6	8592	588.0	5052.294	
Chosen flow		0.037	50.4	8592	12.8	110.026	
Assurance of flow		0.000	0.0	0	0.0		
Design flow	**60%**	**0.780**	**113.8**	**5088**	**609.8**	**3898.0**	

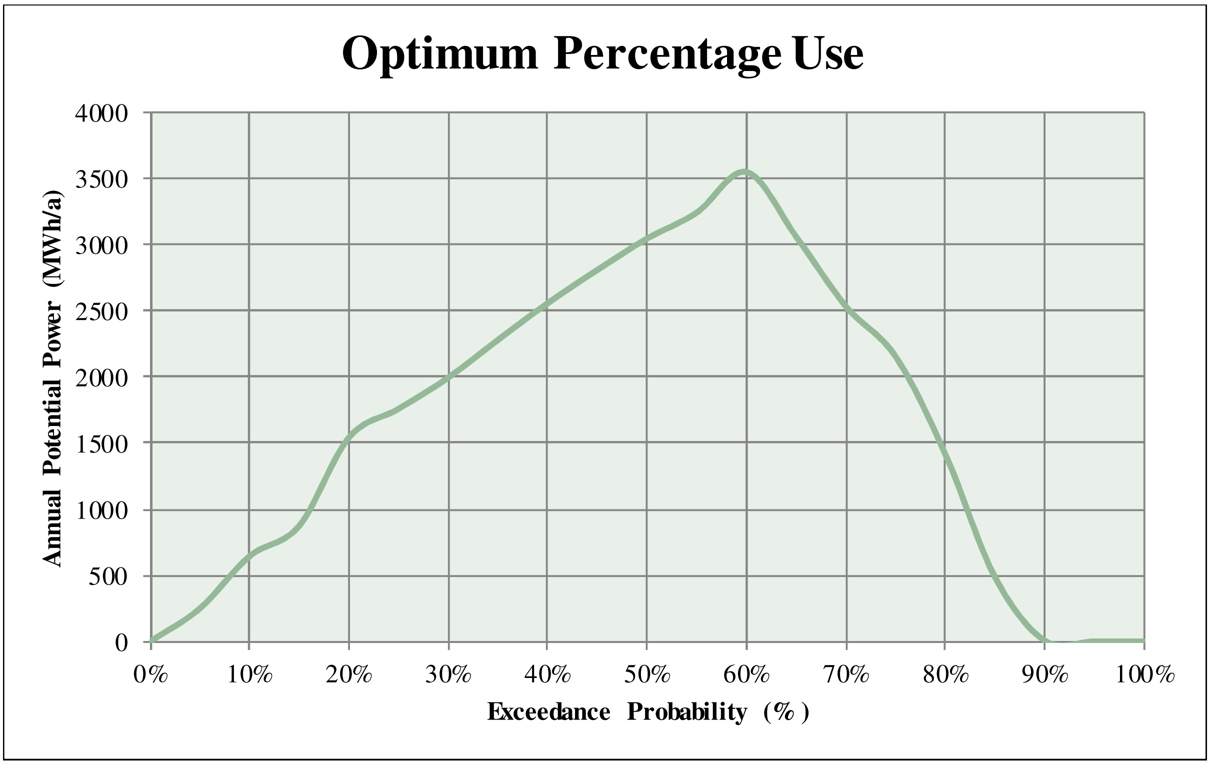


Figure 4-2: Example of an optimum percentage-use curve

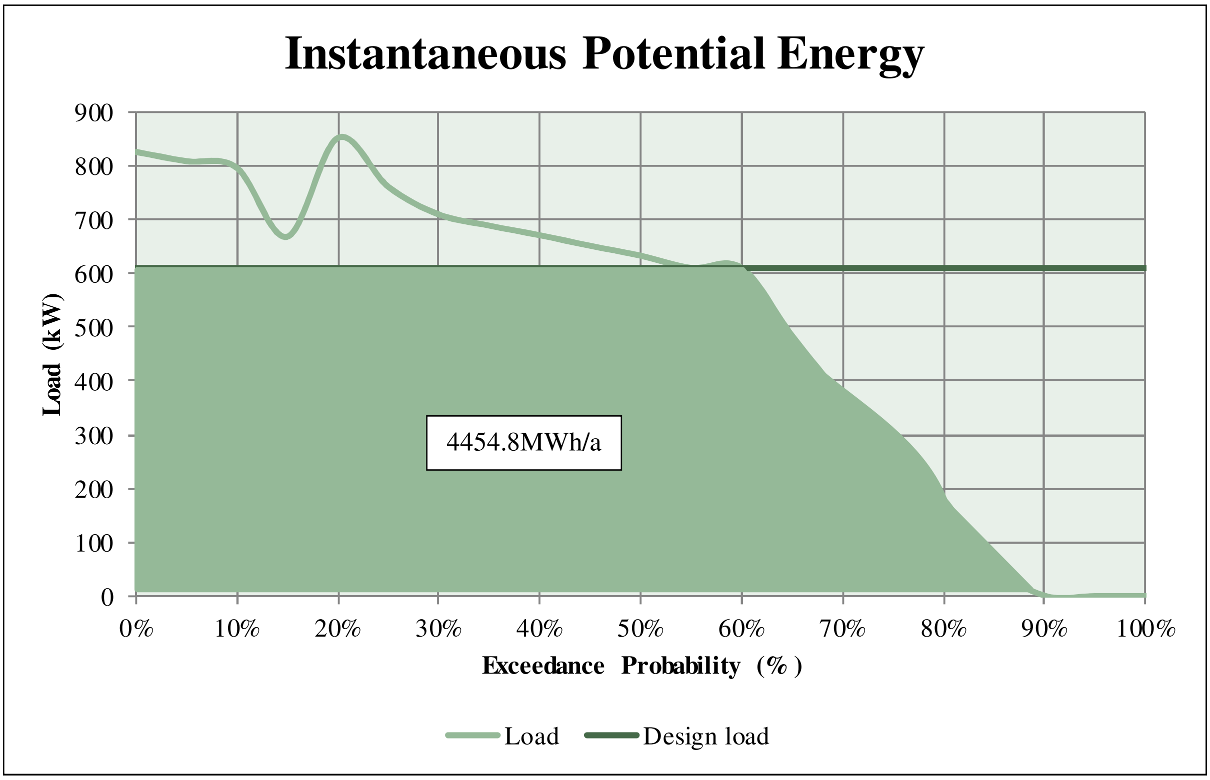


Figure 4-3: Example of an annual potential energy-calculation curve

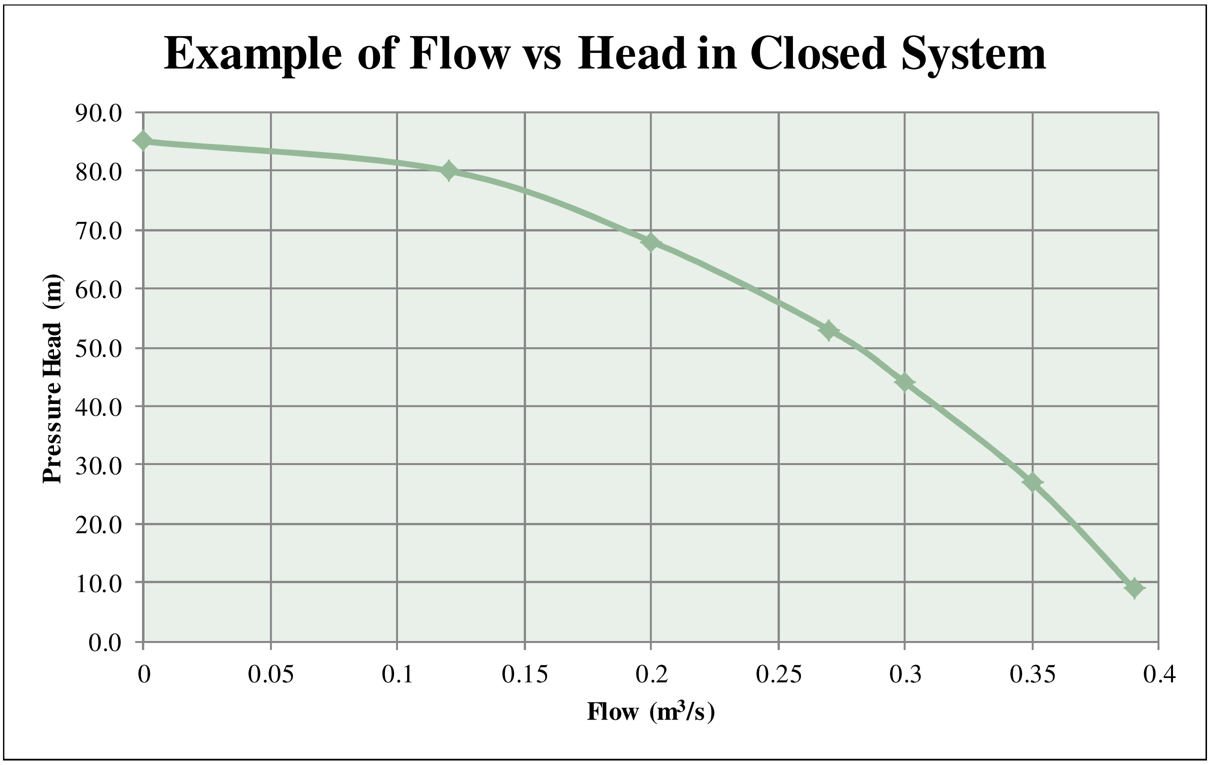


Figure 4-4: Example of a flow vs. head curve for a closed system

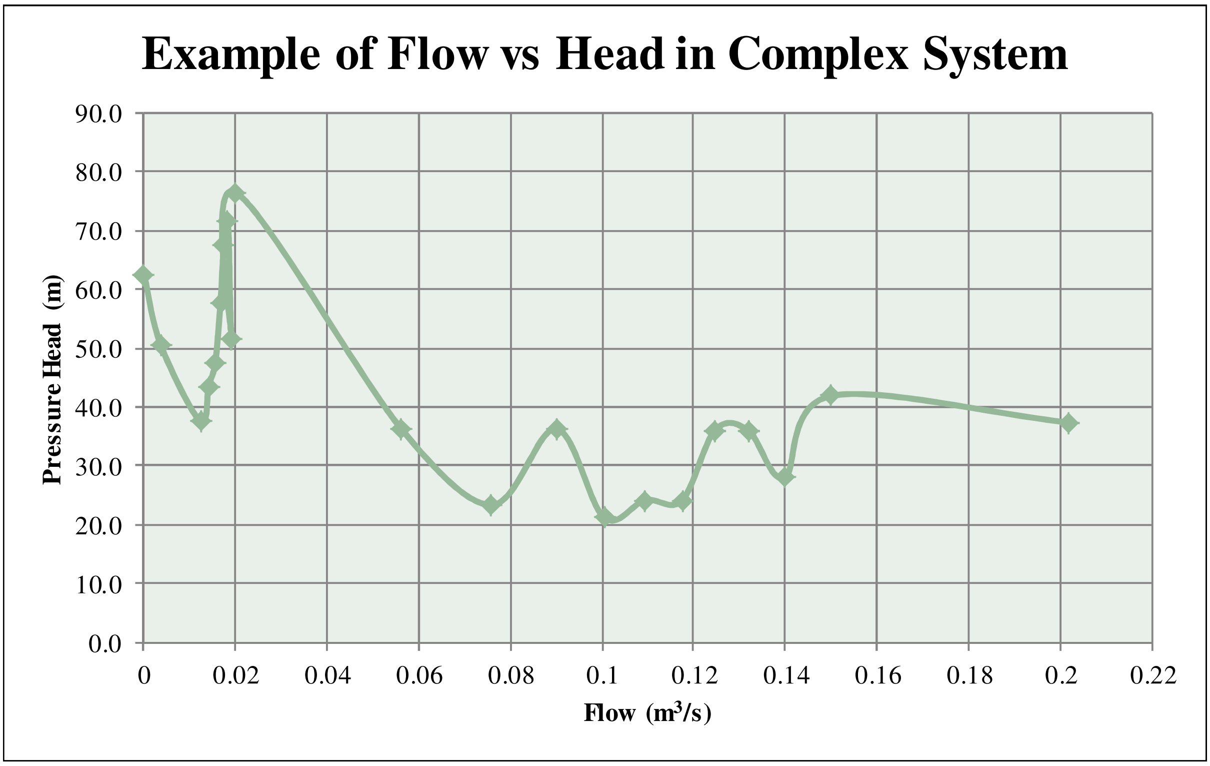


Figure 4-5: Example of a flow vs. head curve for an open system

Operation of site within system 5

The site has to be evaluated as part of the larger distribution system. The influence of a hydropower plant at the site should be investigated considering that water supply is the main function of the system and that the plant should not influence supply reliability.

The system should be optimised to allow for the maximum power generation (or generation at times with high potential income, in grid-connected projects) without negatively impacting water supply to users. This is especially the case when power should be supplied at a high assurance level, but current operational regimes include many hours of maximum flow rate. An alternative operational practice may be that supply should be provided at lower flow rates, but for longer periods at a time. Another possibility would be to ensure a constant flow and head into the reservoir for the time of day when electricity is needed.

It is important to note that no operational procedure should negatively affect water supply to users. If operational changes to the system are not possible, due to constraints and water-supply preferences, a thorough investigation should be done to determine whether the generated power could be effectively used at the times when it is able to generate power. This is especially the case when the generated electricity is not supplied to a larger grid; alternative energy sources are not available for an islanded (or on-site) system; or power is generated to supply peak demand in the electricity network.

Future development 6

It may be that current flow and head will not generate a significant amount of hydropower. If this is the case, an investigation should be carried out to determine whether future development that may increase the potential is planned. If so, the future values should be used in further analyses, or phasing of hydropower development should be considered.

If future development will decrease the hydropower potential, this should be noted and the economic feasibility analysis should be done with an applicable design life for current circumstances.

Turbine selection 7

The design flow and head, together with the required power, can now be used for the initial selection of an appropriate turbine. The CHD Tool includes a graph (**Figure 4-6**) to facilitate this process. If necessary, turbine suppliers may be contacted for more detailed information.

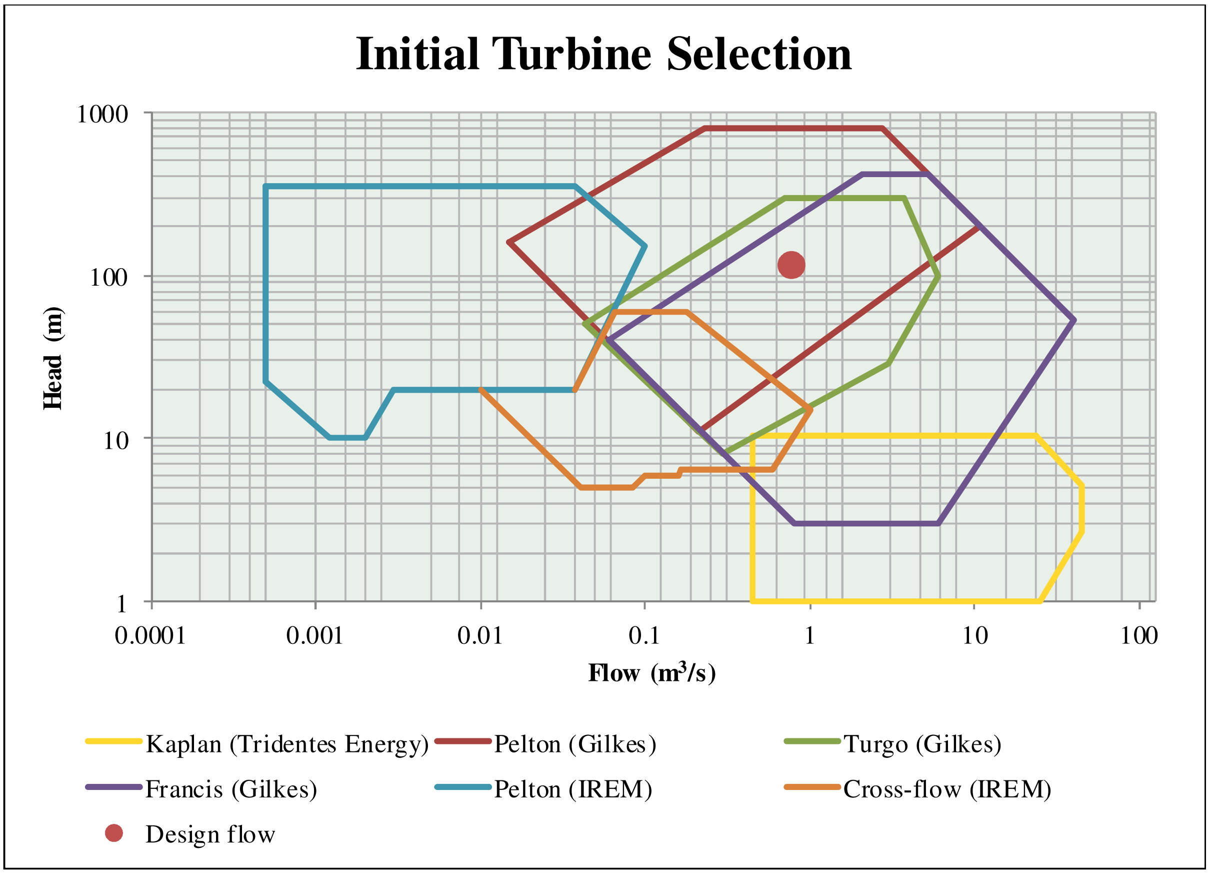


Figure 4-6: Example of an initial turbine-selection curve

4.2.4 ENERGY USE CONSIDERATIONS

Use of energy 8

Potential uses for electricity should be identified. It is important to note whether there are any settlements close to the site, or, if no settlements exist, whether generated electricity will be used on site or requires a grid connection. Generated energy can be used for one, or a combination of, the following options:

- Feeding electricity into an existing grid;
- islanded systems that are far from an electricity grid; and/or
- Reservoirs or other sites in the network that need local lighting, security and telemetry.

Distance of site to energy users 9

If the generated electricity is to be connected to the grid, it is important to know how far the hydropower plant would be from the connection point. If the plant is far away from a grid connection, it might have a significant impact on the economic feasibility of the project.

Energy demand vs. energy potential 10

Once potential users or uses have been identified for the generated electricity, the expected demand should be established. This can be done by either assessing current energy usage through measurement or electricity bills and estimation of future use.

The energy potential and energy demand should be compared to determine whether the project may be feasible and whether further investigation should be undertaken. This is especially true in the case of islanded systems or on-site usage, as insufficient hydropower potential would mean that additional sources of energy should also be utilised.

It is important to consider implementation of energy-efficiency measures to reduce demand. Energy efficiency may be increased by using low-energy lights and appliances and encouraging users to switch off unused or unnecessary lights and appliances.

4.2.5 FEASIBILITY STAGE REGULATORY ASSESSMENT

At this point, a regulatory assessment should be done, as it is important to consider the social and environmental aspects of the project. The following sections will deal with these points.

Environmental aspects 11

Hydropower plants installed in existing distribution systems should have minimal additional environmental impacts, as very little additional infrastructure is required. The noise from the powerhouse should account for the largest impact, but this can be mitigated by insulating the powerhouse. Other negative effects normally associated with hydropower projects, like fish migration restriction and possible flooding do not apply to conduit hydropower development. Therefore, the requirements and licences necessary for this type of scheme should be far less extensive than the requirements for conventional hydropower (Gaius-Obaseki, 2010).

Nevertheless, many regulations and protocol will still apply. Every construction project that is undertaken in South Africa is subject to environmental regulations under the National Environmental Management Act of 1998. According to this Act an environmental impact assessment (EIA) or basic assessment (BA) is needed before certain construction activities may commence. The regulations were studied and the activities possibly related to the construction of a conduit hydropower plant are listed in **Table 2-10**. It should, however, be noted that additional provincial regulations are applicable that have not been listed. It is recommended that an environmental practitioner assess the site and determine the necessity or not of an EIA or BA.

NERSA licensing 12

As described in **Chapter 2**, Section 8 of the Energy Regulation Act (Act 4 of 2006) stipulates that a licence is required for:

d) 'operat(ion) of any generation, transmission or distribution facility;
e) import or export (of) any electricity; or
f) involve(ment) in trading (of electricity).'

However, Schedule II of this Act exempts some parties from holding a licence. Exemption is granted to:

4. 'Any generation plant constructed and operated for demonstration purposes only and not connected to an inter connected power supply
5. Any generation plant constructed and operated for own use
6. Non-grid connected supply of electricity except for commercial use.'

The National Energy Regulator of South Africa (NERSA) is responsible for granting energy generation licences in terms of the Energy Regulation Act (Act 4 of 2006). The application form consists of 12 sections that include: the applicant's information; desired commencement date of the licence; details of the generation station; details of arrangements with primary energy suppliers; maintenance programmes and decommissioning costs; customer particulars; financial overview; human resource particulars; other relevant regulatory permits; information on the Broad-Based Black Economic Empowerment (BBBEE) status of the project; any additional relevant information; and a declaration of accuracy. An example of the application form can be viewed in **Appendix A** (NERSA, 2006).

A similar application form exists for energy distribution licences in terms of the Energy Regulation Act (Act 4 of 2006). This application form consists of 11 sections that include: the applicant's information; desired commencement date of the licence; area of operation under the licence; details of the distribution system; maintenance programmes; customer particulars; financial overview; human resource particulars; other relevant regulatory permits; information on the Broad-Based Black Economic Empowerment (BBBEE) status of the project; and any additional relevant information (NERSA, 2007). An example of the application form can also be viewed in **Appendix A.**

Water-use licensing

As noted in **Chapter 2** the National Water Act (Act 36 of 1998) states that water-use licensing is required in various cases. The cases that may be applicable to hydropower generation include:

a) 'taking water from a water resource;
b) storing water;
c) impeding or diverting the flow of water in a watercourse;' (Section 21)
d) 'a power generation activity which alters the flow regime of a water resource;' (Section 37) and
e) 'disposing of waste in a manner of water which contains waste from, or which has been heated in, any industrial or power generation process.' (Section 21).

However, Section 22 states *inter alia* that water may be used without a licence 'if that water use is permissible as a continuation of an existing lawful use'. As municipalities and water boards have existing licences and conduit hydropower should not have a detrimental effect on the water quality, a water-use licence will not generally be required for conduit hydropower in water pipelines of municipalities or water boards.

Social aspects

As part of the environmental assessment phase, the interested and affected parties are identified and provided with opportunities to voice their concerns and objections with regard to the proposed project. As noted in **Chapter 2**, the general areas of consideration are:

- The cultural heritage of the site.
- Potential public health threats resulting from changes in downstream flow regimes or changes in the water quality.
- Public acceptance by the community and affected parties to increase buy-in and reduce vandalism.
- Impacts on downstream agricultural activities.
- The balance between community upliftment and the preservation of traditional ways of life.

It is recommended that a specialist consultant be appointed to assess the social aspects of a proposed project.

4.2.6 FEASIBILITY PHASE ECONOMIC ANALYSIS 15

A feasibility phase economic analysis should be done with the additional information gathered during this phase. A life-cycle approach should be used. At this stage of the project, estimated values and functions will still be used for both costs and income, but all available information should be included, to render the analysis as accurate as possible. If future development will decrease the hydropower potential, this should be noted and the economic feasibility analysis should be done with an applicable design life for current circumstances.

It is proposed that at least the net present value (NPV) and internal rate of return (IRR) should be determined at this stage using the formulas as indicated in **Chapter** 2. The payback period may also be calculated, preferably considering inflation. However, it should not be used as the deciding factor in project selection. It should only be used as a tool for initial screening to supplement other methods, as it does not give sufficient information to stand alone as an evaluation tool (ESHA, 2004; Blank and Tarquin, 2004).

4.2.7 OTHER REASONS FOR CONDUIT HYDROPOWER 16

As mentioned in the pre-feasibility stage, in some cases there might be reasons other than economic feasibility to justify the use of conduit hydropower. These reasons include:

- islanded systems that are far from the national electricity grid.
- Reservoirs that need local lighting, security and telemetry.
- Areas where cable theft may be a problem.
- Areas that need additional peak-time electricity.
- Political reasons for developing greener renewable energy sources.

If another reason for considering hydropower exists, the economic feasibility should not be the deciding factor for continuing the investigation.

4.2.8 OUTCOME OF PHASE 2

The function of Phase 2 is to determine feasibility of a proposed conduit hydropower plant, with as much detail and information as is available. This phase does not contain a detailed design. It does, however, include an initial estimation of the design flow and head, using measured data. The CHD Tool also includes a graph to facilitate the initial selection of an appropriate turbine and a more detailed economic analysis than Phase 1.

4.3 THIRD PHASE INVESTIGATION: DETAILED DESIGN

If the initial assessments of hydropower potential indicate the practicability of a micro-hydropower plant, then a detailed engineering design and economic analysis can be done.

The complexity of the design should match the operators' level of skill and the resources available. Local economic conditions should be carefully studied before determining the financial viability of a project (Harvey et al., 1993).

This section will include generic design guidelines and necessary considerations for the different components of a hydropower plant in an existing distribution network. Discussed components will include pipework, valves, the turbine and power distribution. However, it should be borne in mind that this phase includes a detailed design and therefore a specialist consultant should be approached to ensure that all factors are carefully considered and incorporated into the final solution.

4.3.1 DETAILED HYDRAULIC STUDY

This study is done to determine the hydropower potential of the reservoir in question. The outcome will show how flow varies throughout the day and year. This information will be important when comparing the demand for electricity with the potential available power.

Historical flow and pressure records

It is important to know the necessary functional pressure and flow ranges of the planned turbine. In order to accurately determine the potential energy at a particular reservoir (as well as the optimum turbine), historical flow and pressure records should be obtained, if they are available. If historical data are not available, flow and pressure should be measured as described in the following paragraph before proceeding.

Measurement of flow and pressure

Whether historical flow and pressure measurements are available or not, current measurements should be taken. These data will be used to determine daily patterns and consequently the functional pressure and flow ranges of the planned turbine.

A flow meter (refer to **Table 2-5** for examples of typical flow meters) and pressure transducer (refer to **Table 2-7** for examples of typical pressure transducers) should be placed on a straight section of pipe directly upstream of the location of the proposed turbine and connected to a data logger.

At this stage recorded data should preferably reflect weekly and seasonal variations in flow and pressure. Therefore a year's worth of data would be ideal. However, if this much data cannot be recorded, assumptions should be made to account for seasonal fluctuations in water demand.

The data should be critically evaluated and all gaps should be discarded before continuing. Care should be taken not to discard zero values, unless it is known that faulty measuring equipment caused incorrect zero values to be recorded at certain times.

Optimisation and operation of site within system 3

The site has to be evaluated as part of the larger distribution system. The influence of a hydropower plant at the site should be investigated considering that water supply is the main function of the system and that the plant should not influence supply reliability.

The system should be optimised to allow for the maximum power generation (or generation at times with high potential income, in grid-connected projects) without negatively impacting water supply to users. This is especially the case when power should be supplied at a high assurance level, but current operational regimes include many hours of maximum flow rate. An alternative operational practice may be that supply should be provided at lower flow rates, but for longer periods at a time. Another possibility would be to ensure a constant flow and head into the reservoir for the time of day when electricity is needed.

In grid-connected applications, the operational regime should allow for power generation at times with high potential income (energy tariff peak times). There should be a definite correlation between hours of high electricity value (peak times) and hours with high power potential. **Figure 4-7** shows an example of an operational procedure that does not optimally exploit potential income, with high potential for power generation during the night, when tariffs are low. It is important to note that no operational procedure should negatively affect water supply to users.

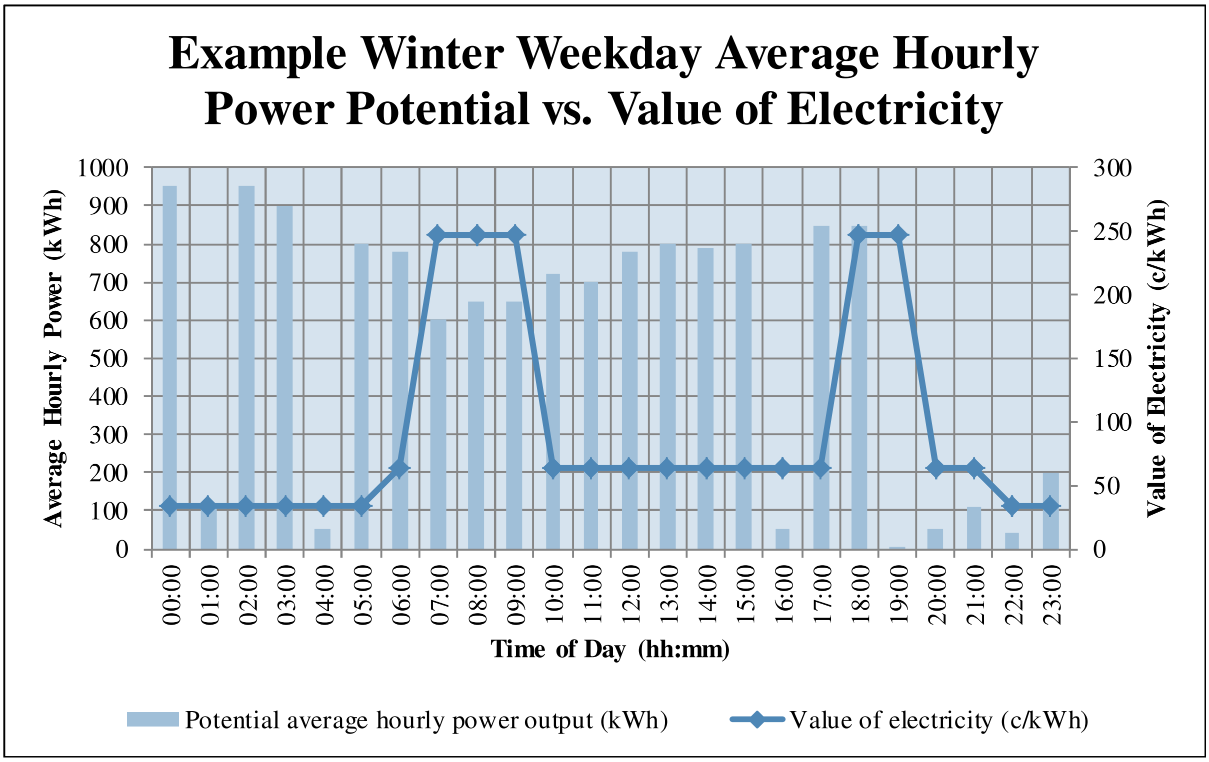


Figure 4-7: Example of a power potential vs. peak income curve (with poor correlation)

If optimisation of the system is not possible, due to operational constraints and water-supply preferences, a thorough investigation should be done to determine whether the generated power could be effectively used at the times when power generation is possible. This is especially the case when the generated electricity is not supplied to a larger grid; alternative energy sources are not available for an islanded (or on-site) system; or when power is generated to supply peak demand in the electricity network.

Design flow and associated power 4

A detailed study of available power can be done during the Third Phase, using the additional gathered information. The following formulas (with values as indicated in **Equations 4-3** to **4-5**), can be used:

$$\frac{P_1}{\rho g}+\frac{v_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{v_2^2}{2g}+Z_2+h_f+h_l$$ **Equation 4-3**

where:

P_1 = pressure at Station 1 (N/m^2)

ρ = density of water (kg/m^3)

g = acceleration due to gravity (m/s^2)

v_1 = velocity of the flow at Station 1 (m/s)

Z_1 = elevation of the water above datum line, in the streamline at Station 1 (m)

P_2 = pressure at Station 2 (N/m^2)

v_2 = velocity of the flow at Station 2 (m/s)

Z_2 = elevation of the water above datum line, in the streamline at Station 2 (m)

h_f = friction loss (m)

h_L = secondary losses (m)

and

$$h_f=\frac{\lambda L V^2}{2gD}$$ **Equation 4-4**

$$h_l=\frac{K V^2}{2g}$$ **Equation 4-5**

where:

h_f = friction loss (m)

h_L = secondary losses (m)

λ = friction coefficient of penstock or pipe (m)

L = length of penstock (m)

v = velocity of water flow in penstock pipe (m/s)

g = acceleration due to gravity (m/s^2)

D = diameter of penstock or pipe (m)

K = secondary loss coefficient (K is normally 0.5 at inlet and 1 at outlet)

The design flow and head can be calculated by generating a flow-rating curve (**Figure 4-1**) and calculating the available power for different combinations of flow and associated head. The design flow and head are calculated in different ways, depending on the application of the generated energy. At this stage the required operational bands of the turbine should be selected and, if necessary, the operational philosophy of the pipeline should be adjusted to accommodate the required flow and pressure bands, as discussed in Step 3.

If electricity should be supplied at a certain assurance level, the flow at that percentage may be used as the design flow, with its corresponding head. If the maximum potential is used, then the design flow and head will be the combination that generates the optimum potential annual power. **Table 4-2** is an example of the table that may be used to obtain the optimum potential annual power. It is important to not only consider the design flow and head at this stage, but also the bands within which the turbine should function.

Table 4-2: Example of a Phase 3 potential analysis

PHASE 3 POTENTIAL ANALYSIS								
Flow rating curve	Load factor (%)	Flow (m^3/s)	Head available (m)	Efficiency (%)	Time in use (h)	Power rating (kW)	Potential power (MWh/a)	Potential power for optimum use (MWh)
	100	0	125	0%	8592	0.0	0.000	0.000
	95	0.000	123.4	0%	8154	0.0	0.000	0.000
	90	0.001	139.5	0%	7716	0.0	0.000	0.000
	85	0.059	143.9	22%	7278	18.2	132.465	5.681
	80	0.184	142.9	55%	6840	141.8	969.865	5.681
	75	0.310	138.0	80%	6402	335.7	2149.311	5.681
	70	0.412	131.2	83%	5964	440.1	2624.710	5.681
	65	0.553	127.4	84%	5526	577.0	3188.704	5.681
	60	0.780	113.8	84%	5088	727.4	3701.165	5.681
	55	0.959	92.6	84%	4650	727.5	3382.977	5.681
	50	0.974	94.6	84%	4212	754.5	3177.821	5.681
	45	0.981	96.6	84%	3774	776.5	2930.541	5.681
	40	0.986	99.0	84%	3336	799.9	2668.550	5.681
	35	0.992	101.0	84%	2898	821.1	2379.499	5.681
	30	0.999	103.4	84%	2460	846.0	2081.116	5.681
	25	1.009	109.8	84%	2022	907.3	1834.488	5.681
	20	1.025	120.9	84%	1584	1015.6	1608.761	5.681
	15	1.105	88.0	84%	1146	796.6	912.925	5.681
	10	1.194	97.1	84%	708	949.2	672.001	5.681
	5	1.372	85.8	84%	270	964.0	260.286	5.681
	0	1.456	82.6	84%	0	984.5	0.000	5.681
Optimum flow	60	0.780	113.8		5088	727.4	3701.165	102.259
Average flow		0.767	111.6	84%	8592	701.4	6026.665	
Chosen flow	USE	0.032	50.4	84%	8592	13.0	111.735	
Assurance of flow		0.000	0.0	84%	0	0.0	0.000	
Design flow	**Chosen**	**0.032**	**50.4**		**8592**	**13.0**	**111.7**	
Flow range								
Minimum flow	55	0.959	92.6		727.5	3382.977		
Design flow	60	0.0315	50.4		13.0	111.735		
Maximum flow	55	0.959	92.6		727.5	3383.0		

Town development forecast 5

Anticipated future patterns are just as useful as current flow and pressure patterns. Therefore, a study should be done to determine the growth (or decline) in demand on the reservoir or pipeline in question. Daily demand patterns, as well as seasonal demand variations, should be analysed and extrapolated for any new developments or extensions planned over the design life of the hydropower plant.

It is important to indicate the appropriate timeframe for future demand, whether projections are done for every five or ten years, or just for the demand at the end of the life cycle. It is important to specify clearly which figures subsequent studies (e.g. design and financial planning) are based on and how demand growth is accommodated (Harvey et al., 1993).

If it is anticipated that future development will decrease the hydropower potential, this should be noted and the economic feasibility analysis should be done with an applicable design life for current circumstances.

Required turbine range 6

Another important factor to consider is flow-rate variation, as turbine efficiency might be severely impacted if high variation is experienced. For example, Francis and propeller type turbines have high efficiencies at design flow, but very low efficiencies for other flow rates. On the other hand, cross-flow and Pelton turbines can sustain high efficiencies over a wide range of flow rates. **Figure 4-8** shows the efficiencies of the most common turbine types.

Because different types of turbines have different efficiencies when operated at flows other than the design flow, it is important to determine not only the design flow and head, but also the required range of operation of the turbine. **Figure 4-9** provides an example of a flow and pressure range for a design flow of 55% assurance, maximum flow of 40% and minimum flow of 70% assurance.

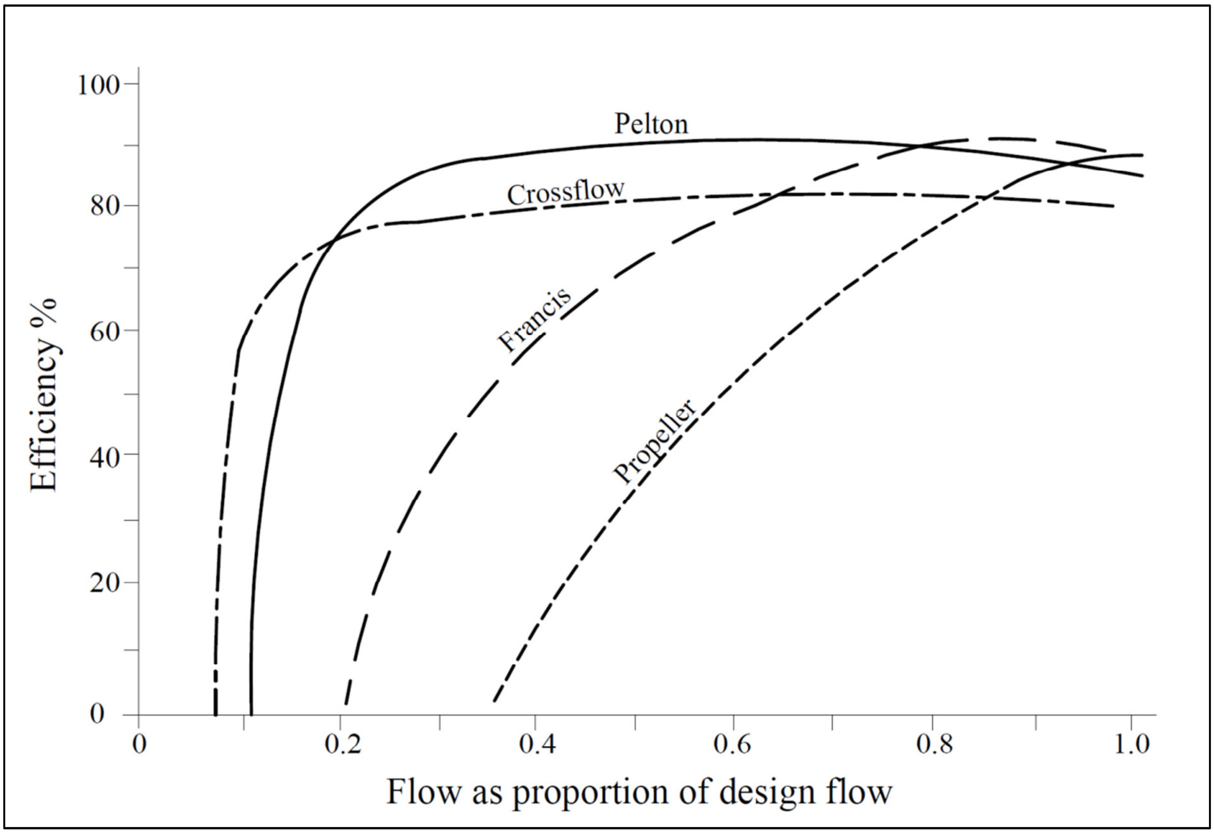


Figure 4-8: Part-flow efficiencies of different turbines (Paish, 2002)

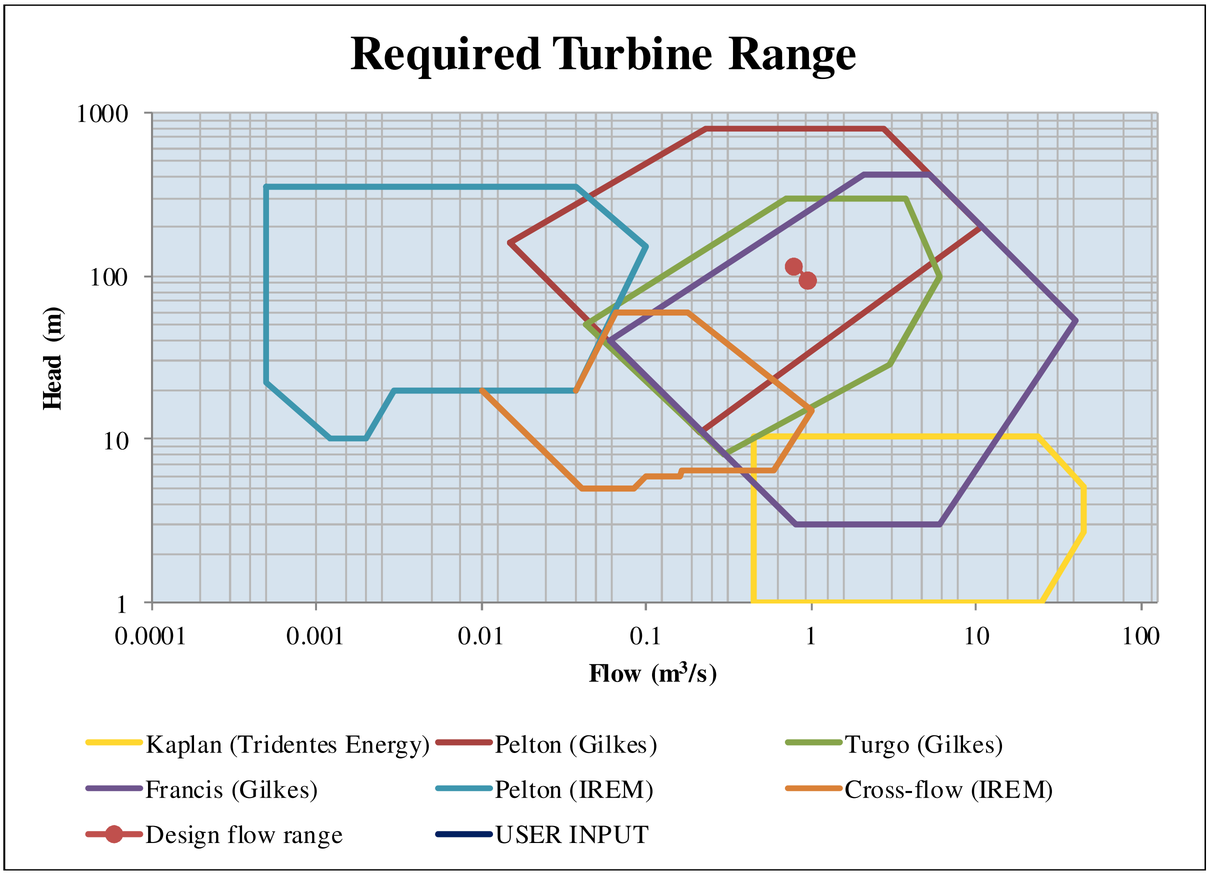


Figure 4-9: Example of a Phase 3 turbine range selection

Turbine selection for current flows

The next step will be to use the obtained information to select a suitable turbine. As discussed in **Chapter** 2, there are various types and sizes of turbines. It is therefore important to select the appropriate turbine for the conditions at the specific site.

The key factors to consider in turbine selection and design are the pressure head across the turbine and the manageable flow range. These values are plotted on operational charts which give envelopes of limiting operational conditions for each type of turbine. Other factors to consider in turbine selection include specific speed, cavitation and efficiency (ESHA, 2004). A summary of the applicability of each type of turbine is given in **Table 4-3** and **Figure 4-10**.

Table 4-3: Operational ranges of different turbines (ESHA, 2004)

Type of turbine	Head range (m)	Acceptance of flow variation	Acceptance of head variation	Maximum efficiency (%)
Kaplan/Propeller	2 - 40	High	Low	91 - 93
Francis	25 - 350	Medium	Low	94
Pelton	50 – 1 300	High	High	90
Cross-flow	2 – 200	High	Medium	86
Turgo	50 - 250	Low	Low	85

In determining what turbine to use, the prevailing flow and pressure conditions need to be established. Different turbine types have different performance characteristics and each has its own advantages and disadvantages of use. The variation in future predicted flow rate also affects the choice of turbine as it may be detrimental to turbine efficiency.

This CHDSS does not discuss turbine design, as it falls outside the engineer's scope of work on a hydropower project.

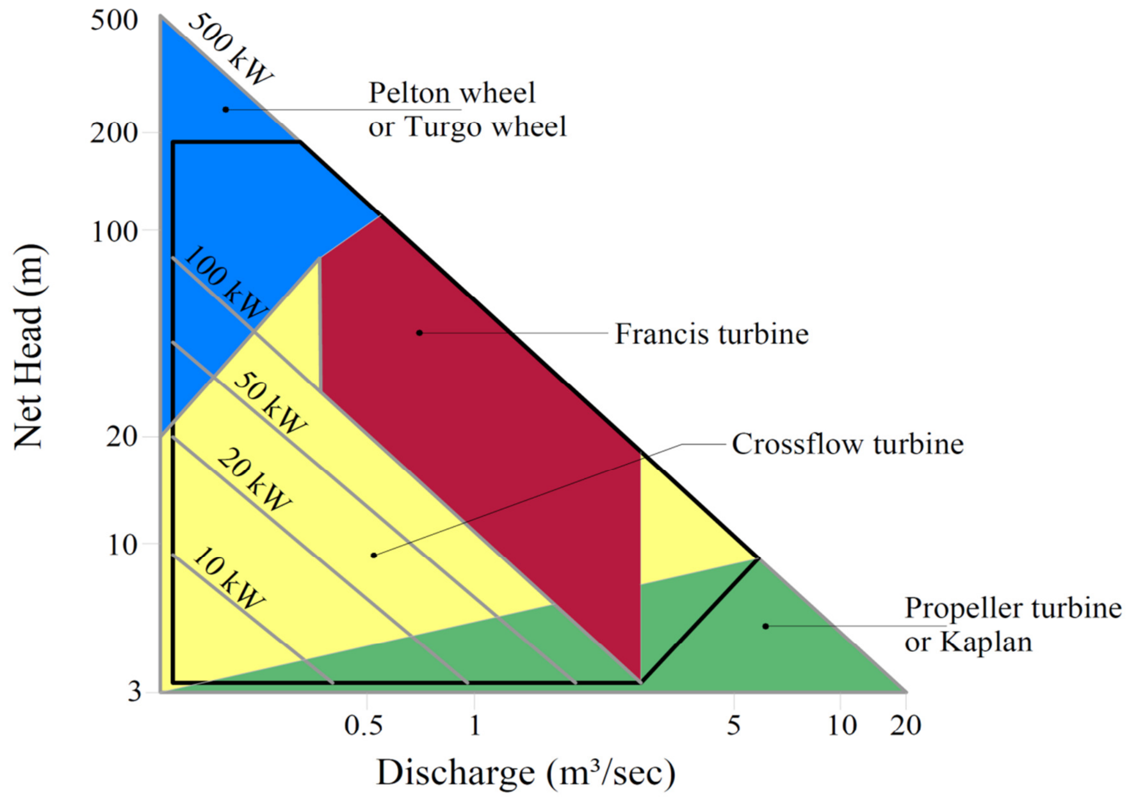


Figure 4-10: Head-flow ranges of hydro-turbines (Paish, 2002)

Efficiency

The ratio between electricity output an input, at a specific time, is the electric power plant efficiency of a generator. The efficiency of a hydropower turbine (η) can be calculated (**Equation 4-6**) by comparing the actual power output with the theoretical output at 100% efficiency, as follows:

Equation 4-6

where:

η	=	turbine efficiency (%)
P_{actual}	=	actual power output of turbine (W)
$P_{theoretical}$	=	theoretical output at 100% efficiency (W)

The actual electrical output of the turbine can be determined by multiplying the current of the electric flow by its potential difference:

$$P = IV$$ **Equation 4-7**

where:

P	=	electrical power output (W)
I	=	electrical current (A)
V	=	potential difference (V)

Natural Resources Canada (2004) proposes efficiency ranges for different turbines (**Table 4-4**) and ESHA (2004) proposes efficiencies of small generators (**Table 4-5**).

Table 4-4: Typical efficiency of turbines and water wheels (Natural Resources Canada, 2004)

Prime mover	Efficiency range
Impulse turbines:	
Pelton	80-90%
Turgo	80-95%
Cross-flow	65-85%
Reaction turbines:	
Francis	80-90%
Pump-as-turbine	60-90%
Propeller	80-95%
Kaplan	80-90%
Waterwheels:	
Undershot	25-45%
Breastshot	35-65%
Overshot	60-75%

Table 4-5: Typical efficiencies of small generators (ESHA, 2004)

Rated power (kW)	Best efficiency
10	0.910
50	0.940
100	0.950
250	0.955
500	0.960
1000	0.970

Turbine selection for future flows

At this stage, future scenarios should be compared with the turbine selection for the current flow regime. If future flow rates differ significantly from current rates, this should be incorporated in the design. This can be done in one of two ways, which will be discussed in the next paragraphs.

If future flow rates do not differ significantly from current rates, a turbine with high efficiencies at a number of flows can be selected, bearing in mind the future design flow during the sizing of the turbine.

However, in many cases, future flow rates will differ significantly from current rates and cannot be accommodated by the selected turbine. In these cases, space should be allowed in the turbine room and pipework for additional turbines to be added as the need arises. The economic analysis should also allow for capital expenditure at the forecast date when additional capacity will be necessary.

4.3.2 ENERGY USAGE

The amount of energy needed, as well as required production patterns, will depend on the use of the generated electricity. In general, there are three potential uses for energy generated in the water-distribution network:

- Electricity can be fed into an existing grid;
- It can be used for islanded systems that are far from an electricity grid; and/or
- It can be utilised at reservoirs, or other sites in the network that need local lighting, security and telemetry.

If the generated electricity is fed into an existing grid and only comprises a small portion of electricity in a stable grid, then the demand patterns are not an important aspect during design. In these cases, electricity may be fed into the grid whenever it is produced.

If the generated electricity is used to supply peak demand in an existing grid, the generation of electricity should be synchronised with peak demands in the system. Similarly, if electricity is generated to supply an islanded system or on-site needs, the generation should match the demands, considering time of day and time of year.

It is therefore necessary to determine the current and forecast energy-demand patterns for these cases.

Distance of site to energy users [11]

If the generated electricity is to be connected to the grid, it is important to know how far the hydropower plant would be from the connection point. If the plant is far away from a grid connection, it might have a significant impact on the economic feasibility of the project.

Grid-connection requirements [12]

As noted in **Chapter 2**, permission should be granted by Eskom if the generator is to be synchronised with an Eskom grid. To obtain permission, the applicant should complete the relevant application form (Eskom, 2011b) (attached in **Appendix A**) and comply with Eskom's interconnection standard (Eskom, 2008) (which can also be viewed in **Appendix A**).

The process can be summarised as follows (the complete Eskom *Guide for IPP Grid Application Process* can be seen in **Appendix A**) (Eskom, 2011c):

1. Complete the application form
2. Submit the application form
3. Obtain a quotation from Eskom
4. Accept the budget quote and sign the connection and use of system agreement
5. Connect and use the system

Municipalities also have grid-connection requirements. As an example, the CoT requirements are attached in **Appendix A** (City of Tshwane Energy & Electricity, 2010).

Current and forecast demand 13

The daily energy demand patterns need to be obtained. This should be compared with the power supplied by the hydropower plant to determine whether the plant will be able to provide a significant portion of the required energy, or whether it will only supply a small percentage, making it possibly unfeasible.

Future scenarios of increase (or possibly decrease) in energy demand should also be drawn up. Daily demand patterns, as well as seasonal demand variations, should be analysed and extrapolated for any new developments or extensions planned over the design life of the hydropower plant.

It is important to indicate the appropriate timeframe for future demand, whether projections are done for every five or ten years, or just for the demand at the end of the life cycle. It is important to specify clearly which figures design and financial planning are based on and how demand growth is accommodated (Harvey et al., 1993).

Demand vs. energy potential 14

In the case of an on-site or islanded project, daily and seasonal demand variation should be obtained for both current and future energy usage. This could be illustrated using graphs that depict energy usage vs. time in a 24 h period, for both summer and winter scenarios.

After both energy demand and hydropower potential have been studied, these values should be compared. The energy demand study will be used to indicate the daily and seasonal variation in electricity demand, whereas the hydraulic study will present the variation in potential power supply. This stage of the study should clearly indicate how well the supply-and-demand patterns correlate. Examples of comparative graphs for summer and winter scenarios can be seen in **Figure 4-11** and **Figure 4-12**, respectively.

If supply-and-demand patterns do not correlate, one should either adjust the operational procedure to ensure better correlation, or supply batteries to store energy produced until it is needed. In the case of on-site or islanded system supply, it is also important to ensure that the power supplied by the turbine does not grossly outstrip current and future power needs. If the potential power is more than the usable power, a smaller turbine should be selected.

It is important to consider implementation of energy-efficiency measures to reduce demands. Energy efficiency may be increased by using low-energy lights and appliances and encouraging users to switch off unused or unnecessary lights and appliances

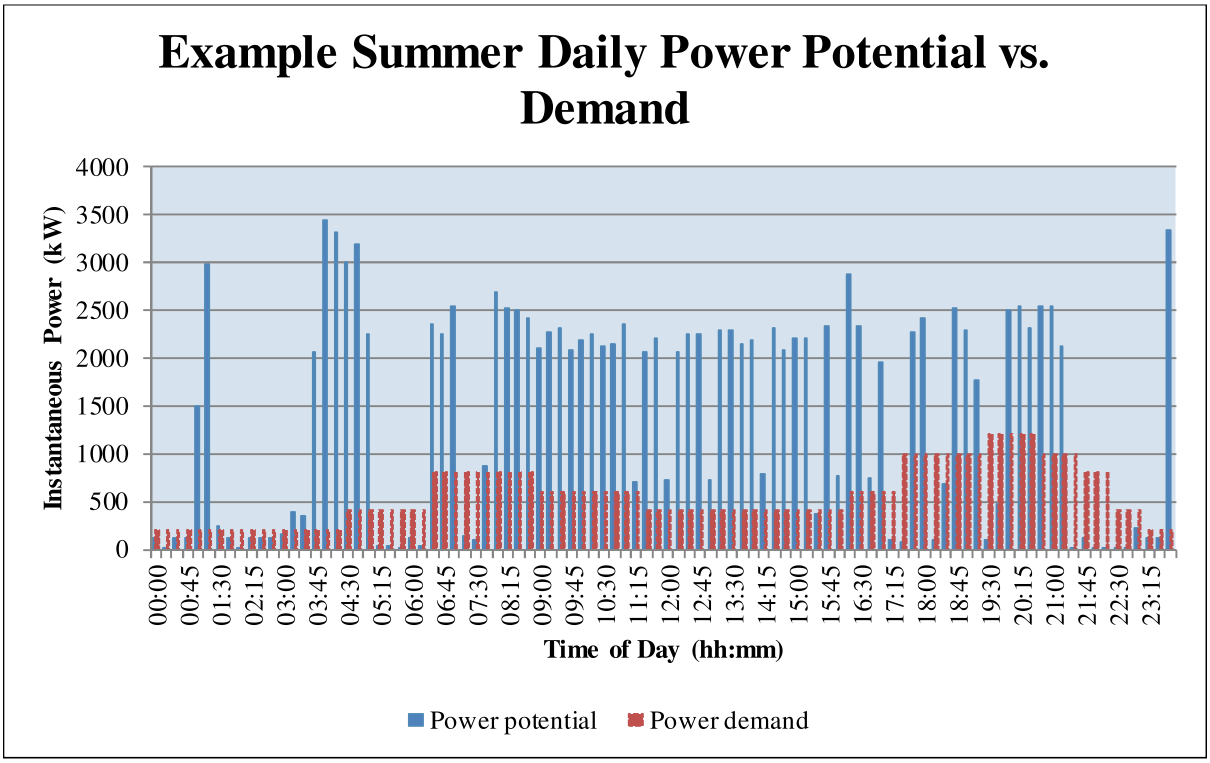


Figure 4-11: Example of summer daily power potential vs. electricity demand

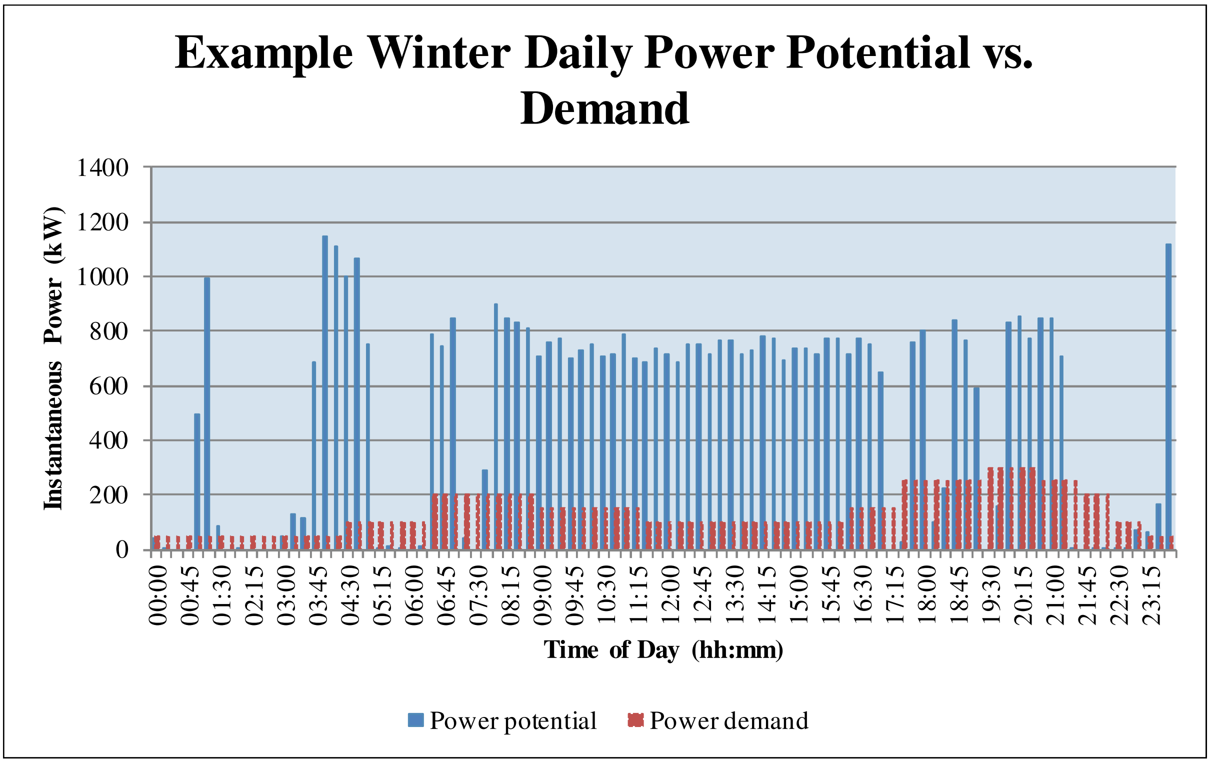


Figure 4-12: Example of winter daily power potential vs. electricity demand

4.3.3 DETAILED SITE EVALUATION

The detailed site evaluation will include practical issues, including the necessary components of the plant, space restrictions, safety and the required hydropower plant set-up. The outcome of this step will indicate whether the system is practically feasible. It is important to note that the information provided here is only a guideline and it is **recommended that specialist consultant input be obtained for all detailed designs.**

Mechanical and electrical works

Table 4-6 was adapted from ESHA (2004) and Natural Resources Canada (2004) and provides a summary of electrical and mechanical design features. Specialist consultant input is recommended.

Table 4-6: Electrical and mechanical design considerations

Component	Discussion
Turbine	The selection of an applicable turbine has been discussed in detail in **Chapter 4.3.1**. The selected turbine should operate at a high efficiency for the design flow range.
Generator	The generator is used to convert mechanical energy from the turbine to electrical energy. Asynchronous generators are generally more robust and cheaper than synchronous generators. However, if the electricity will not be fed into a stable grid, a synchronous generator must be used to ensure high quality electricity.
Driver	A driver is used to keep voltage and frequency of the generated electricity stable. The driver system can be a belt, pulley, direct drive or gearbox.
Control	A control system is required to compensate for variation in flow and pressure at the turbine. Speed governors regulate the speed of the generator by controlling the flow through the turbine. Electronic load controllers manage decreased loads by switching to a pre-set resistance to maintain system frequency.
Transmission	Electricity is transported from the powerhouse to the users via electric cables (either overhead or underground). The size and type of the cables are determined by the amount of power to be transmitted and the distance between the plant and the users. For small systems, single-phase electricity may be sufficient. In larger systems a transformer or three-phase electricity is required to minimise losses. Eskom and Municipalities have grid-connection requirements. As an example, the Eskom requirements (Eskom, 2011c) and CoT requirements (City of Tshwane Energy & Electricity, 2010) are attached in **Appendix A**.

Civil works

Table 4-7 provides a summary of civil design considerations. It is important to note that the information given here only provides a guideline and that specialist consultant input is advised.

Table 4-7: Civil design considerations

Component	Discussion
Powerhouse	The powerhouse should be designed to protect the turbine and associated equipment from the elements, animals, as well as from theft and vandalism. If the installation is done on ground level, a chamber similar to a pump house can be constructed. If the installation is done on a reservoir roof, a lightweight construction (for example a steel frame with chromadek sheeting) must be considered. Ample ventilation should be provided. It is important to provide a stable footing for the turbine. If the installation is done on ground level, an appropriately sized concrete block should be designed. If the installation is done on a reservoir roof, the turbine should rest on beams that span between reservoir columns. In this case it is also important to ensure that the reservoir columns and roof will be able to bear the weight imposed by the hydropower plant.
Pipework	Pipes with the correct diameter and pressure class should be specified. The pipework should be designed to have as few as possible sharp bends and no bends greater than 90^0. A bypass should be provided to divert water away from the turbine in the case of a malfunction or maintenance. All standard design requirements for pipework are applicable.
Valves	Isolating valves should be placed at least upstream of the turbine and at the upstream end of the bypass. The bypass should also have a pressure-reducing valve of adequate size to absorb the excess pressure if water is diverted away from the hydropower turbine.
Dynamic analysis	A dynamic analysis should be performed by a specialist if water hammer in the pipeline is a possibility. If the analysis indicates potential water-hammer damage, surge tanks or other mitigation measures should be designed.

Conduit hydropower set-up 17

Next, it is important to assess whether there would be sufficient space at the reservoir to install the turbine and related equipment. To do this, the dimensions of the turbine and all necessary auxiliary equipment should be obtained. It is important to verify whether a specific distance should be present between some of the devices. It is also important to allow space for movement of both people and equipment in the turbine room (for installation, operation and maintenance purposes). The necessary information may be gathered from the respective turbine supplier.

This section will provide diagrams of several options for typical installations. As the final installation will be site-specific, this section will act as a guideline and may be adapted to suit site-specific circumstances.

The basic set-up is similar to a conventional hydroelectric power plant configuration. In this case the water-distribution pipe acts as a penstock. The net pressure head at the point where the turbine is placed will generate the power. Various hydropower set-ups, using different turbines, may be feasible depending on the dominant flow, pressure and distribution network.

A bypass option should be included to be used in case of a malfunction or maintenance of the turbine. The bypass must have a PRV or other pressure-reducing mechanism fitted, as the bypass has to be able to dissipate excess energy in the pipe.

Figure 4-13and **Figure 4-14** show a basic plan and an elevation view, respectively, of a typical impulse turbine set-up.

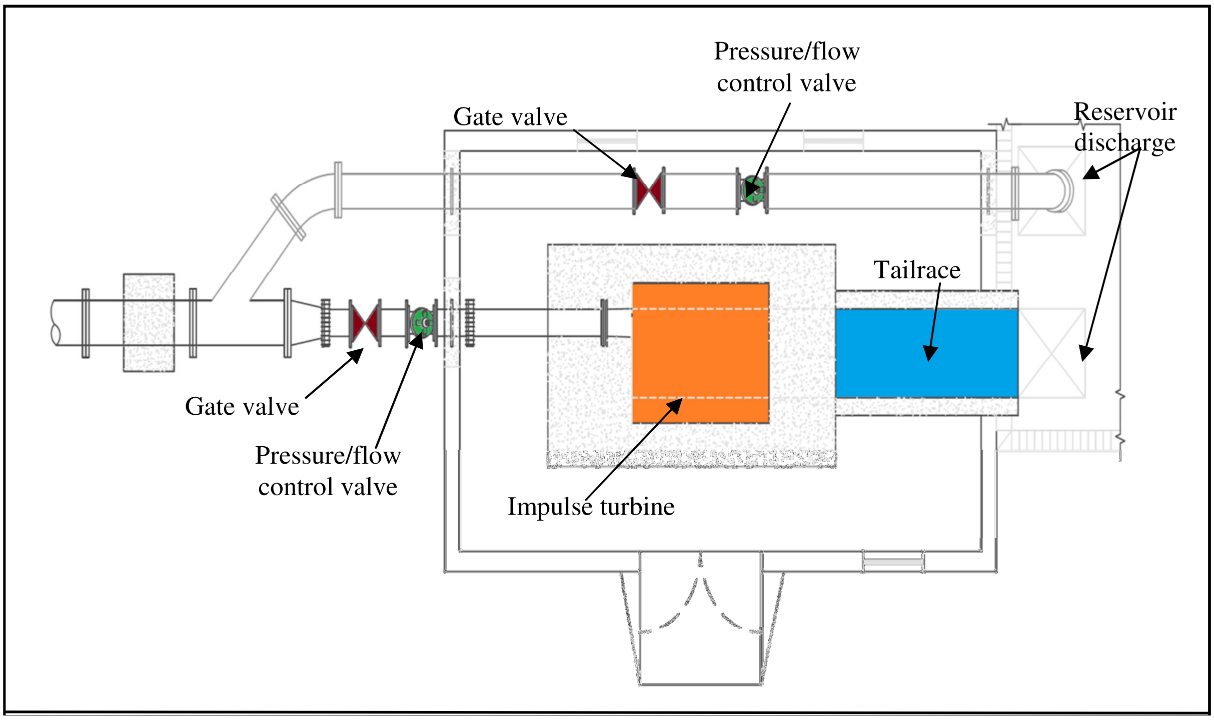


Figure 4-13: Basic plan view of a hydropower set-up using an impulse turbine

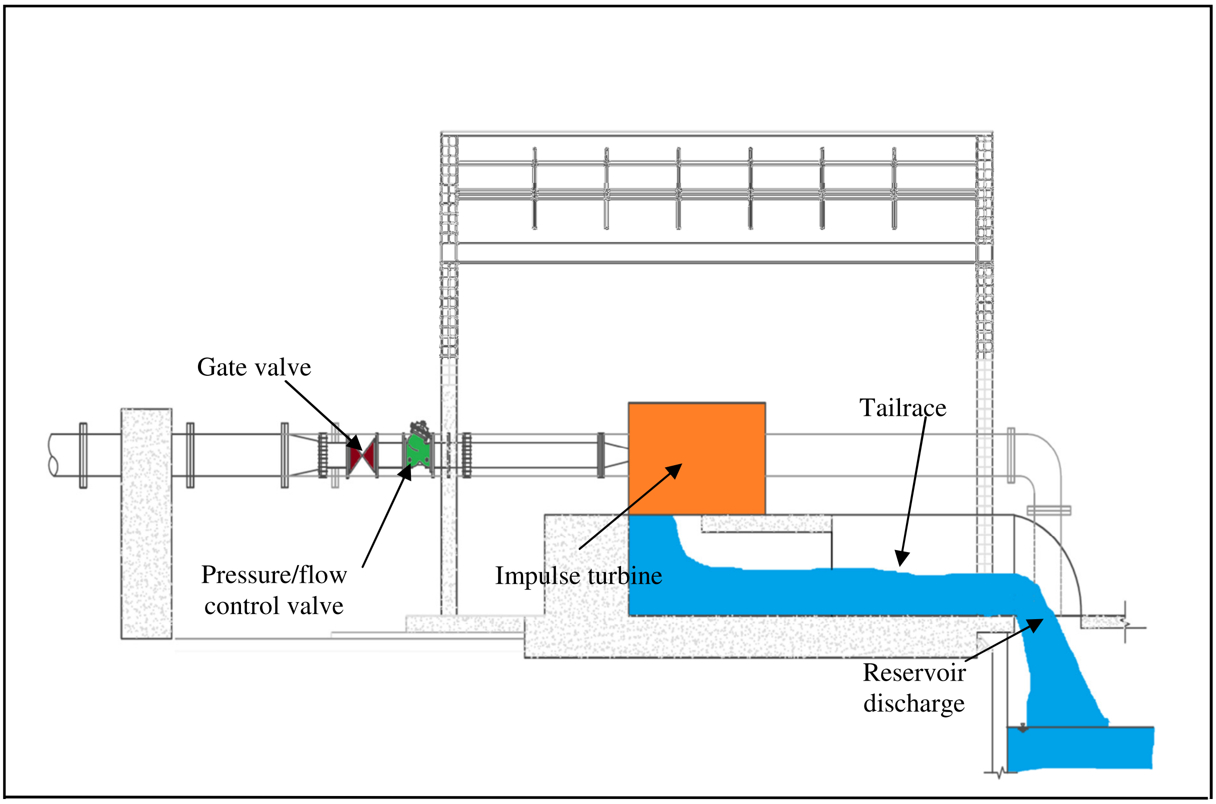


Figure 4-14: Basic elevation view of a hydropower set-up using an impulse turbine

Figure 4-15 and **Figure 4-16** show a basic plan and an elevation view, respectively, of a typical bottom-entry reservoir inflow of a hydropower plant, which will normally be served by a reaction type turbine.

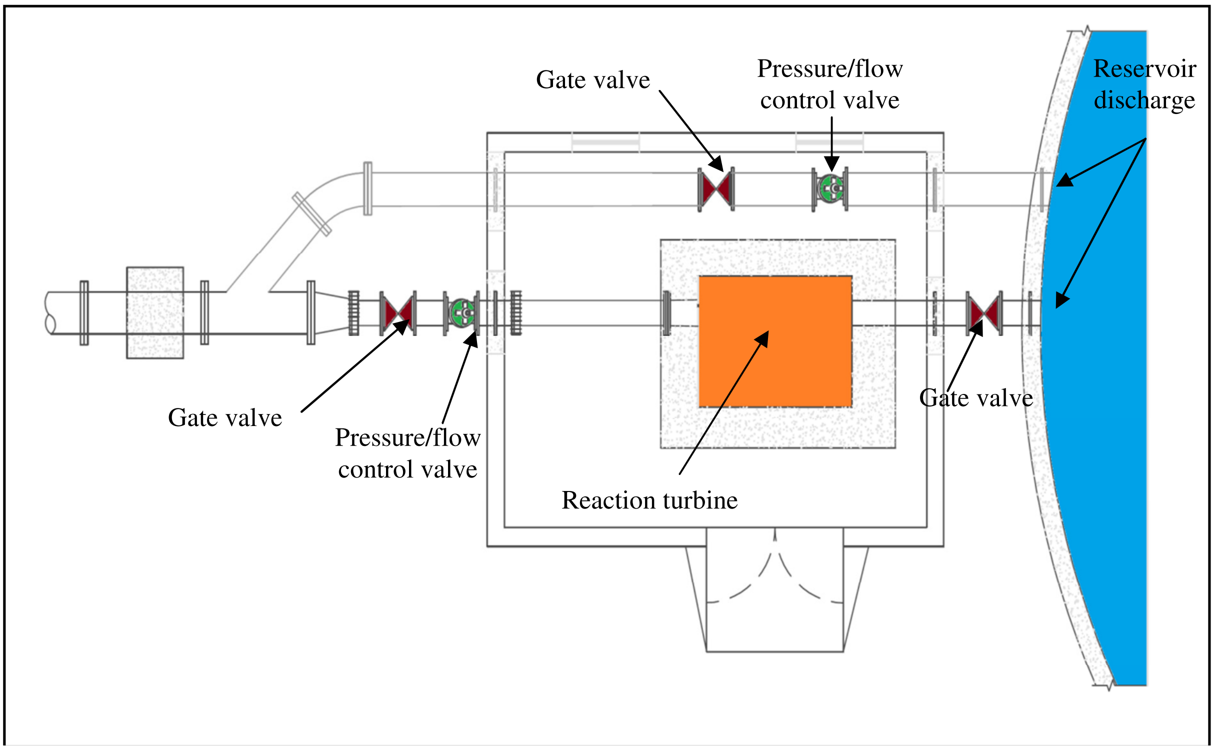


Figure 4-15: Basic plan view of a possible hydropower set-up using a reaction turbine

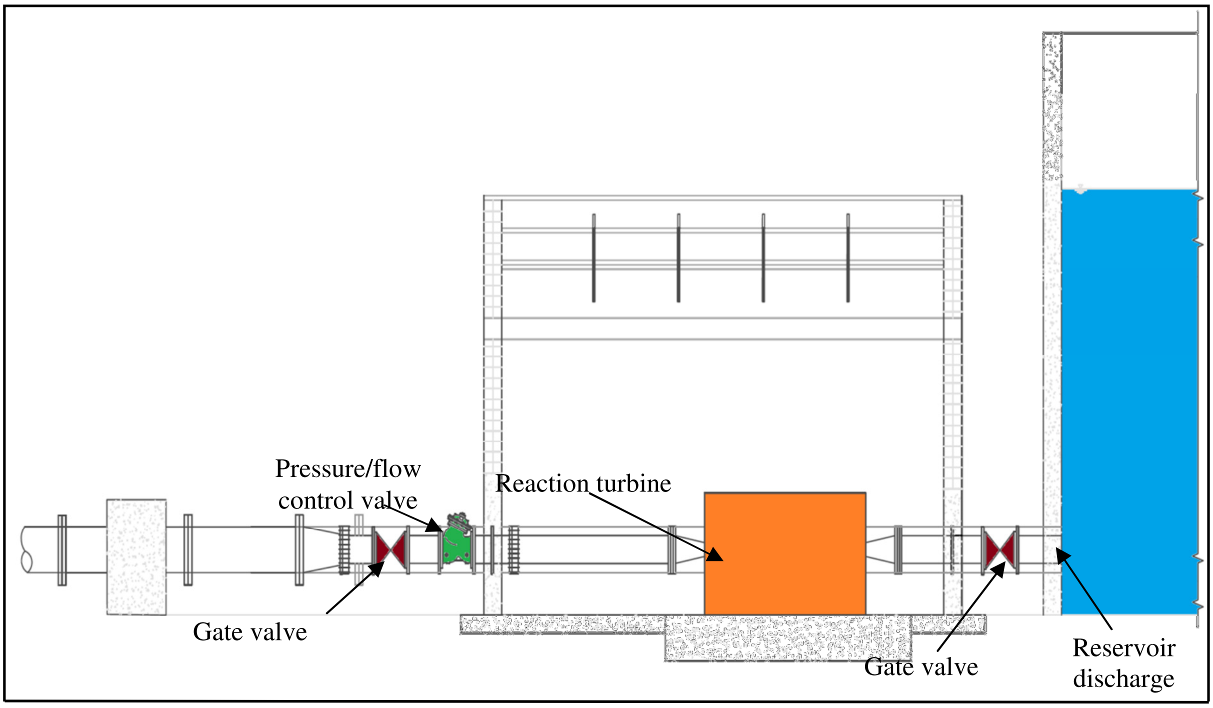


Figure 4-16: Basic elevation view of a possible hydropower set-up using a reaction turbine

Safety of equipment 18

It is imperative to ensure that equipment is kept safe from vandalism and theft and that it cannot become damaged by the elements. It is therefore necessary to ensure that there is proper security (in the form of fencing and removable ladders) and a housing structure for the turbine and related equipment.

4.3.4 DETAILED ECONOMIC EVALUATION 19

The detailed economic analysis should be done with the additional information gathered during this phase. A life-cycle approach should be used to determine whether the project is economically feasible. At this stage of the project, values used for both costs and income should be carefully calculated, to render the analysis as accurate as possible.

It is proposed that the net present value (NPV) and internal rate of return (IRR), with formulas as indicated in **Chapter** 2, be calculated to estimate economic feasibility of the project. The costs that need to be considered include: planning cost, design cost, capital cost, annual operating costs and annual maintenance cost. Income will include savings from not buying power and renting lines from Eskom, and/or revenue from selling electricity.

General inflation, as well as yearly inflation of electricity, operating costs and maintenance costs should be accounted for. Sensitivity analyses should be done to determine the risk if the above-mentioned inflation rates differ from the expected values. This will be discussed later.

If future development will decrease the hydropower potential, this should be noted and the economic feasibility analysis should be done with an applicable design life for current circumstances.

4.3.5 OTHER REASONS FOR CONDUIT HYDROPOWER 20

As mentioned in the previous phases, in some cases there might be reasons other than economic feasibility to justify the use of conduit hydropower. These reasons include:

- So-called islanded systems that have no grid connection, or are far from the national electricity grid.
- Reservoirs that need local lighting, security and telemetry.
- Areas where cable theft may be a problem.
- Areas that need additional peak-time electricity.
- Political reasons for developing greener renewable energy sources.

If another reason for considering hydropower exists, the economic feasibility should not be the deciding factor for constructing a hydropower plant at a given site.

4.3.6 FUNDING OF CONDUIT HYDROPOWER PROJECTS

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Historically, funding for power-generation projects was provided by the public sector. However, privately financed and owned projects are increasing. According to IEA (2000) and Van Dijk et al. (2012b), general financing alternatives include (refer to **Chapter** 2 for a discussion of each of these options):

- own funds
- commercial bank loans
- Development Bank of Southern Africa (DBSA) loans
- funding from the South African National Energy Development Institute (SANEDI)
- joint venture with a sponsor
- limited recourse project financing
- leasing
- development and operation agreement
- payment with electricity
- supplier credit

22

4.3.7 SENSITIVITY ANALYSIS AND ACCEPTABLE RISK

Because many factors may change unexpectedly during the design life of a hydropower plant, it is imperative that various sensitivity analyses be done. These analyses will determine the outcome if existing information is incorrect, to establish whether the project would still be economically feasible under different circumstances.

Factors that should be tested for sensitivity are inflation of the various yearly incomes and expenses. A higher than expected and lower than expected value for each of these should be included to derive a band of possible net present values and internal rates of return.

The risk of different outcomes should be evaluated and a decision should be made on the acceptability of said risk.

4.3.8 OUTCOME OF PHASE 3

The outcome of this phase would be a conduit hydropower plant, designed, with cost analysis done, and ready for construction. Staff training, as well as other operation and maintenance aspects, fall outside the scope of this document but are extremely important factors to consider and to include going forward with the project.

5 TESTING OF PROCEDURAL DECISION SUPPORT SYSTEM

5.1 INTRODUCTION

This chapter illustrates the application of the proposed procedural method described in the previous chapter in a municipal context. The City of Tshwane (CoT) Metropolitan Municipality Bulk Water Services division was approached as a partner in the research project. Therefore, all analyses were performed on sites within the CoT's water-distribution network.

A significant portion of Tshwane's water demand is supplied by Rand Water. The water gravitates from Rand Water (in Johannesburg) to the relatively lower lying hills in Tshwane. **Figure 5-1** shows the CoT water-distribution network, consisting of 160 reservoirs, 42 water towers, more than 10 000 km of pipe and more than 260 pressure-reducing stations. Consequently there are many sites within CoT that may have exploitable conduit hydropower potential.

The procedure described in the diagrams in **Chapter** 3 will be followed step-by-step; the first two steps being a city-wide hydropower potential evaluation and the rest being applied to three selected case studies.

5.2 HYDROPOWER POTENTIAL IN THE CITY OF TSHWANE

A scoping study was performed by Van Vuuren (2010) to obtain a first-order estimate of conduit hydropower potential in the CoT water-distribution network, as shown in **Figure 5-1**. This study is used to illustrate the first two steps of the CHDSS.

The scoping study identified the ten larger reservoir sites in CoT. **Table 5-1** reflects the conservative assumptions used to calculate the potential annual hydropower generation from these pressurised supply pipelines. These assumptions were used to calculate the potential annual hydropower generation at reservoirs in Tshwane. The analysis can be seen as a conservative estimate of the potential hydropower capacity of the sites. **Figure 5-2** and **Table 5-2** indicate the potential hydropower generation capacity at the ten most favourable sites in the City of Tshwane water-supply area.

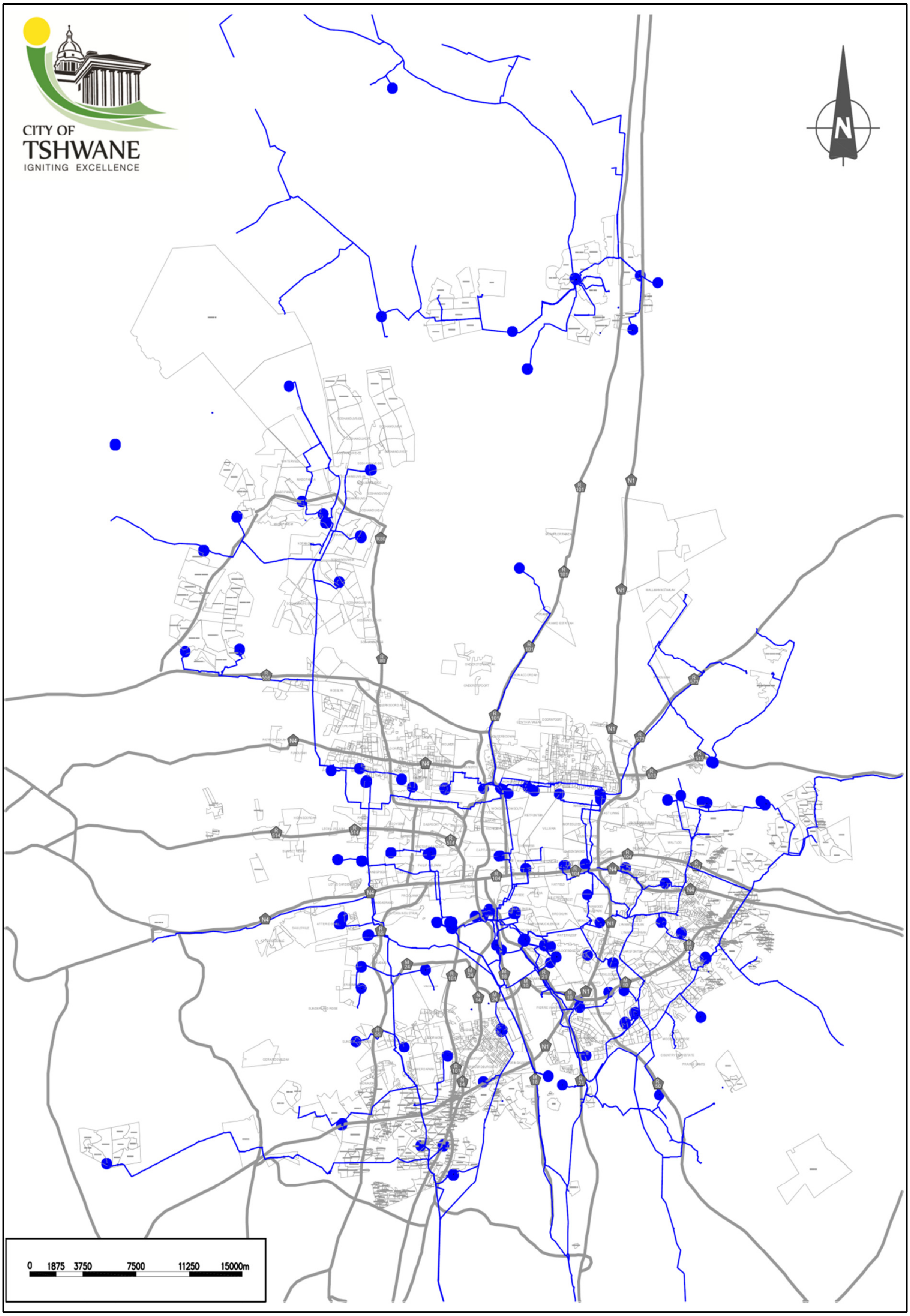

Figure 5-1: Reservoirs and bulk pipelines in the CoT WDS (Van Vuuren, 2010)

Table 5-1: Assumptions used in the determination of hydropower generation capacities in CoT reservoirs (Van Vuuren, 2010)

Variable used for the calculation of potential annual income for power generation at reservoirs in Tshwane	Value	Units
Percentage of the available static head that can be used to generate power	50	%
Hours per day when power can be generated	6	h

Table 5-2: Potential annual hydropower generation capacity at the ten most favourable reservoirs in the City of Tshwane water-distribution system (Van Vuuren, 2010)

Reservoirs	TWL (m amsl)	Capacity (kℓ)	Pressure (m)	Flow (ℓ/s)	Annual potential power generation (kWh) #
Garsfontein	1 508.4	60 000	165	1 850	3 278 980
Wonderboom	1 351.8	22 750	256	470	1 292 471
Heights LL	1 469.6	55 050	154	510	843 673
Heights HL	1 506.9	92 000	204	340	745 062
Soshanguve DD	1 249.5	40 000	168	400	721 859
Waverley HL	1 383.2	4 550	141	505	721 483
Waverley LL	1 332.9	4 550	166	505	721 483
Akasia	1 413.8	15 000	193	340	693 930
Clifton	1506.4	27 866	196	315	663 208
Magalies	1438.0	51 700	166	350	624 107
Montana	1387.6	28 000	82	463	407 829
Total calculated annual power generation in Tshwane					**±10 000 000**

Note: *# Refer to the assumptions listed in Table 5-1*

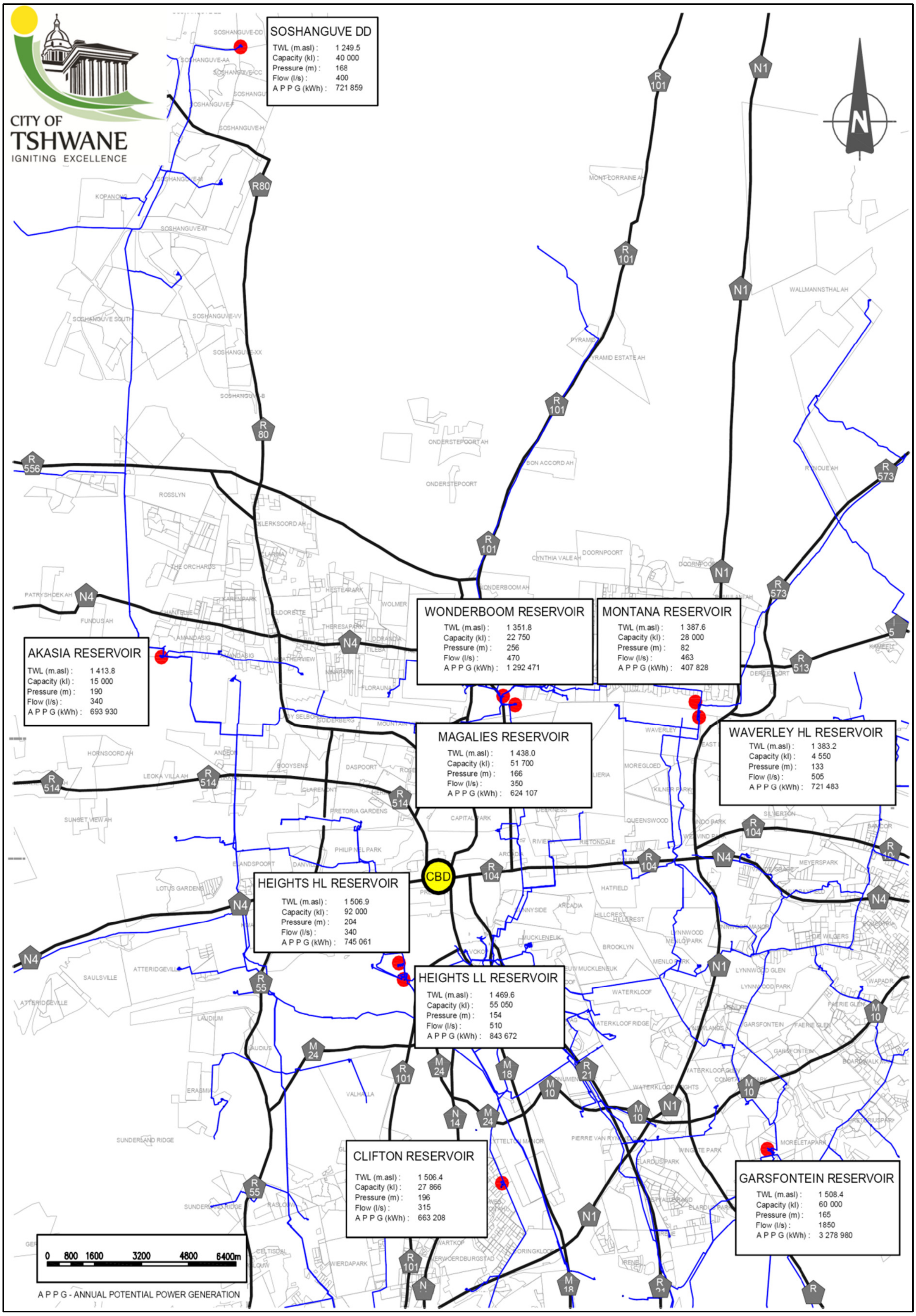

Figure 5-2: Hydropower generation capacity at different reservoirs in the CoT WDS (Van Vuuren, 2010)

5.3 SELECTION OF CASE STUDIES

Three case studies were used to test the applicability of the procedures discussed in **Chapters 3 and 4**. The three case-study sites were selected to represent a variety of circumstances that would enable comprehensive testing of the procedural method and are therefore not necessarily the three sites with the highest hydropower potential in CoT. This chapter describes the three case studies used to verify the applicability of the proposed procedural step-by-step Conduit Hydropower Decision Support System (CHDSS) and CHD Tool. Each case study will be discussed separately. Calculations are included in **Appendix E**.

5.4 CASE STUDY 1: GARSFONTEIN RESERVOIR

5.4.1 LOCATION

The Garsfontein Reservoir is located in Wekker Street, Moreleta Park, as can be seen in **Figure 5-3**. The GPS coordinates are 25°49'35.8"S and 28°17'33.6"E and the base of the reservoir is situated at an elevation of 1 497 m above mean sea level (amsl).

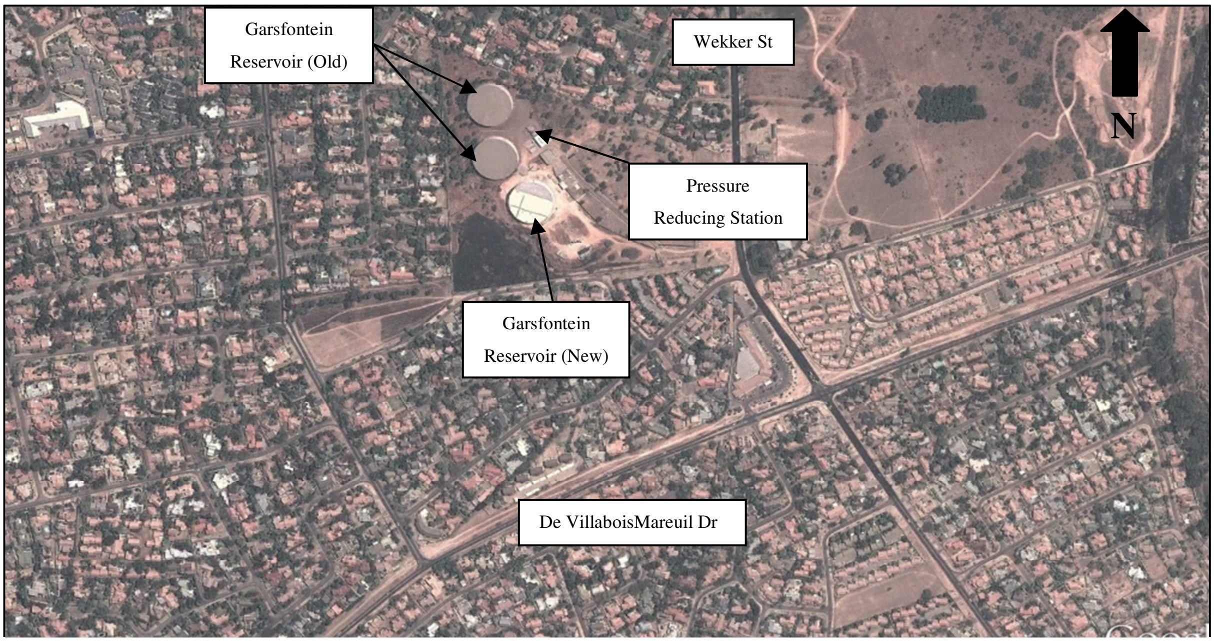

Figure 5-3: Location of Garsfontein Reservoir (Google Earth, 2012)

5.4.2 SITE DESCRIPTION

Water to the Garsfontein Reservoir is supplied from Rand Water sources and the Rietvlei Dam. The reservoir consists of three structures and is a bulk reservoir in the water-distribution network to a significant portion of the eastern parts of the Tshwane Metropolitan area, as shown in **Figure 5-4**. All three structures are cylindrical reservoirs built using post-tensioned reinforced concrete, with capacities of 30 000 m^3 each.

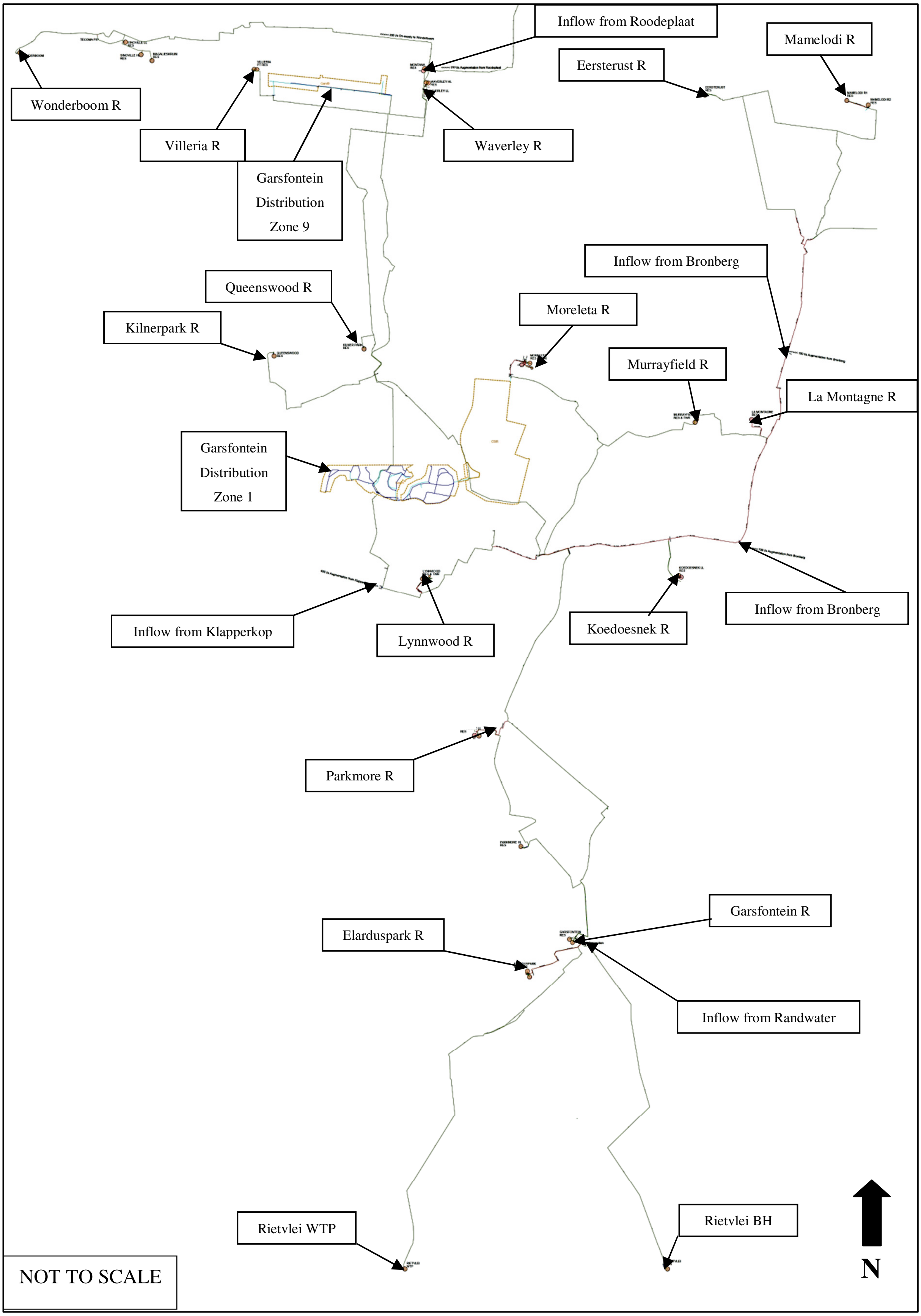

Figure 5-4: Garsfontein Reservoir water-distribution zone (IMQS)

5.4.3 PHASE 1 ANALYSIS AND RESULTS

The information used in the first phase study was obtained from The City of Tshwane Metropolitan Municipality's IMQS (Infrastructure Management Query Station) database. The relevant information can be seen in **Table 5-3.** This information was entered into the CHD Tool for Phase 1, with default values as indicated in **Appendix C** and the output is also shown in **Table 5-3**.

Table 5-3: Garsfontein Phase 1 analysis summary

DSS step	Description	Value	Unit	Source
	Reservoir name	Garsfontein		IMQS
3	Owner of infrastructure	City of Tshwane		
4	Present average annual daily demand	85 475	kℓ/d	IMQS
	Future average annual daily demand	176 463	kℓ/d	
	Average flow	0.989	m^3/s	CHD Tool
	Static head (pressure head used)	165.5 (100)	m	IMQS
5	Theoretically available power	676.6	kW	CHD Tool
6	Potential use	Grid connected		Decided
7	Distance to grid	0.5	km	Measured
8	On-site peak energy demand	N/A	kW	N/A
9	Average power/max demand	N/A	%	
10	Design life	15	Years	CHD Tool
	Estimated cost of plant (based on theoretically available power)	13 234 700	Rand	
	NPV of costs	16 265 700	Rand	
	NPV of income	36 048 300	Rand	
	NPV	19 782 600	Rand	
	IRR	20	%	
	Payback period	7	years	
	Economically feasible?	YES		
11	Consider next phase?	YES		

Suitable future flow rates and pressure heads for hydropower generation cannot be guaranteed at this site for future scenarios. It is assumed that parallel pipes will be installed in future, so that the final conditions at the site will be twice the current flow, but with the same corresponding pressure heads. However, as this is only a rough estimate, future upgrades will not be allowed for in the economic analysis and a design life of only 15 years was selected to determine economic feasibility for in case future conditions do not suit hydropower. It was argued that the turbine may be moved to another location if conditions become unsuitable. If future conditions prove to be positive, an additional feasibility study for the expansion can be done in years to come. This can almost be seen as a separate project and will therefore not have an impact on the feasibility study of this project.

With an IRR of 20% and a positive NPV of more than R19 000 000, the Phase 1 analysis indicated that a full feasibility study should be undertaken.

5.4.4 PHASE 2 ANALYSIS AND RESULTS

The first phase hydropower potential analysis indicated economic feasibility and therefore a Phase 2 analysis was also performed. After determining first phase feasibility (CHDSS Step 1), it was necessary to visit the site and assess the practicability of a hydropower plant there.

Considered aspects included: space for the hydropower plant; safety of the turbine and other equipment from theft or vandalism; noise impact on the surroundings; and accessibility to the site during construction. The analysis is summarised in **Table 5-4**.

Table 5-4: Garsfontein Phase 2 site analysis summary

DSS step	Practicability aspect	Discussion	Conclusion
2	Available space	The Garsfontein Reservoir is situated on a large plot with sufficient space for a hydropower plant, as shown in **Figure 5-3** and **Figure 5-5**.	Sufficient space exists on site
	Safety	The site is located on CoT property in a suburban area that is fenced and locked.	Sufficient security is present
	Noise impact	As this reservoir is located within a residential area, the impact of noise may be disturbing to residents. However, various PRVs are currently installed in chambers and no complaints have been received.	Noise impact will be sufficiently low
	Accessibility of site	As shown in **Figure 5-3**, the site is just off Wekker Street in Moreleta Park. Access to the site by construction vehicles may be gained through the front gate.	Easily accessible

Figure 5-5: Garsfontein Reservoir site

As the practicability of this site had been established, measuring instrumentation was installed to measure flow and pressure in the system, as recommended in the CHDSS Step 3 of Phase 2. Flow and pressure data were collected at the PRS upstream of the reservoir, as indicated in **Figure 5-3**. Data loggers were installed as shown in **Figure 5-6** (downstream pressure) and **Figure 5-7** (flow rates).

Figure 5-6: Pressure measurement at Garsfontein pressure-reducing station

Figure 5-7: Flow measurement at Garsfontein Reservoir

Figure 5-8 shows the unedited measured data for flow rates, as well as upstream and downstream pressures. A major gap in upstream pressure data was encountered between June and July. This was due to a lost connection between the pressure-gauging equipment and the pipe after maintenance was done to the pipe. Various minor gaps exist in the pressure and flow data. The reason for the gaps is possibly a communication error between the modem on site and the server where information is stored. These gaps were removed before continuing with the analysis.

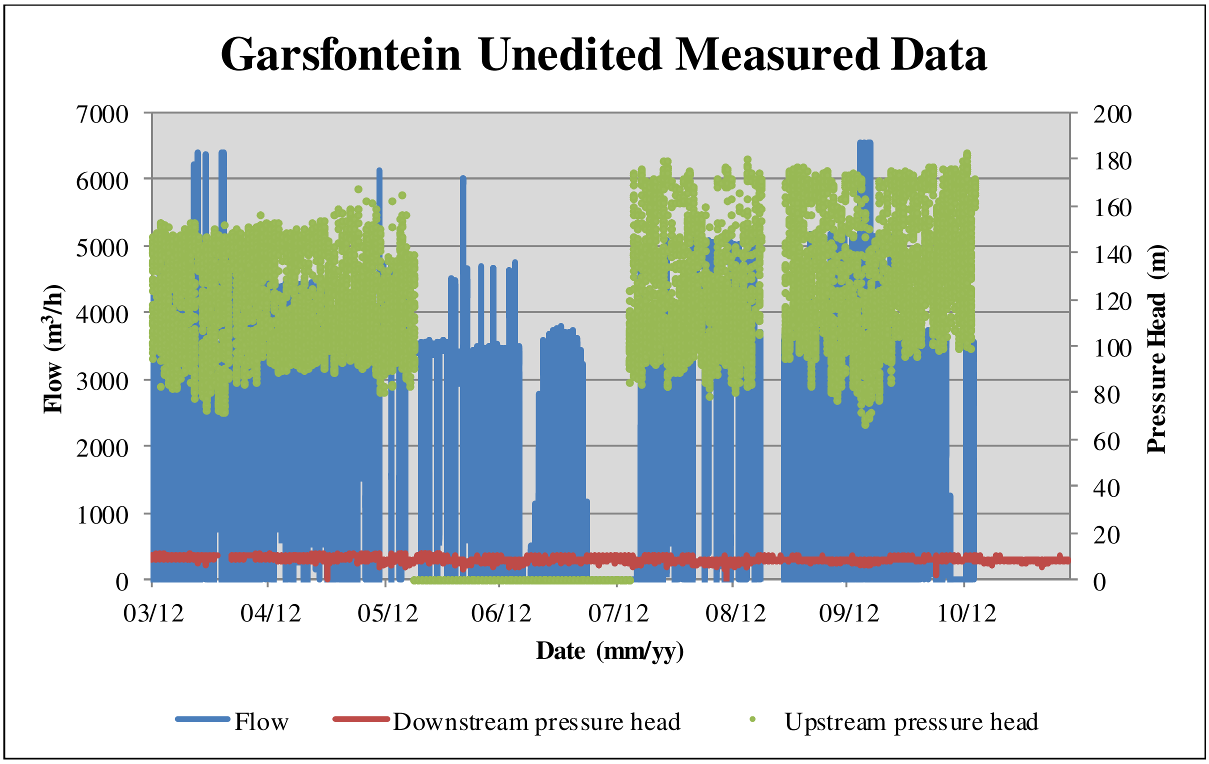

Figure 5-8: Garsfontein unedited measured data

The obtained data set was entered into Phase 2 of the CHD Tool to analyse the records (as per CHDSS Step 4 of Phase 2) and to populate **Table 5-5**. **Figure 5-9**, **Figure 5-10** and **Figure 5-11** were also generated using the CHD Tool. CHDSS Step 6 was not followed for this site, as there is already significant hydropower potential. In Phase 3 allowance will be made for future expansion of the plant as potential increases due to higher flow rates.

Table 5-5: Garsfontein Phase 2 potential analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Garsfontein		IMQS
4	Measured and calculated values	Optimum flow	0.780	m^3/s	Measured
		Pressure head	113.8	m	
		Power rating (**Figure 5-9**)	609.8	kW	CHD Tool
		Annual energy (**Figure 5-9**)	3 898.0	MWh/a	
	Assurance of supply (% of time) (**Figure 5-10**)		N/A	%	N/A
	Design values	Design flow	0.780	m^3/s	CHD Tool
		Pressure head	113.8	m	
		Power rating	609.8	kW	
		Annual energy	3 898.0	MWh/a	
5	What operational changes could be considered?		This reservoir feeds many distribution zones and other reservoirs, so operational changes are not recommended		
7	Selected turbine (**Figure 5-11**)		Turgo		
8	Electricity use		Grid-connected		
9	Distance from grid connection		0.5	km	Measured
10	On-site power demand		N/A	kW	N/A
	Power rating/max demand		N/A	%	

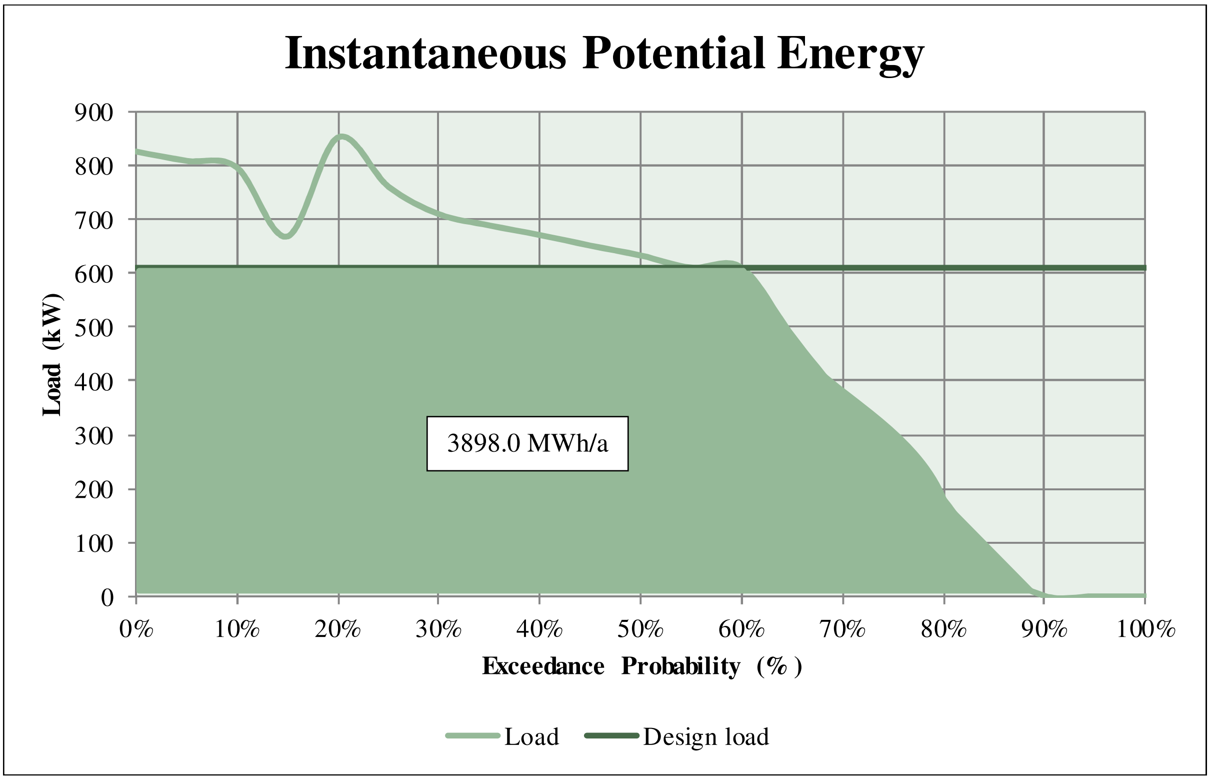

Figure 5-9: Garsfontein Phase 2 instantaneous potential energy

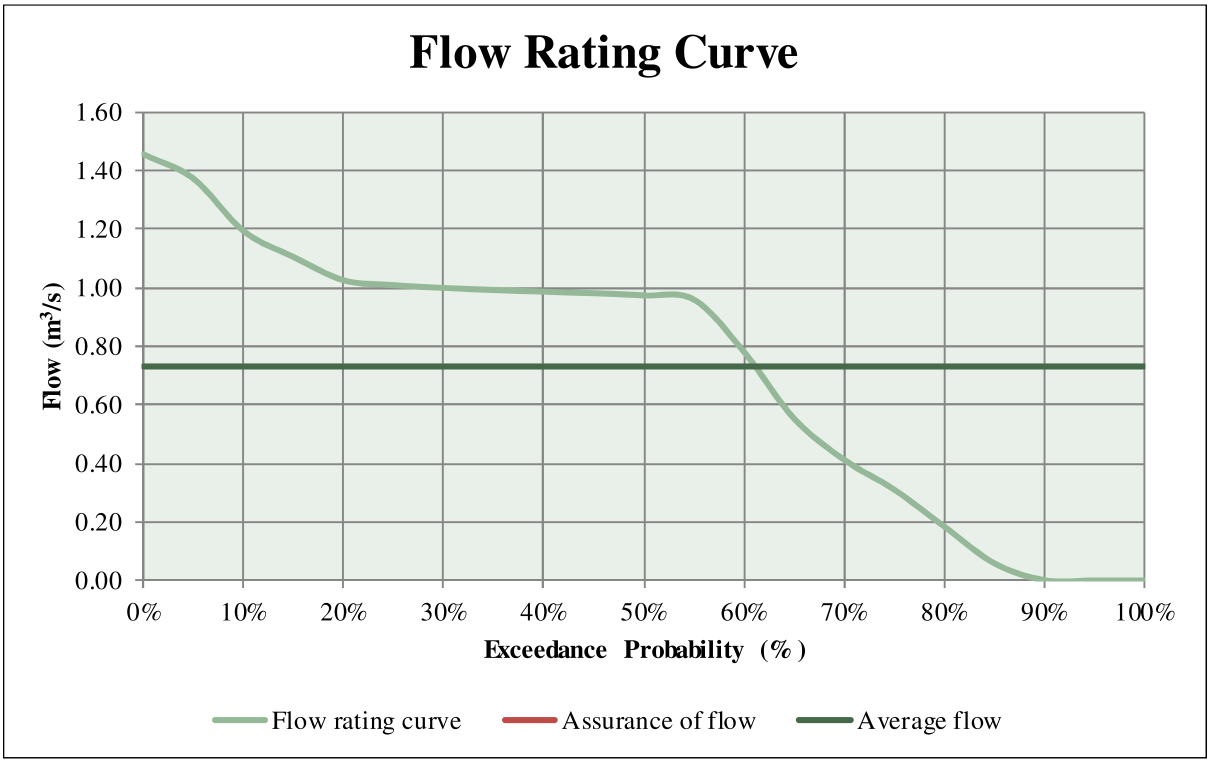

Figure 5-10: Garsfontein Phase 2 flow-rating curve

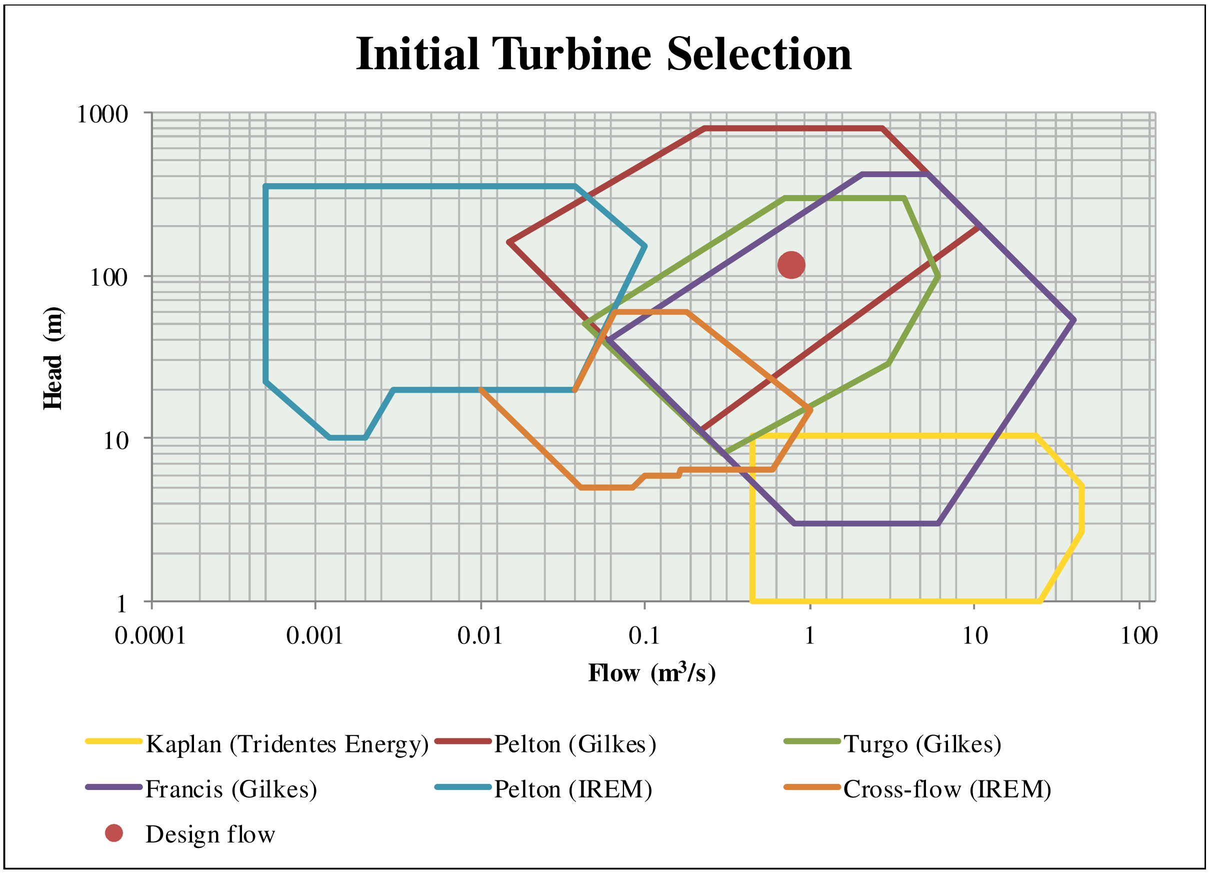

Figure 5-11: Garsfontein Phase 2 initial turbine-selection curve

CHDSS Steps 11 to 14 deal with regulatory requirements. These steps are summarised in **Table 5-6**.

Table 5-6: Garsfontein Phase 2 regulatory analysis

DSS step	Regulatory aspect	Discussion	Conclusion
11	Environmental studies	All power plant and construction areas are smaller than the minimum sizes for which environmental studies are required, according to the National Environmental Management Act (Act 107 of 1998) (refer to **Table 2-10**)	Neither BA nor EIA required
12	NERSA licence	As the generated electricity would be fed into the municipal grid and sold commercially, NERSA licensing would be required. An example of a completed generation application form is attached in **Appendix D**.	Generation licence required
13	Water-use licence	Water-use licensing would not have to be obtained, as this project can be seen as a continuation of an existing lawful use under Tshwane's water-use licence.	Not required
14	Social requirements	A public participation process (PPP) would have to be followed wherein a notice board, meeting the requirements set in Government Notice 543 of 18 June 2010, is displayed on the boundary fence. If complaints are received, public hearings should be held.	PPP required

The next step was to perform an economic evaluation for Phase 2. The CHD Tool was used, with default values and cost functions as discussed in **Appendix C**. **Table 5-7** was populated with the input and calculated values.

Table 5-7: Garsfontein Phase 2 economic analysis

<table>
<tr><th>DSS step</th><th colspan="2">Description</th><th>Value</th><th>Unit</th><th>Source</th></tr>
<tr><td></td><td colspan="2">Reservoir name</td><td>Garsfontein</td><td></td><td>IMQS</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">Design values</td><td>Design flow</td><td>0.780</td><td>m^3/s</td><td rowspan="2">Measured</td></tr>
<tr><td>Pressure head</td><td>114</td><td>m</td></tr>
<tr><td>Power rating</td><td>610</td><td>kW</td><td rowspan="3">CHD Tool</td></tr>
<tr><td>Annual energy potential</td><td>3 898.0</td><td>MWh/a</td></tr>
<tr><td>7</td><td colspan="2">Selected turbine</td><td>Turgo</td><td></td></tr>
<tr><td rowspan="14">15</td><td colspan="2">Planning cost per MW</td><td>1 350 000</td><td>R</td><td>Industry average</td></tr>
<tr><td colspan="2">Planning cost for this site</td><td>823 300</td><td>R</td><td rowspan="2">CHD Tool</td></tr>
<tr><td colspan="2">Turbine cost</td><td>6 708 200</td><td></td></tr>
<tr><td colspan="2">Capital cost per MW (excluding turbine)</td><td>13 300 000</td><td>R</td><td>Industry average</td></tr>
<tr><td colspan="2">Total capital cost for this site (including turbine)</td><td>14 818 800</td><td>R</td><td rowspan="3">CHD Tool</td></tr>
<tr><td colspan="2">Annual operation and maintenance cost (for year 1)</td><td>270 800</td><td>R</td></tr>
<tr><td colspan="2">Annual income (for year 1)</td><td>2 260 800</td><td>R</td></tr>
<tr><td colspan="2">Design life</td><td>15</td><td>years</td><td>Decided</td></tr>
<tr><td colspan="2">NPV of costs</td><td>19 266 800</td><td>R</td><td rowspan="5">CHD Tool</td></tr>
<tr><td colspan="2">NPV of income</td><td>41 090 200</td><td>R</td></tr>
<tr><td colspan="2">Total NPV</td><td>21 823 400</td><td>R</td></tr>
<tr><td colspan="2">Internal rate of return</td><td>19.74</td><td>%</td></tr>
<tr><td colspan="2">Payback period</td><td>8</td><td>years</td></tr>
</table>

With an NPV of almost R22 000 000 and an IRR of 19.74%, without considering Eskom SOP tariffs, the Phase 2 economic analysis indicated that a detailed design was warranted.

5.4.5 PHASE 3 ANALYSIS AND RESULTS

The Phase 2 economic analysis indicated financial feasibility. Therefore the Phase 3 analysis and detailed design was completed. The first step in this phase was to obtain historical flow and pressure records. Longer historical records (of a year or more) would be useful, as they would improve accuracy. However, as longer records were not available for this site, the same measured flow and pressure records were used as in Phase 2, for Step 2 of Phase 3.

The third step of this phase was to consider the effect of system optimisation. **Figure 5-12** shows the flow rates and corresponding pressures during a representative week in September 2012. From this figure it is clear that flow in the pipe is normally controlled at either about 3 600 m^3/h or 5 100 m^3/h until the reservoir is full, at which stage the flow in the pipe becomes almost zero. **Figure 5-13** shows that hours with high power potential do not typically correlate well with hours of high electricity value (peak times). Therefore operational changes to ensure better correlation would produce higher income.

However, as the Garsfontein Reservoir serves various distribution zones and other reservoirs in Tshwane (as shown in **Figure 5-4**), it is not advisable to adjust the operational philosophy of this reservoir significantly to obtain a more constant flow, as this might have a detrimental effect on water supply downstream. The potential analysis was therefore done with unchanged operational philosophy for current flows, as shown in **Table 5-8.**

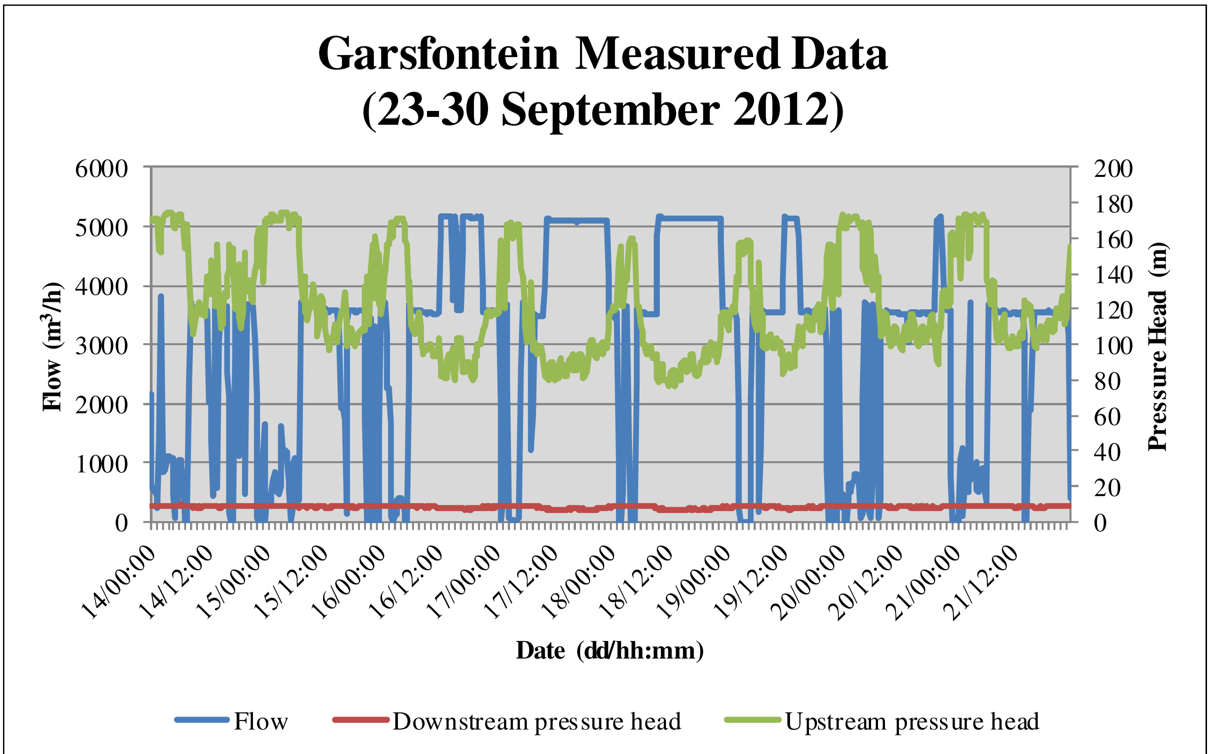

Figure 5-12: Garsfontein measured data for a typical week

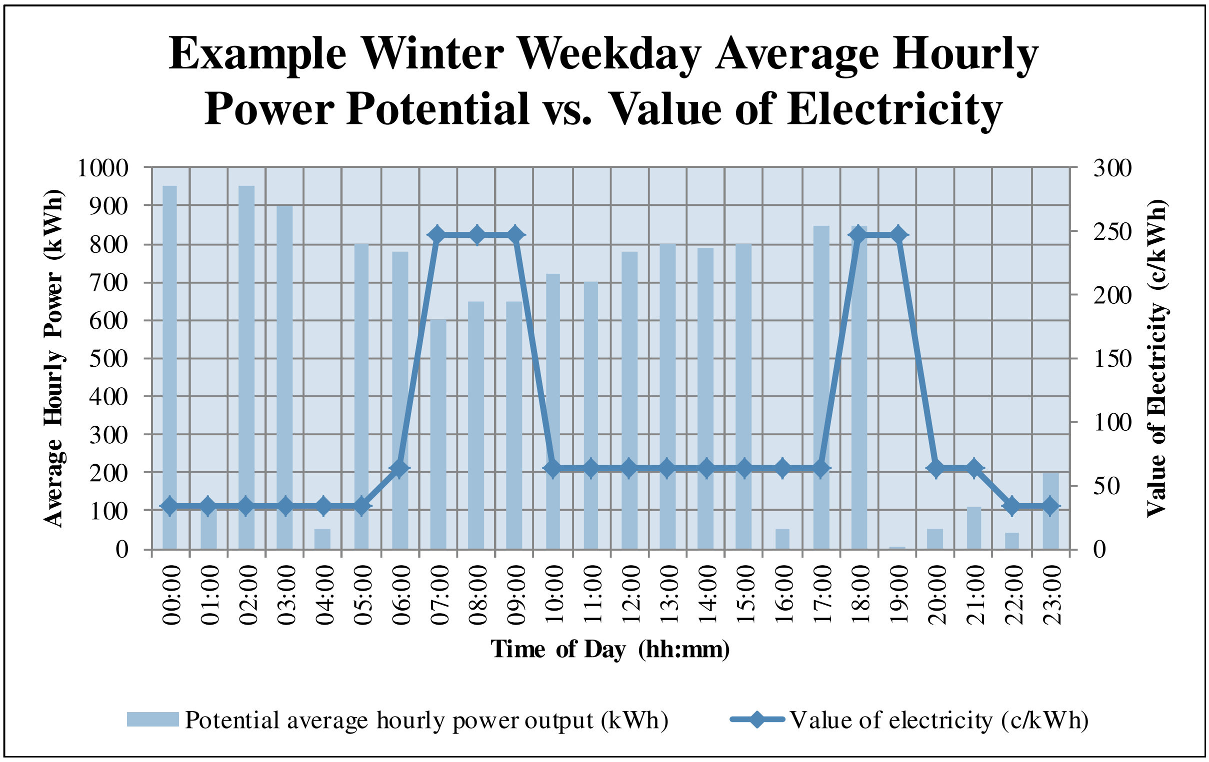

Figure 5-13: Garsfontein typical correlation between power potential and electricity tariffs

According to IMQS, the maximum future AADD at Garsfontein Reservoir will be approximately 176 000 kℓ/d, which is double the current AADD of 85 000 kℓ/day. For this analysis it was assumed that parallel pipes would be installed in future, so that the final conditions at the site would meet the future AADD, but with the same corresponding pressure heads. As this is only a rough estimate, future upgrades will not be allowed for in the economic analysis, but space will be provided in the turbine room for future expansion. If future conditions prove to be positive, an additional feasibility study for the expansion can be done in years to come. This can almost be seen as a separate project and will therefore not have an impact on the feasibility study of this project. Future conditions were also analysed and are presented in **Table 5-8**.

Table 5-8: Garsfontein Phase 3 potential analysis

<table>
<tr><th>DSS step</th><th colspan="2">Description</th><th>Value</th><th>Unit</th><th>Source</th></tr>
<tr><td></td><td colspan="2">Reservoir name</td><td>Garsfontein</td><td></td><td>IMQS</td></tr>
<tr><td rowspan="2">3</td><td rowspan="4">Measured and calculated values</td><td>Current design flow</td><td>0.780</td><td>m^3/s</td><td rowspan="4">CHD Tool</td></tr>
<tr><td>Pressure head</td><td>113.8</td><td>m</td></tr>
<tr><td rowspan="2">4</td><td>Power rating</td><td>727</td><td>kW</td></tr>
<tr><td>Annual energy potential</td><td>4 666.0</td><td>MWh/a</td></tr>
<tr><td rowspan="4">5 (4)</td><td rowspan="4">Estimated future values</td><td>Estimated future design flow</td><td>1.561</td><td>m^3/s</td><td>Described</td></tr>
<tr><td>Pressure head</td><td>113.8</td><td>m</td><td>(Conservative)</td></tr>
<tr><td>Power rating</td><td>1 455</td><td>kW</td><td rowspan="2">CHD Tool</td></tr>
<tr><td>Annual energy potential</td><td>9 307.3</td><td>MWh/a</td></tr>
<tr><td>6</td><td colspan="2">Required turbine range for current flow</td><td>700-730</td><td>kW</td><td>CHD Tool</td></tr>
<tr><td>7</td><td colspan="2">Selected turbine for current flow (Figure 5-14)</td><td>Gilkes Turgo</td><td></td><td>Product catalogue</td></tr>
<tr><td>8</td><td colspan="2">Turbine efficiency for current flow</td><td>83.5</td><td>%</td><td>Product catalogue</td></tr>
<tr><td>6</td><td colspan="2">Required turbine range for future flow</td><td>1 390-1 400</td><td>kW</td><td>CHD Tool</td></tr>
<tr><td>9</td><td colspan="2">Additional turbines for future flow</td><td>1 x Gilkes Turgo</td><td></td><td>Product catalogue</td></tr>
<tr><td>8</td><td colspan="2">Turbine efficiency for future flow</td><td>83.5</td><td>%</td><td>Product catalogue</td></tr>
<tr><td>10</td><td colspan="2">Electricity use</td><td>Grid</td><td></td><td></td></tr>
<tr><td>11</td><td colspan="2">Distance from grid connection</td><td>0.5</td><td>km</td><td>Measured</td></tr>
<tr><td>12</td><td colspan="2">Grid-connection requirements</td><td>Appendix A</td><td></td><td></td></tr>
<tr><td rowspan="2">14</td><td colspan="2">Do supply-and-demand patterns correlate?</td><td>N/A</td><td></td><td rowspan="2">N/A</td></tr>
<tr><td colspan="2">Is there sufficient demand?</td><td>N/A</td><td></td></tr>
</table>

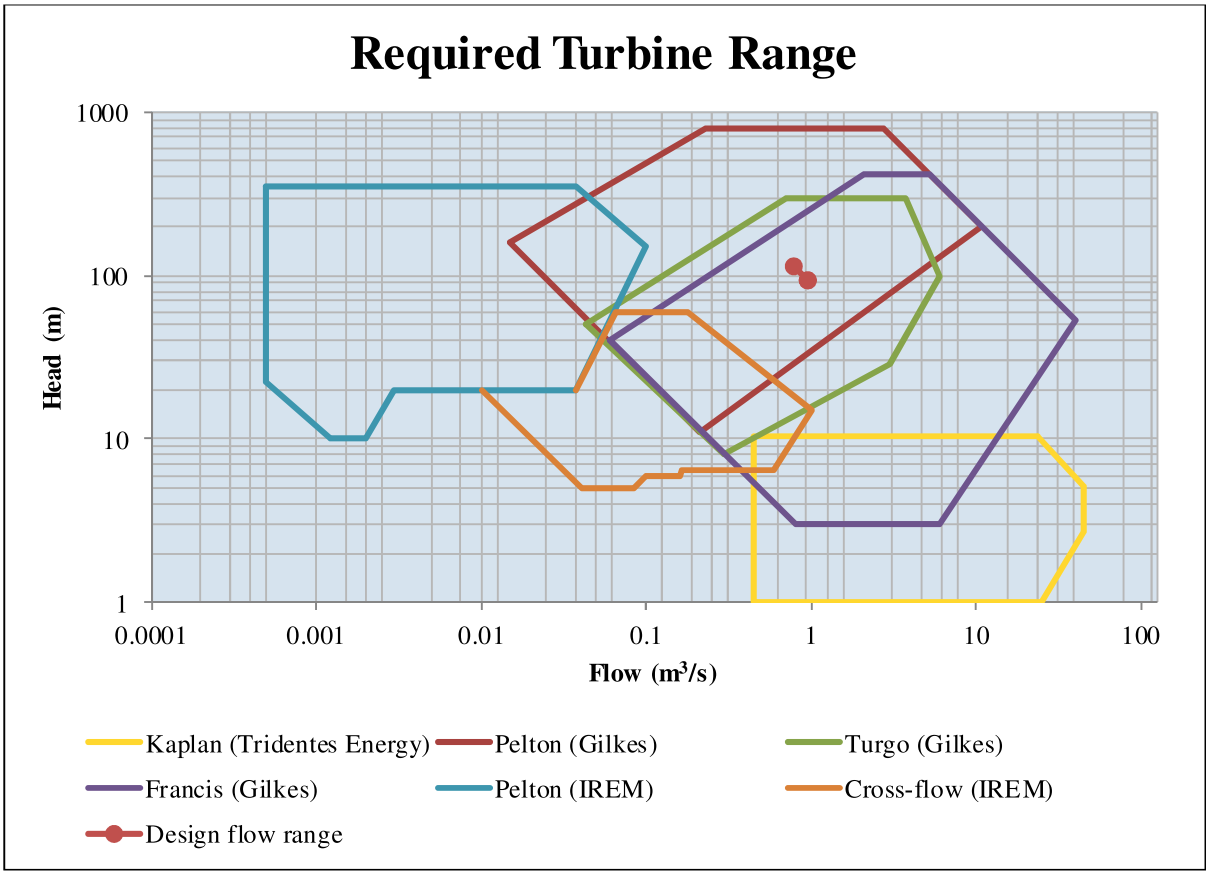

Figure 5-14: Garsfontein Phase 3 turbine selection

The next set of steps involved the detailed design of all the components of the conduit hydropower plant. Due to time constraints, a detailed design was not done for the Garsfontein development. However, a detailed design was done for the Pierre van Ryneveld development and is given in **Chapter 5.5.5**.

A detailed economic evaluation was conducted with obtained costs, where applicable. The results can be seen in **Table 5-9**. A sensitivity analysis was also conducted to determine the sensitivity of project feasibility when considering alternative inflation rates. The results of this analysis are summarised and presented in **Table 5-10**.

Table 5-9: Garsfontein Phase 3 economic analysis

DSS step		Description	Value	Unit	Source
	Reservoir name		Garsfontein		IMQS
4	Design values	Design flow	0.780	m^3/s	CHD Tool
		Pressure head	114	m	
		Power rating	727	kW	
		Annual energy potential	4 666	MWh/a	
6	Selected turbine		Gilkes Turgo		
19	Costs	Planning and design	1 200 000	R	Industry average
		Preliminary and general	1 300 000	R	
		Turbine	7 404 700	R	
		Other electrical and mechanical	1 100 000	R	
		Civil and construction	1 000 000	R	
		Transformer	400 000	R	
		Transmission	300 000	R	
		Contingencies	1 300 000	R	
		Disposal (present value)	0	R	
		Annual O&M (for year 1)	291 100	R	
	Annual income (for year 1)		2 706 300	R	
	Design life		15	years	Decided
	Total initial cost (planning and capital)		16 724 700	R	CHD Tool
	NPV of costs		20 617 800	R	
	NPV of income		49 185 600	R	
	Total NPV		28 567 800	R	
	Internal rate of return		22.14	%	

Step 21 of the CHDSS concerns funding of the project. This project has a projected capital expenditure of just over R16 700 000. At the time of writing, the municipality was considering paying for the project out of own funds, as renewable energy is currently a focus point in both the city and the country. It should be noted that CoT is a major city with a large budget. Smaller municipalities may have trouble financing a project of this magnitude out of own funds and will have to explore alternative funding options, as discussed in **Chapter 4.3.6.**

A sensitivity analysis was done to determine the impact of different future inflation rates. The results are shown in **Figure 5-15**, **Figure 5-16** and **Table 5-10**. It is clear that the current uncertainty about future changes in the value of electricity is likely to cause a more significant impact on the net present value (NPV) of the project than operation and maintenance inflation, with an NPV of between R33 700 000 for high average electricity tariff inflation (12% after 2017) and R20 400 000 for low average electricity tariff inflation (6% after 2017). The expected NPV is R28 600 000, as determined in the economic analysis. The internal rate of return (IRR) of the project was found to have a range of between 19.53% (for low electricity inflation) and 23.47% (for high electricity inflation).

It can therefore be assumed that this project should be feasible even if inflation rates are not as expected.

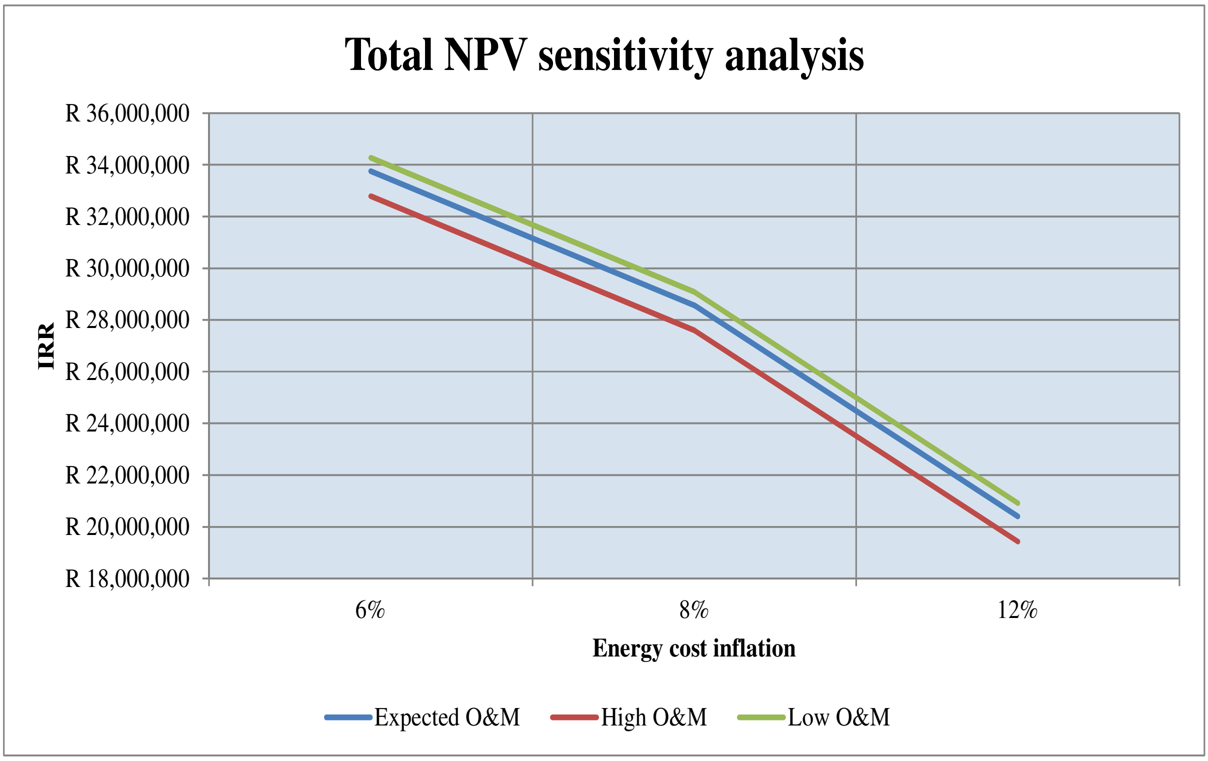

Figure 5-15: Garsfontein Phase 3 NPV sensitivity analysis

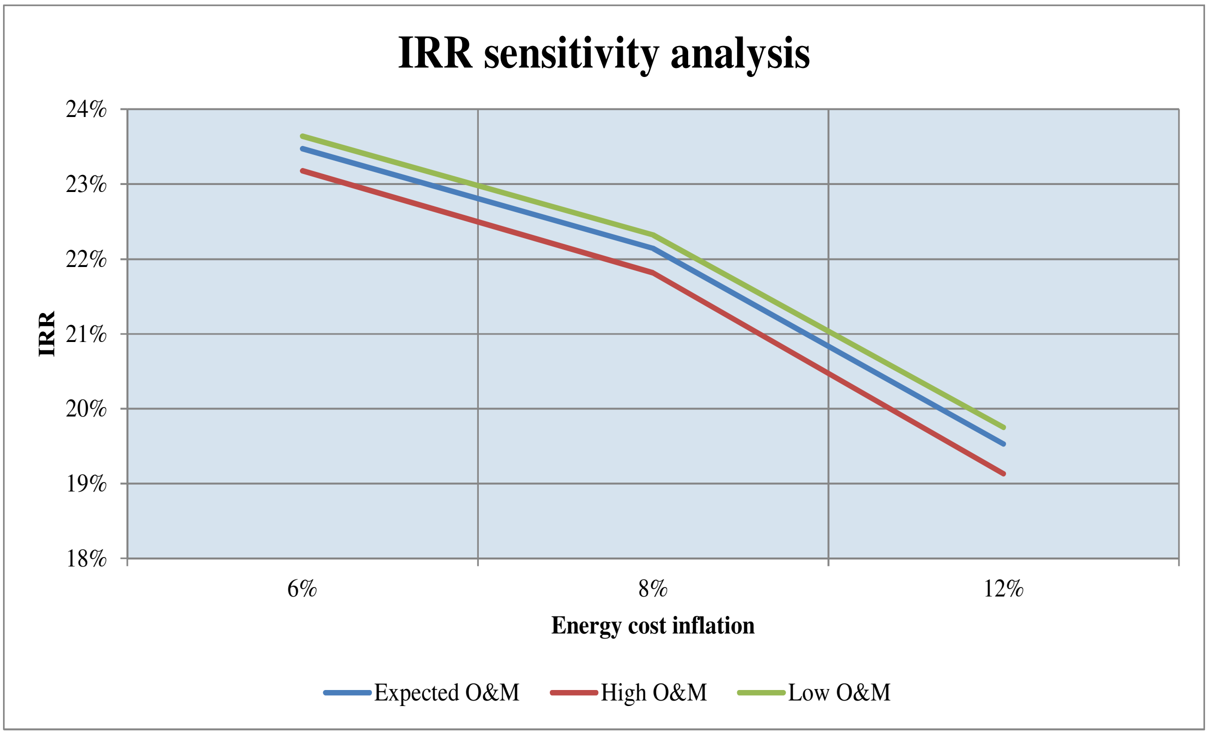

Figure 5-16: Garsfontein Phase 3 IRR sensitivity analysis

Table 5-10: Garsfontein Phase 3 sensitivity analysis summary

DSS step			Electricity inflation		
			High (12%)	Expected (8%)	Low (6%)
22	IRR				
	Operation and maintenance inflation	Expected (6%)	23.47%	22.14%	19.53%
		High (9%)	23.18%	21.81%	19.13%
		Low (4%)	23.64%	22.32%	19.75%
	NPV				
	Operation and maintenance inflation	Expected (6%)	R 33,749,528	R 28,567,728	R 20,398,293
		High (9%)	R 32,784,812	R 27,603,012	R 19,433,576
		Low (4%)	R 34,271,603	R 29,089,804	R 20,920,368

5.4.6 DISCUSSION OF RESULTS

The analysis of hydropower at the Garsfontein Reservoir showed that there is economically exploitable potential at this site, with an expected NPV of R44 000 000 and an IRR of 28%. It is proposed that a 730 kW grid-connected Gilkes Turgo turbine (**Figure 5-17**) be installed for current use, with space allowed for duplication of the capacity for future extension.

This is a bulk reservoir in the water-distribution network to a significant portion of the eastern parts of the City of Tshwane. Therefore, operational changes to increase hydropower were not made, as water-supply reliability is the primary concern.

Another option that may be considered is to use a pump-as-turbine installation, as this installation would not have to be positioned on the reservoir roof and would therefore require a smaller capital investment. Another advantage of a pump-as-turbine would be that maintenance staff would be more familiar with the equipment.

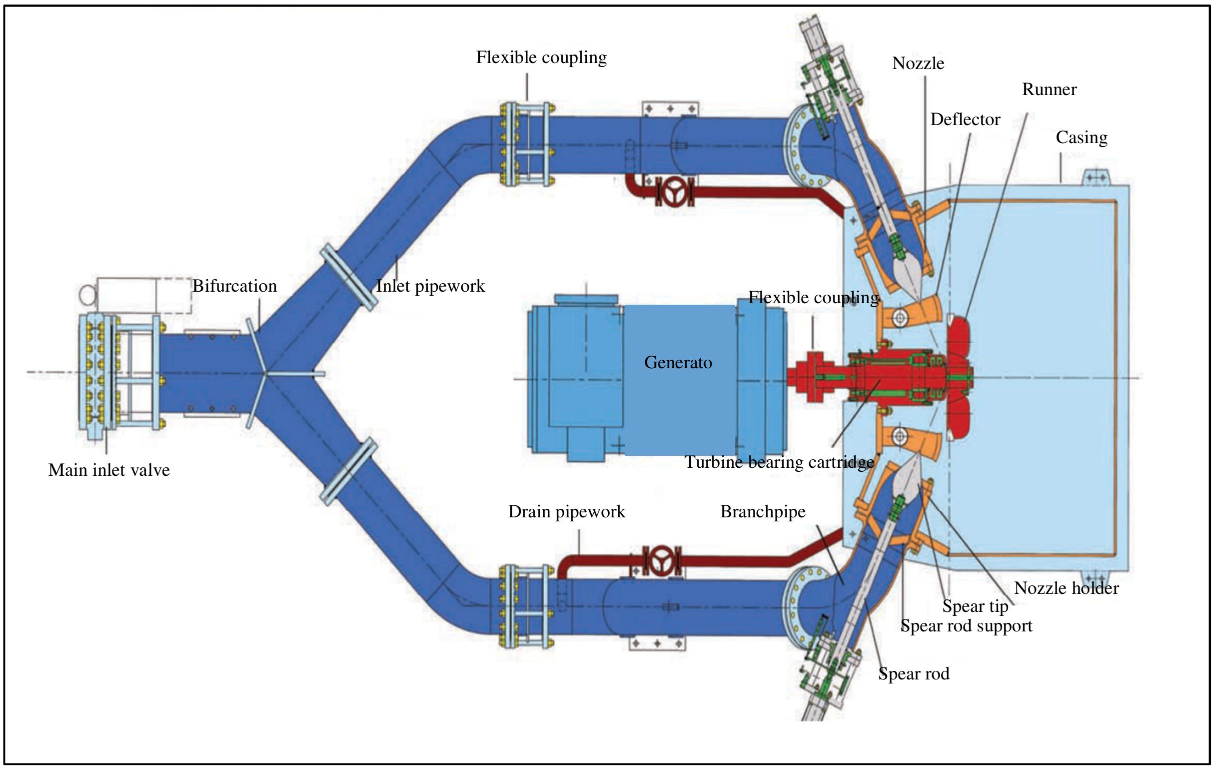

Figure 5-17: Typical Gilkes Turgo layout (Gilkes, 2012)

5.5 CASE STUDY 2: PIERRE VAN RYNEVELD RESERVOIR

5.5.1 LOCATION

The Pierre van Ryneveld Reservoir consists of two structures that are located in the Country Lane Estate in Rietvalleirand, City of Tshwane, as can be seen in **Figure 5-18**. The GPS coordinates are 25°51'8.50"S and 28°15'26.09"E and the base of the reservoir is situated at an elevation of 1 559 m amsl.

There is a booster pump station on the western side of the R21 that is used occasionally during summer when demand is exceptionally high (this pump station will become redundant when new pipelines are completed and the pressure of the off-take from the Rand Water pipeline increases). This site also houses a series of PRVs that are used under normal flow conditions.

Figure 5-18: Location of Pierre van Ryneveld Reservoir (Google Earth, 2012)

5.5.2 SITE DESCRIPTION

As is the case in much of the City of Tshwane, water to the Pierre van Ryneveld Reservoir is supplied by Rand Water. It gravitates from a higher altitude in Johannesburg to a lower elevation in Tshwane. The reservoir supplies potable water to the Pierre van Ryneveld suburb in Centurion. **Figure 5-19** shows the reservoir's water-distribution zone. The site currently consists of two structures; both were built using post-tensioned reinforced concrete. The older structure has a capacity of 7 600 m^3 and the newer structure has a capacity of 15 000 m^3. The flow meter and pressure gauges were installed at the PRSs located at the pump station site west of the R21, as indicated in **Figure 5-18**.

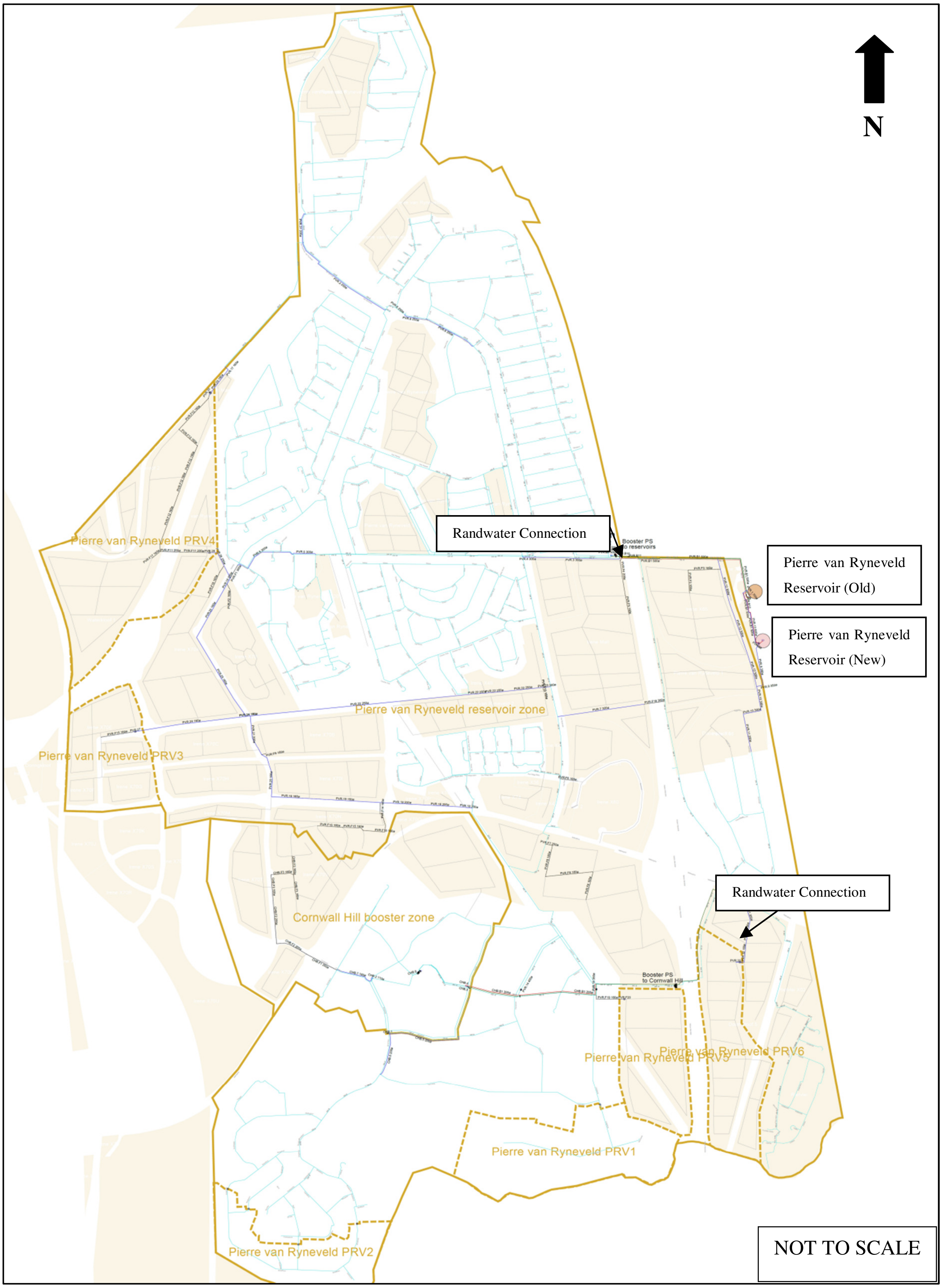

Figure 5-19: Pierre van Ryneveld Reservoir water-distribution zone (IMQS)

5.5.3 PHASE 1 ANALYSIS AND RESULTS

The information used in the Phase 1 study was obtained from The City of Tshwane Metropolitan Municipality's IMQS (Infrastructure Management Query Station) database. The relevant information can be seen in **Table 5-11**. This information was entered into the CHD Tool for Phase 1, with default values as indicated in **Appendix C** and the output is also shown in **Table 5-11**.

Suitable future flow rates and pressure heads for hydropower generation cannot be guaranteed at this site for future scenarios. Therefore a short design life of 15 years was selected, to determine economic feasibility if future conditions do not suit hydropower. It was argued that the turbine may be moved to another location if conditions become unsuitable.

With an IRR of 1% and a negative NPV, the Phase 1 analysis indicated that a full feasibility study should not be undertaken, unless another reason exists for considering conduit hydropower (CHDSS Step 11). The City of Tshwane is currently committed to developing more renewable energy sources and political reasons can therefore be given for continuing with subsequent phases. It may also be that operational changes can have a positive impact on the economic feasibility of a project. As this might be the case at Pierre van Ryneveld, a Phase 2 analysis was done.

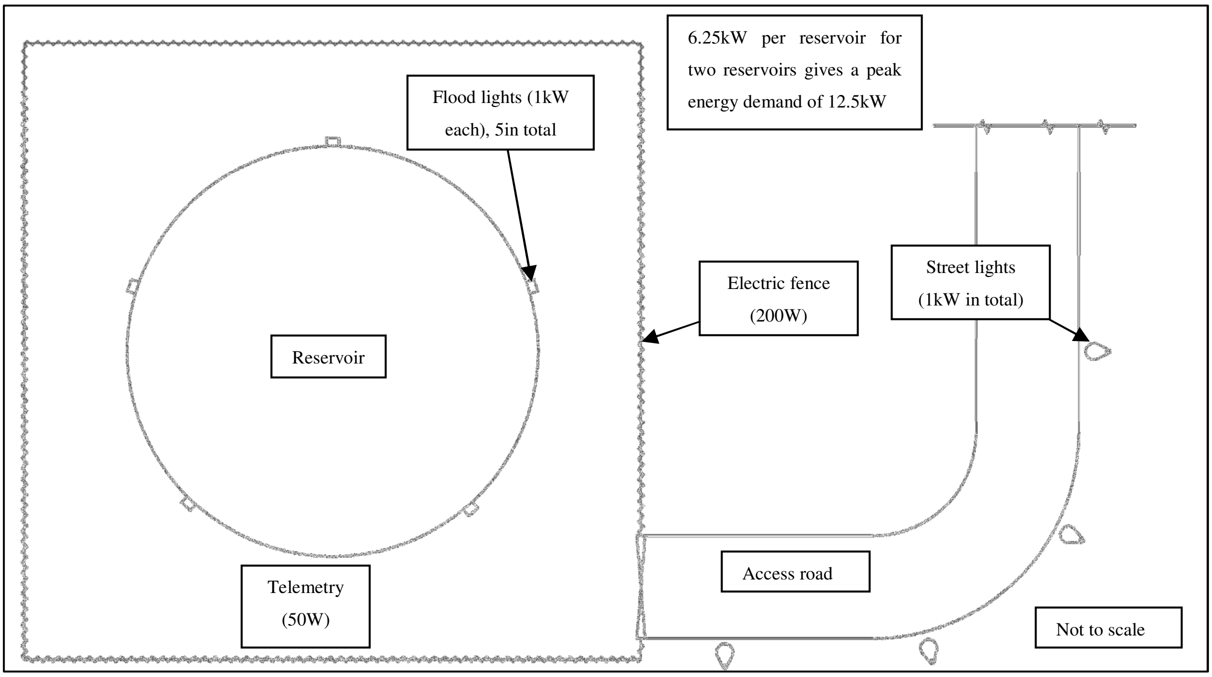

Figure 5-20: Schematic layout of on-site electricity use at Pierre van Ryneveld Reservoir

Table 5-11: Pierre van Ryneveld Phase 1 analysis summary

DSS step	Description	Value	Unit	Source
	Reservoir name	Pierre van Ryneveld		IMQS
3	Owner of infrastructure	City of Tshwane		
4	Present average annual daily demand	7 123	kℓ/d	IMQS
	Future average annual daily demand	25 961	kℓ/d	
	Average flow	0.082	m^3/s	CHD Tool
	Static head (used head)	40 (24)	m	IMQS
5	Theoretically available power	13.6	kW	CHD Tool
6	Potential use	On-site		Decided
7	Distance to grid	N/A	km	
8	On-site peak energy demand	12.5	kW	**Figure 5-20**
9	Average power/max demand	109	%	
10	Design life	15	Years	CHD Tool
	Estimated cost of plant (based on on-site peak energy demand)	856 900	Rand	
	NPV of costs	848 500	Rand	
	NPV of income	723 900	Rand	
	NPV	-124 600	Rand	
	IRR	4	%	
	Payback period	16	years	
	Economically feasible?	NO		
11	Consider next phase?	YES		Other reasons

Although this phase did not indicate economic feasibility, operational changes to the system may have a positive impact on the viability of the project (CHDSS Step 11).

5.5.4 PHASE 2 ANALYSIS AND RESULTS

The first phase hydropower potential analysis did not indicate economic feasibility. However, a Phase 2 analysis was performed, because operational changes may have a positive impact on the power potential and economic feasibility of the project (CHDSS Step 1). (A conduit hydropower plant has already been installed here as a pilot project (**Figure 5-21**), because CoT was in the process of constructing a second reservoir on the site and therefore had a construction team to build a valve chamber and install the necessary pipework.)

To complete the CHDSS Step 2, it was necessary to visit the site and assess the practicability of a hydropower plant there. Considered aspects included: space for the hydropower plant; safety of the turbine and other equipment from theft or vandalism; noise impact on the surroundings; and accessibility to the site during construction.

Figure 5-21: Existing Pierre van Ryneveld Reservoir hydropower installation

Table 5-12: Pierre van Ryneveld Phase 2 site analysis summary

DSS step	Practicability aspect	Discussion	Conclusion
2	Available space	This site already has a pico unit installed on the reservoir roof, as shown in **Figure 5-21**, therefore it has already been confirmed that enough space exists at this site.	Sufficient space exists on site
	Safety	The site is located within the boundaries of the Country Lane Estate, which has electric fencing and 24 hour security.	Sufficient security is present
	Noise impact	As this reservoir is located within the boundaries of a residential estate, the impact of noise may be disturbing if a large turbine is installed. However, due to the anticipated size of the turbine, noise should be minimal	Noise impact will be sufficiently low
	Accessibility of site	As shown in **Figure 5-18**, the site is located close to the R21 Nellmapius off-ramp. Access to the site by construction vehicles may be achieved by using the service gate to the south of the reservoir.	Easy accessibility

As the practicability of this site had been established, measuring instrumentation was installed to measure flow and pressure in the system, as recommended in CHDSS Step 3 of Phase 2. Flow and pressure data were collected at the PRS next to the booster pump station to the west of the R21, as indicated in **Figure 5-18**. Data loggers were installed as shown in **Figure 5-22** and **Figure 5-23**.

Figure 5-22: Pressure measurement at Pierre van Ryneveld pressure-reducing station

Figure 5-23: Flow measurement at Pierre van Ryneveld Reservoir

Gaps in measured data occurred at various times. **Figure 5-24** shows the unedited measured data for flow rates, as well as upstream and downstream pressures. A major gap in flow data was experienced between June and September. This was due to the installation of new pipes and the construction of a new valve chamber on site. Various minor gaps exist in the pressure data. The reason for the gaps is possibly a communication error between the modem on site and the server where information is stored. These gaps were removed before continuing with the analysis.

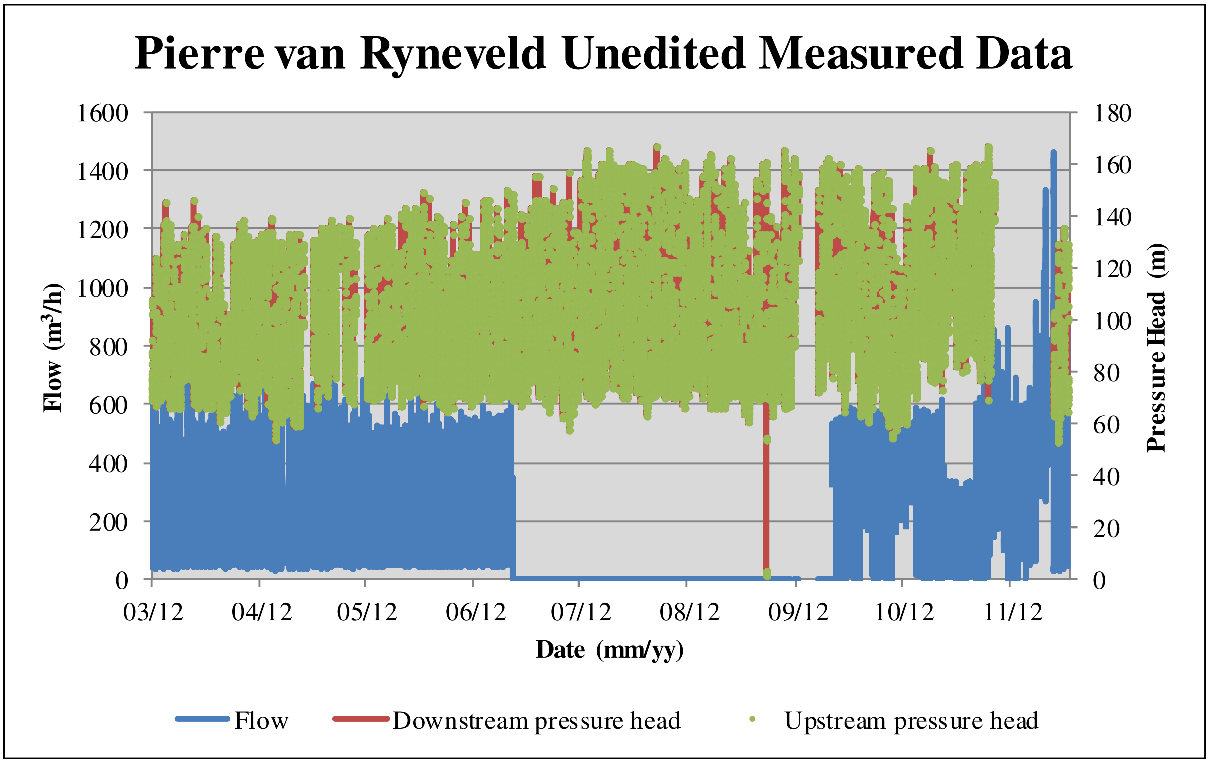

Figure 5-24: Pierre van Ryneveld unedited measured data

The obtained data set was entered into Phase 2 of the CHD Tool to analyse the records (as per CHDSS Step 4 of Phase 2) and to populate **Table 5-13**. **Figure 5-25** and **Figure 5-26** were also generated using the CHD Tool.

Table 5-13: Pierre van Ryneveld Phase 2 potential analysis (original)

DSS step	Description		Value	Unit	Source
	Reservoir name		Pierre van Ryneveld		IMQS
4	Measured and calculated values	Optimum flow	0.082	m^3/s	Measured
		Pressure head	41.9	m	
		Power rating	23.7	kW	CHD Tool
		Annual energy	123.1	MWh/a	
	Assurance of supply (% of time) (**Figure 5-25**)		95	%	Decided
	Initial Design values	Design flow	0.003	m^3/s	CHD Tool
		Pressure head	79.8	m	
		Power rating	1.5	kW	
		Annual energy	12.5	MWh/a	
5	What operational changes could be considered?		The reservoir feeds one distribution zone, so consider constant flow		
4	Design values after operational change	Design flow	0.067	m^3/s	
		Pressure head	50.4	m	
		Power rating	23.1	kW	
		Annual energy	198.3	MWh/a	
7	Selected turbine (**Figure 5-26**)		Cross-flow		
8	Electricity use		On-site		Decided
9	Distance from grid connection		N/A	km	Decided
10	On-site power demand		12.5	kW	**Figure 5-20**
	Power rating/max demand		185	%	

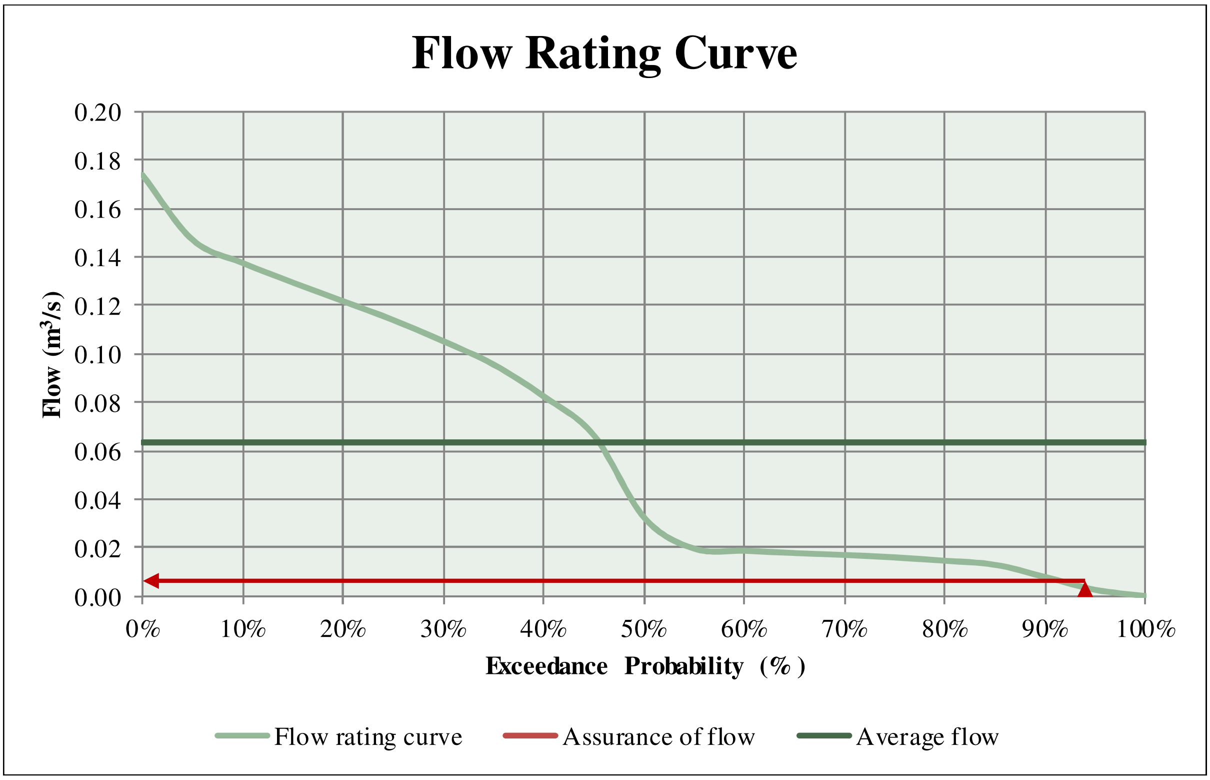

Figure 5-25: Pierre van Ryneveld Phase 2 flow-rating curve

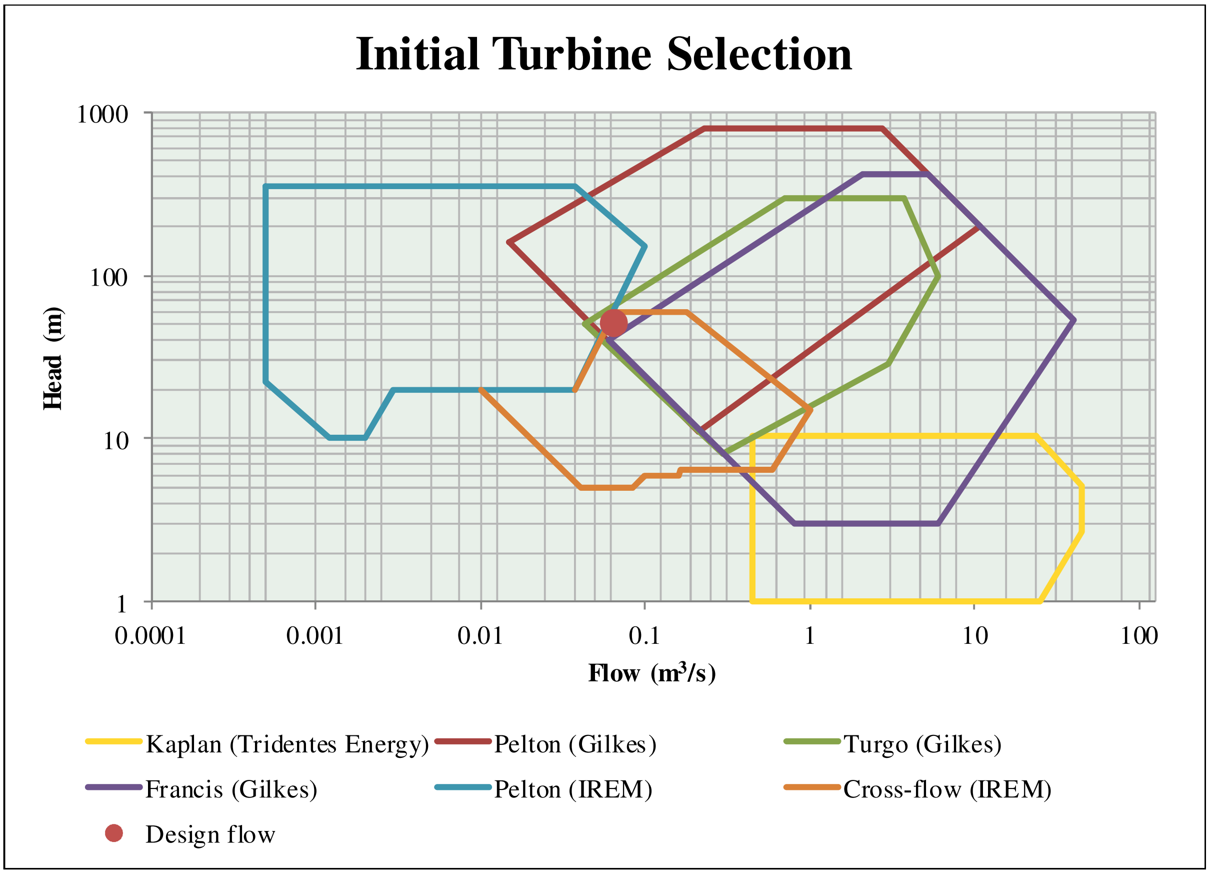

Figure 5-26: Pierre van Ryneveld Phase 2 initial turbine-selection curve (original)

From **Table 5-13**, it is clear that the power potential exceeds the energy requirements if operational changes are made to the system to allow a more constant flow rate into the reservoir. Therefore, the future development of the reservoir distribution zone was not considered in detail, as per CHDSS Step 6. It should be noted, however, that future conditions at the reservoir are uncertain. Future total flow rates will increase as development increases, but it is not clear whether parallel pipes will be installed or not to ensure a similar pressure head. Therefore a design life of 15 years was used for the site, assuming constant flow and pressure. If the project is economically feasible for the short design life and conditions remain favourable, the project will only become more profitable. If conditions change significantly, the turbine can be moved to another location after decommissioning.

The use of a smaller turbine was, however, considered, as the power potential exceeds the energy requirements if operational changes are made to the system to allow a more constant flow rate into the reservoir (**Table 5-13**). A lower flow rate was used to populate **Table 5-14**, **Figure 5-27** and **Figure 5-28**.

Table 5-14: Pierre van Ryneveld Phase 2 potential analysis (final)

DSS step		Description	Value	Unit	Source
		Reservoir name	Pierre van Ryneveld		IMQS
		Assurance of supply (% of time)	95	%	Decided
	Final design values	Design flow	0.037	m^3/s	CHD Tool
		Pressure head	50.4	m	
		Power rating (**Figure 5-27**)	12.8	kW	
		Annual energy (**Figure 5-27**)	110.0	MWh/a	
7		Selected turbine (**Figure 5-28**)	Pelton		
8		Electricity use	On-site		
9		Distance from grid connection	N/A	km	Decided
10		On-site power demand	12.5	kW	**Figure 5-20**
		Power rating/ max demand	102	%	CHD Tool

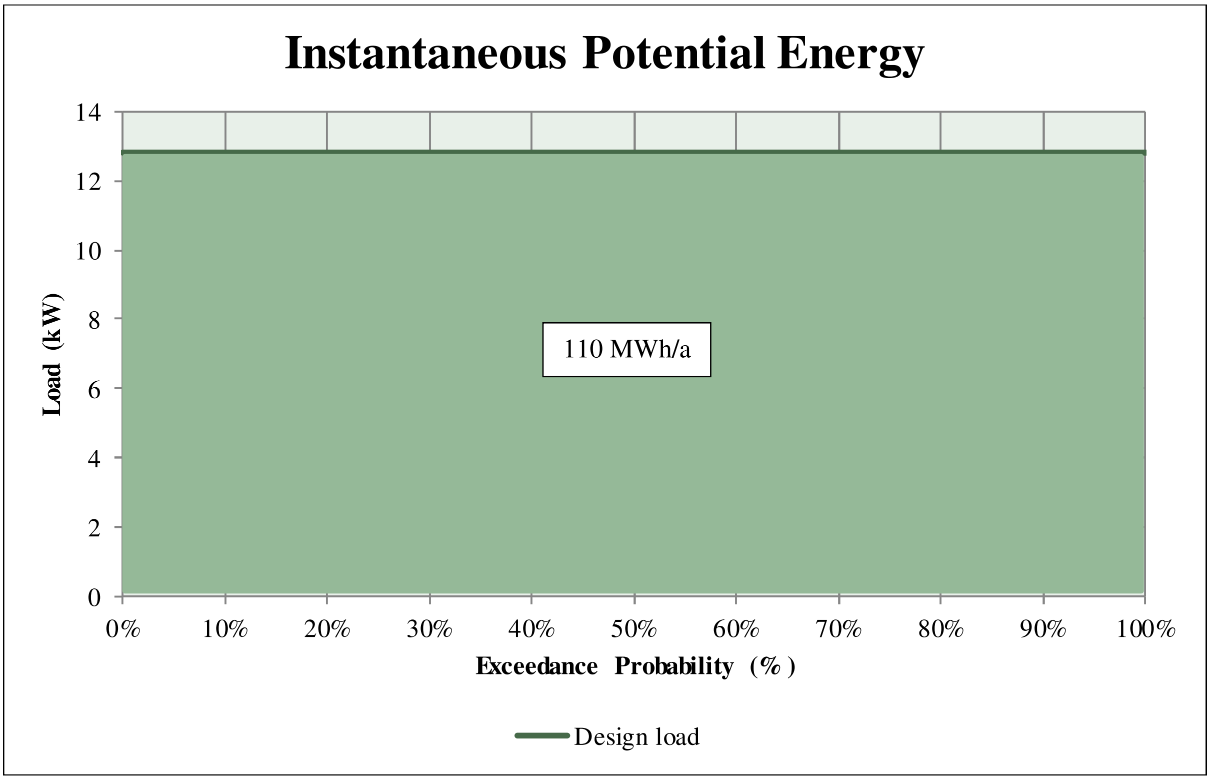

Figure 5-27: Pierre van Ryneveld Phase 2 instantaneous potential energy

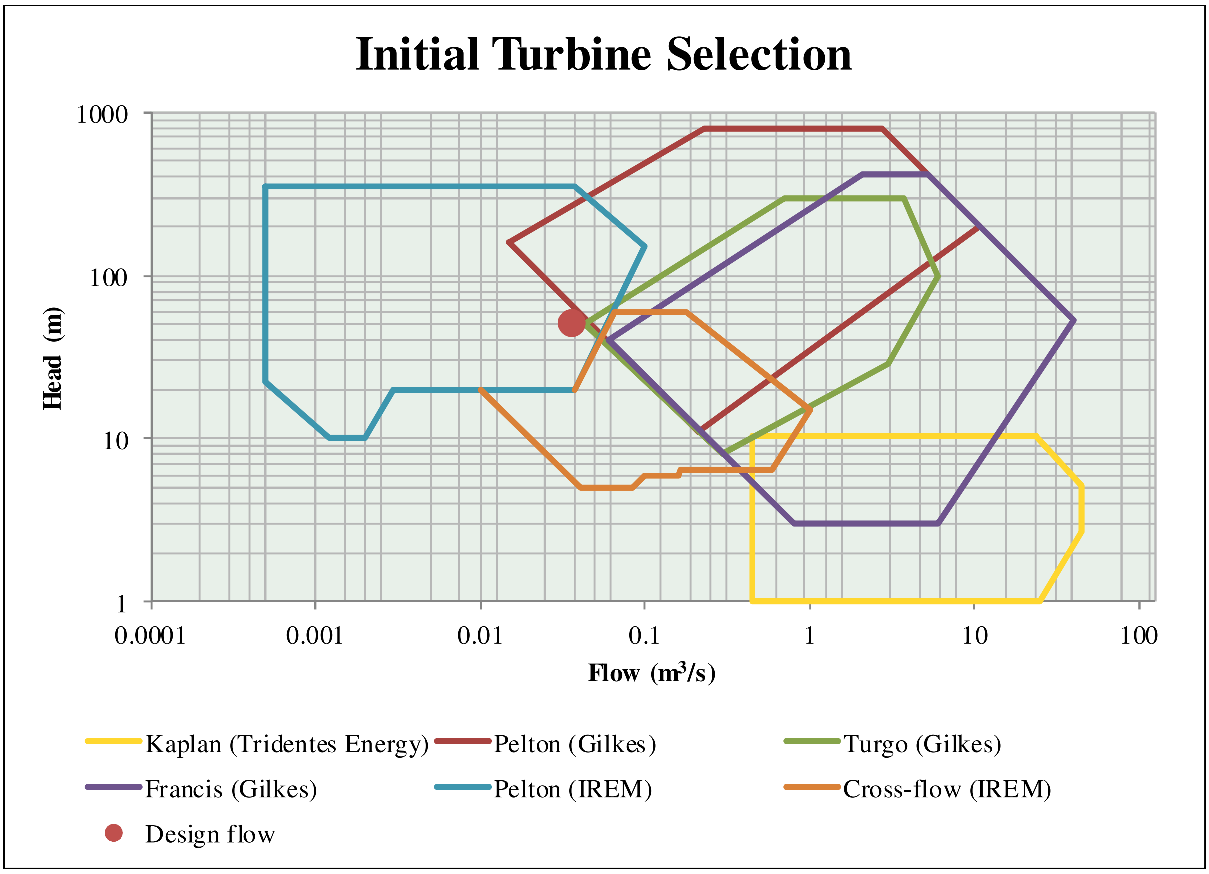

Figure 5-28: Pierre van Ryneveld Phase 2 initial turbine-selection curve (final)

CHDSS Steps 11-14 deal with regulatory requirements. These steps are summarised in **Table 5-15**.

Table 5-15: Pierre van Ryneveld Phase 2 regulatory analysis

DSS step	Regulatory aspect	Discussion	Conclusion
11	Environmental studies	All power plant and construction areas are smaller than the minimum sizes for which environmental studies are required, according to the National Environmental Management Act (Act 107 of 1998) (refer to **Table 2-10**)	Neither BA nor EIA required
12	NERSA licence	As the generated electricity will be used for lighting and electric fencing on site, this can be classified as 'own use' and is therefore exempt from NERSA licensing (Energy Regulation Act (Act 4 of 2006)	Generation licence not required
13	Water-use licence	Water-use licensing is not needed, as this project can be seen as a continuation of an existing lawful use under Tshwane's water-use licence (National Water Act (Act 36 of 1998)).	Not required
14	Social requirements	A public participation process (PPP) would have to be followed wherein a notice board, meeting the requirements set in Government Notice 543 of 18 June 2010, is displayed on the boundary fence. If complaints are received, public hearings should be held.	PPP required

The next step was to perform an economic evaluation for Phase 2. The CHD Tool was used, with default values and cost functions as discussed in **Appendix C**. **Table 5-16** was populated with the input and calculated values.

Table 5-16: Pierre van Ryneveld Phase 2 economic analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Pierre van Ryneveld		IMQS
4	Design values	Design flow	0.037	m^3/s	Measured
		Pressure head	50.4	m	
		Power rating	12.8	kW	CHD Tool
		Annual energy potential	110	MWh/a	
7	Selected turbine		Pelton		
15	Planning cost per MW		1 350 000	R	Industry average
	Planning cost for this site		17 300	R	CHD Tool
	Turbine cost		389 200		
	Capital cost per MW (excluding turbine)		13 300 000	R	Industry average
	Total capital cost for this site (including turbine)		559 500	R	CHD Tool
	Annual operation and maintenance cost (for year 1)		12 400	R	
	Annual income (for year 1)		63 800	R	
	Design life		15	years	Decided
	NPV of costs		741 900	R	CHD Tool
	NPV of income		1 159 800	R	
	Total NPV		418 000	R	
	Internal rate of return		13.92	%	

With operational changes (as discussed in **Table 5-13**) and the use of a correctly sized turbine (as discussed in **Table 5-14**), a positive NPV and an IRR of around 14% was calculated, which made the project economically feasible. The major contributing factor in the IRR and NPV increases between Phase 1 and Phase 2 is the fact that operational changes will produce a better load factor on the plant.

So, instead of generating 60 MWh/a (with a load factor of 60% in Phase 1), 110 MWh/a (with a load factor of 95% in Phase 2) is now possible. A Phase 3 detailed design analysis was therefore performed.

5.5.5 PHASE 3 ANALYSIS AND RESULTS

The Phase 2 economic analysis indicated financial feasibility. Therefore the Phase 3 analysis and detailed design was completed. The first step in this phase was to obtain historical flow and pressure records. Longer historical records (of a year or more) would be useful, as they would improve accuracy. However, as longer records were not available for this site, the same measured flow and pressure records were used as in Phase 2, for Step 2 of Phase 3.

The third step of this phase was to consider the effect of system optimisation. **Figure 5-29** shows the flow rates and corresponding pressures during a representative week in October 2012. From this figure it is clear that flow in the pipe is normally open until the reservoir is full, at which stage the flow in the pipe becomes almost zero. As the Pierre van Ryneveld Reservoir serves only a single water-distribution zone (as shown in **Figure 5-19**), the operational philosophy of this reservoir can be adjusted easily to obtain a more constant flow. This will in turn provide the opportunity for more constant energy generation, as determined in **Table 5-17**. It should be noted that CHDSS Step 9 was not followed at this site, as the future circumstances at the reservoir are not certain. This site is therefore only evaluated for a 15-year design life, with no increase in flow or pressure.

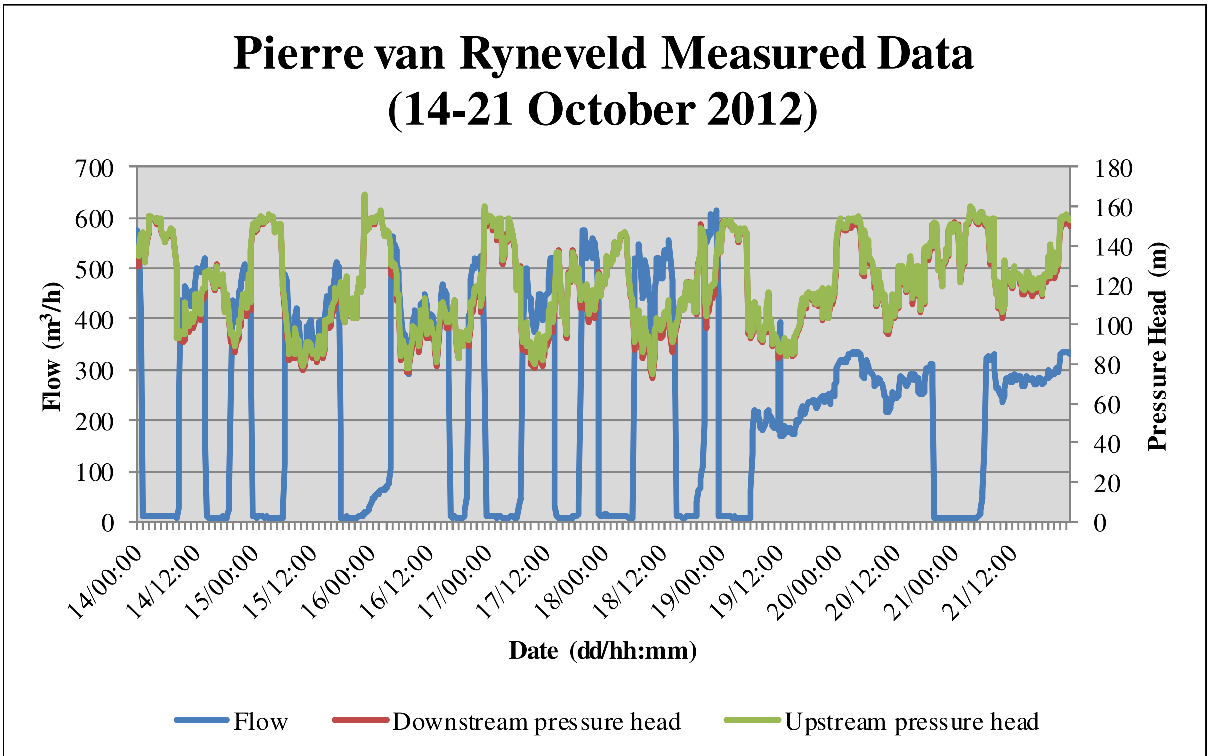

Figure 5-29: Pierre van Ryneveld measured data for a typical week

Table 5-17: Pierre van Ryneveld Phase 3 potential analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Pierre van Ryneveld		IMQS
3	Measured and calculated values	Average current flow	0.067	m^3/s	CHD Tool
3	Measured and calculated values	Pressure head	50.4	m	CHD Tool
4	Measured and calculated values	Power rating	26.4	kW	CHD Tool
4	Measured and calculated values	Annual energy potential	226.7	MWh/a	CHD Tool
4	Assurance of supply (% of time)		98	%	Decided
6	Required turbine range for current flow		21-27	kW	CHD Tool
7	Selected turbine for current flow		IREM Pelton		Product catalogue
8	Turbine efficiency for current flow		78%		Product catalogue
10	Electricity use		On-site		
11	Distance from grid connection		N/A	km	Decided
13	Demand patterns		**Figure 5-30**	kW	CHD Tool
14	Do supply-and-demand patterns correlate?		Supply is higher than peak demand		CHD Tool
14	Is there sufficient demand for the installation size?		No		
6	Required turbine size for demand?		12.5	kW	**Figure 5-30**
4	Final design	Flow	0.041	m^3/s	CHD Tool
4	Final design	Pressure head	50.4	m	
7	Selected turbine (**Figure 5-31**)		BHG Cross-flow		Easily obtainable
8	Turbine efficiency		75%		Supplier information

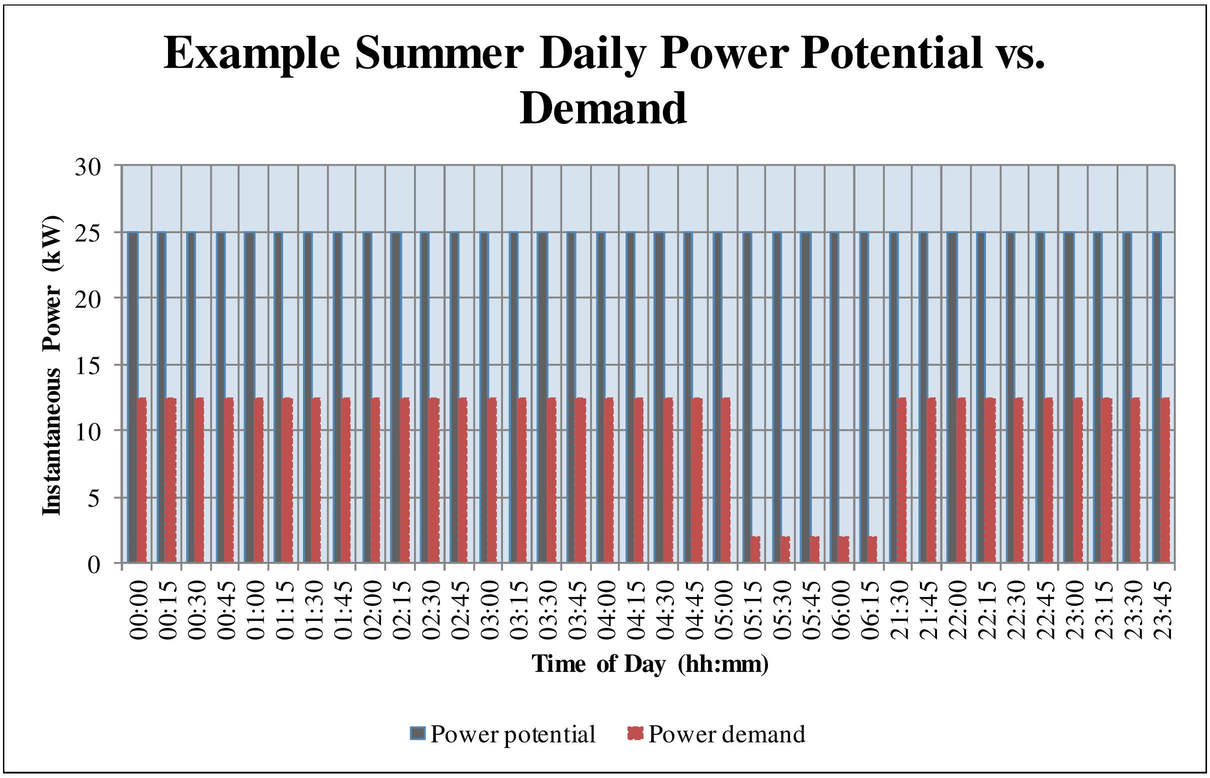

Figure 5-30: Pierre van Ryneveld Phase 3 example power potential vs. power demand

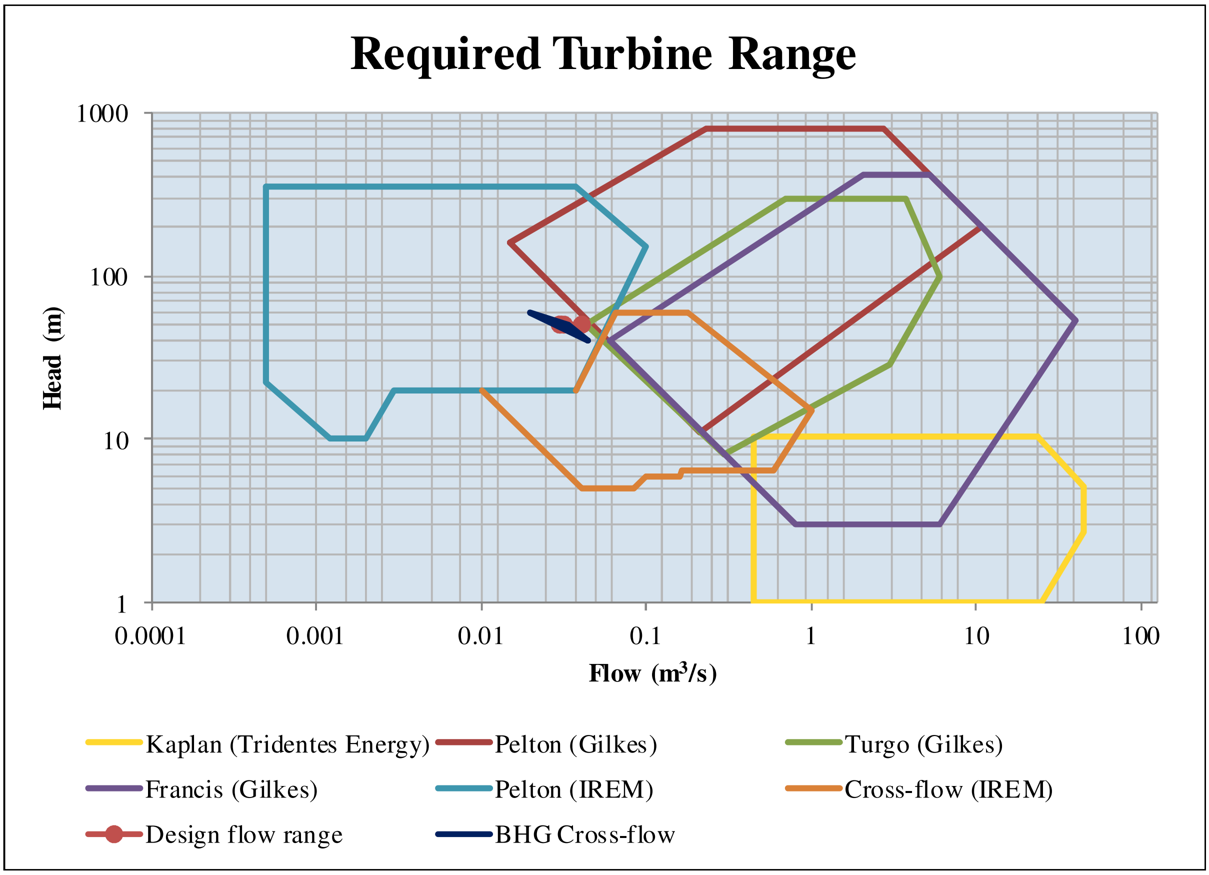

Figure 5-31: Pierre van Ryneveld Phase 3 turbine selection

The next set of steps involved the detailed design of all the components of the conduit hydropower plant. **Table 5-18** to **Table 5-22** provide a summary of the procedure, with references to drawings, photos and other relevant information.

Table 5-18: Pierre van Ryneveld Phase 3 electrical and mechanical design summary

DSS step	Design component	Discussion
15	Electrical and mechanical	A cross-flow turbine (**Figure 5-32**) was selected as it is a low-speed impulse turbine that works best with lower head and higher flow. These turbines have the advantage that water passes through the runner twice, thereby keeping the runner clean from debris. It also has a simple construction and easy maintenance, with only two bearings and three rotating elements. A summary of the technical details is provided in **Table 5-19**. A synchronous generator was selected, because the electricity will be used on-site and not fed into the grid. A summary of the technical details is provided in **Table 5-19**. The belt drive between the turbine and generator is a flat belt of polyamide synthetic material with a leather coating. A load control governor was not used for this turbine. Instead a ballast tank with heating elements to consume excess energy was designed. An emergency bypass (using a pinch valve upstream of the turbine) was also designed to divert flow and pressure away from the turbine in case of a power failure (**Figure 5-38**).

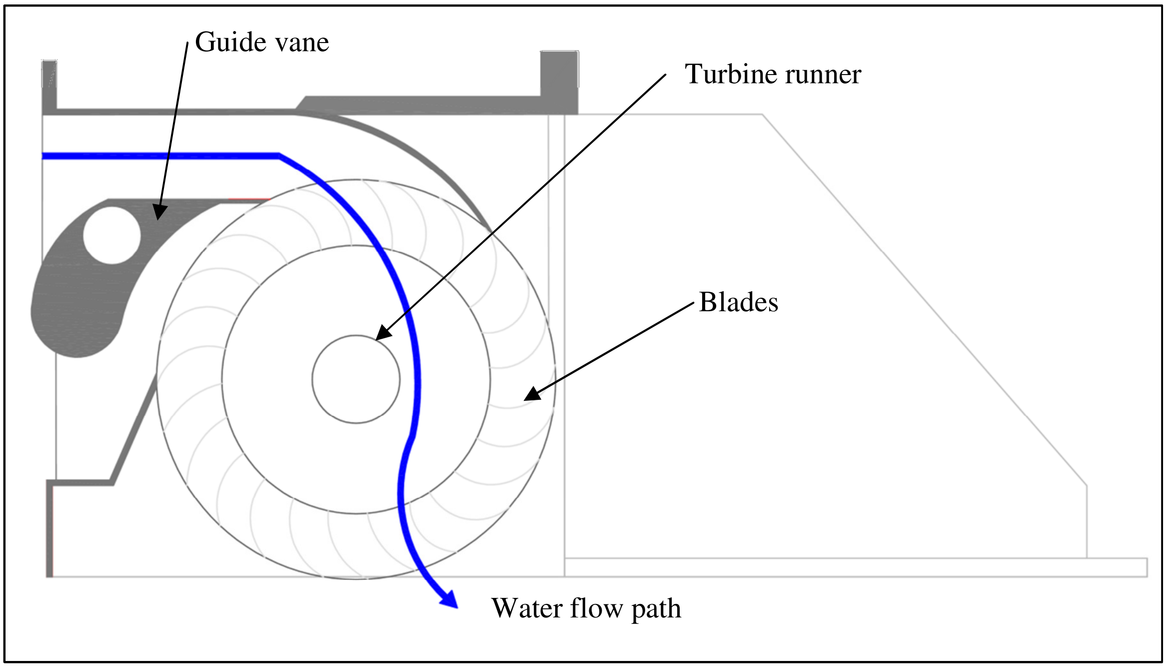

Figure 5-32: Cross-flow turbine

Table 5-19: Pierre van Ryneveld turbine technical details

Description	Normal condition
Rotor diameter	241.9 mm
Rotor length	170 mm
Net operating head	16.7 m
Turbine speed	642 r/min
Generator power	14.9 kW

Table 5-20: Pierre van Ryneveld generator technical details

Description	Normal condition
Generator type	Synchronous
Phasing	3-phase
Frequency	50 Hertz
Generator speed	1 500 r/min
Generator rating	17 kVA, 380/220 Volt

Table 5-21: Pierre van Ryneveld Phase 3 civil design summary

DSS step	Design component	Discussion
16	Civil works	An off-take pipe and connections, as shown in **Figure 5-33**, were designed. The off-take was placed upstream of the existing reservoir PRV and the design of the pipe leading to the turbine on top of the reservoir allowed for fastening to the reservoir wall (**Figure 5-34** shows the pipework under construction). The off-take was enclosed in a valve chamber (**Figure 5-35** shows the completed off-take with control valve and flow meter). To prevent damage to the reservoir roof, steel beams spanning between reservoir columns were designed as an anchor for the turbine (**Figure 5-36**). A steel frame with chromadek cladding was used for the turbine enclosure (**Figure 5-37**).

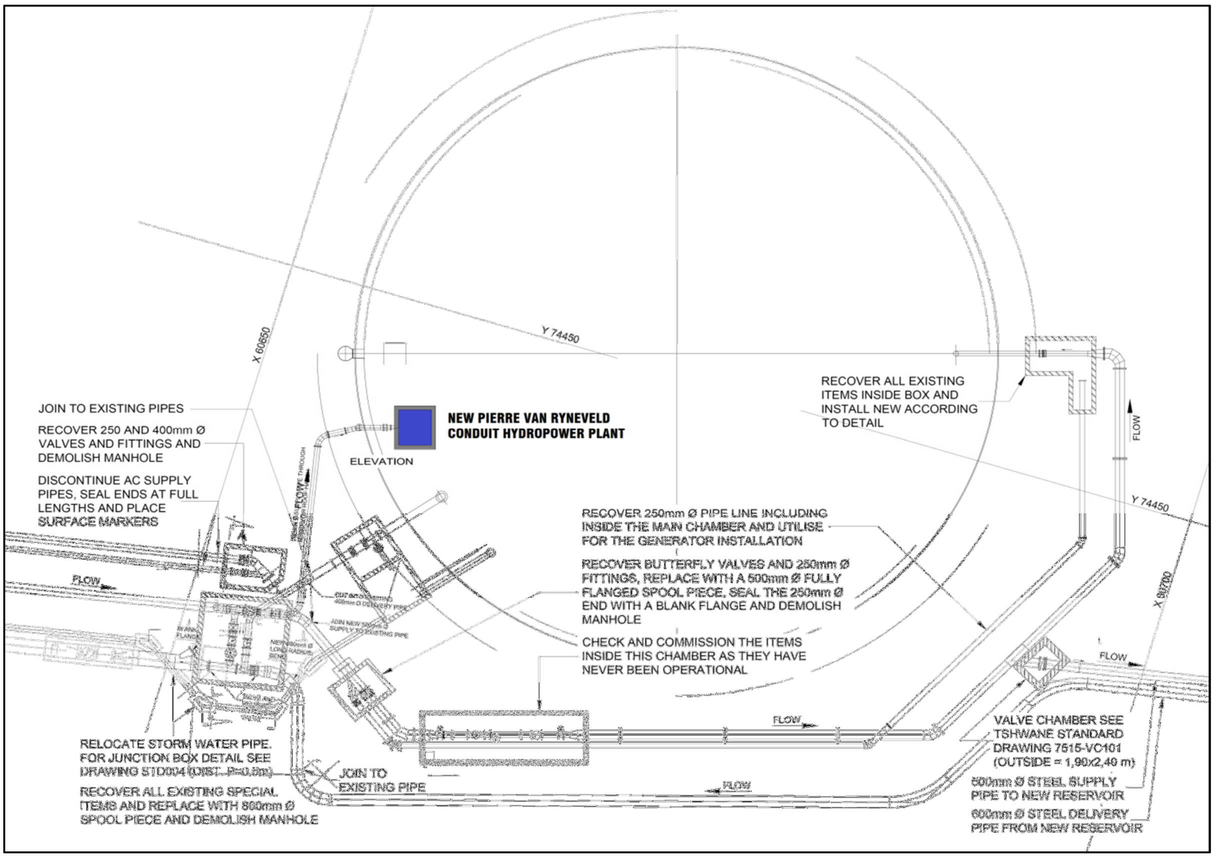

Figure 5-33: Pierre van Ryneveld pipework design

Figure 5-34: Pierre van Ryneveld off-take pipework under construction

Figure 5-35: Completed off-take pipework

Figure 5-36: Completed turbine on steel-beam supports

Figure 5-37: Pierre van Ryneveld turbine enclosure

Table 5-22: Pierre van Ryneveld Phase 3 plant set-up and safety design summary

DSS step	Design component	Discussion
17	Plant set-up	A cross-flow turbine was selected. It is a type of impulse turbine and therefore has to discharge to atmosphere. A set-up with the turbine on the reservoir roof was therefore chosen. **Figure 5-38** shows the turbine set-up on the reservoir roof.
18	Equipment safety	Equipment safety is not a major concern at this site, as the reservoir is located inside a security estate with electric fencing (that will be powered by the hydropower plant) and 24 hour security guard presence.

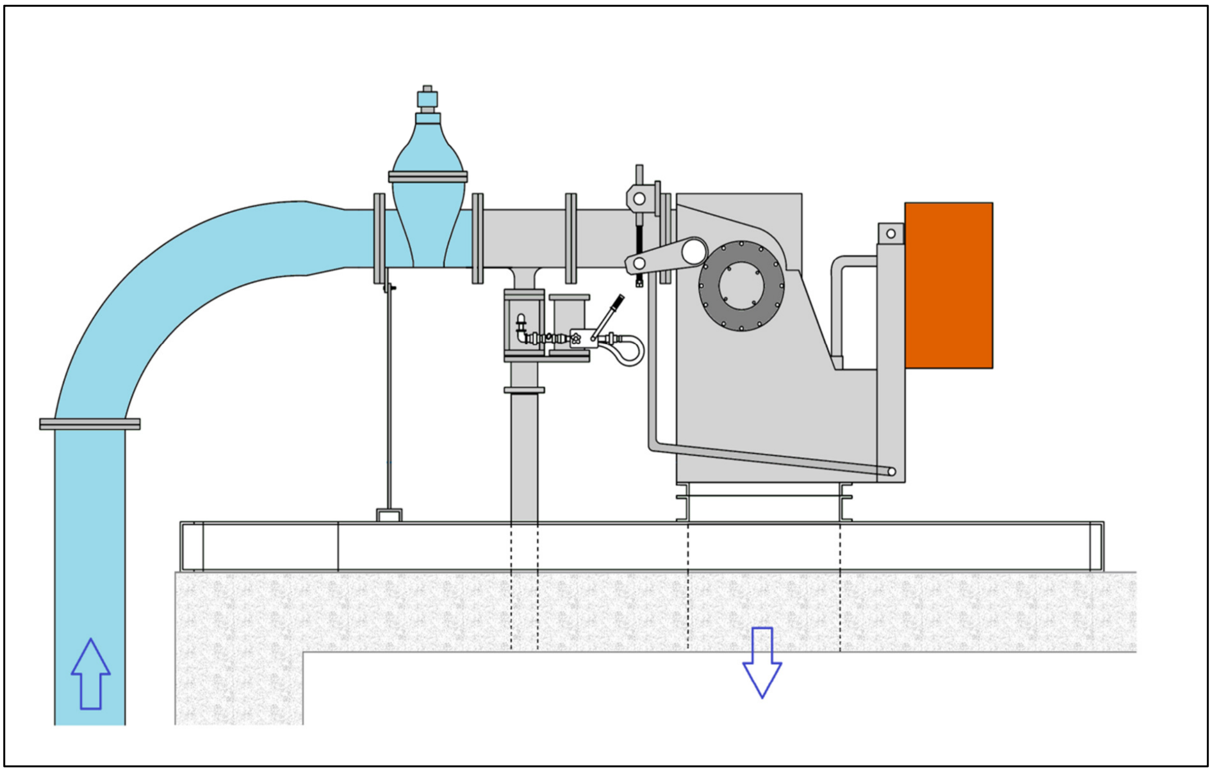

Figure 5-38: Pierre van Ryneveld cross-flow set-up

Next, a detailed economic evaluation was conducted with obtained costs, where applicable. The results can be seen in **Table 5-23**. A sensitivity analysis was also conducted to determine the sensitivity of project feasibility when considering alternative inflation rates. The results of this analysis are summarised in **Table 5-24**.

Table 5-23: Pierre van Ryneveld Phase 3 economic analysis

DSS step	Category	Description	Value	Unit	Source
		Reservoir name	Pierre van Ryneveld		IMQS
4	Design values	Design flow	0.041	m^3/s	CHD Tool
4	Design values	Pressure head	50.4	m	CHD Tool
4	Design values	Power rating	14.9	kW	CHD Tool
4	Design values	Annual energy potential	120	MWh/a	CHD Tool
6		Selected turbine	BHG cross-flow		CHD Tool
19	Costs	Planning and design	74 000	R	Industry average
19	Costs	Preliminary and general	15 000	R	Industry average
19	Costs	Turbine	170 000	R	Industry average
19	Costs	Other electrical and mechanical	102 000	R	Industry average
19	Costs	Civil and construction	150 000	R	Industry average
19	Costs	Data logging and communication	49 000	R	Industry average
19	Costs	Disposal (present value)	0	R	Industry average
19	Costs	Annual O&M (for year 1)	10 300	R	Industry average
19		Annual income (for year 1)	74 800	R	Industry average
19		Design life	15	years	Decided
19		Total initial capital expenditure	685 000	R	CHD Tool
19		NPV of costs	857 000	R	CHD Tool
19		NPV of income	1 360 200	R	CHD Tool
19		Total NPV	537 300	R	CHD Tool
19		Internal rate of return	14.38	%	CHD Tool

Step 21 of the CHDSS concerns funding of the project. Since this project has a projected capital expenditure of less than R700 000, no external funding is required and the municipality can source funds from their own internal budget.

A sensitivity analysis was done to determine the impact of different future inflation rates. The results are shown in **Figure 5-39**, **Figure 5-40** and **Table 5-24**. It is clear that the current uncertainty about future changes in the value of electricity is likely to cause a more significant impact on the net present value (NPV) of the project than operation and maintenance inflation, with an NPV of between R681 000 for high average electricity tariff inflation (12% after 2017) and R311 000 for low average electricity tariff inflation (6% after 2017). The expected NPV is R537 000, as determined in the economic analysis. The internal rate of return (IRR) of the project was found to have a range between 11.65% (for low electricity inflation) and 15.78% (for high electricity inflation).

It can therefore be assumed that this project should be feasible even if inflation rates are not as expected.

Table 5-24: Pierre van Ryneveld Phase 3 sensitivity analysis summary

DSS step			Electricity inflation		
			High (12%)	Expected (8%)	Low (6%)
22	IRR				
	Operation and maintenance inflation	Expected (6%)	15.78%	14.38%	11.65%
		High (9%)	15.37%	13.99%	11.15%
		Low (4%)	15.92%	14.60%	11.92%
	NPV				
	Operation and maintenance inflation	Expected (6%)	R 680,606	R 537,305	R 311,381
		High (9%)	R 638,518	R 503,201	R 277,278
		Low (4%)	R 691,080	R 555,764	R 329,840

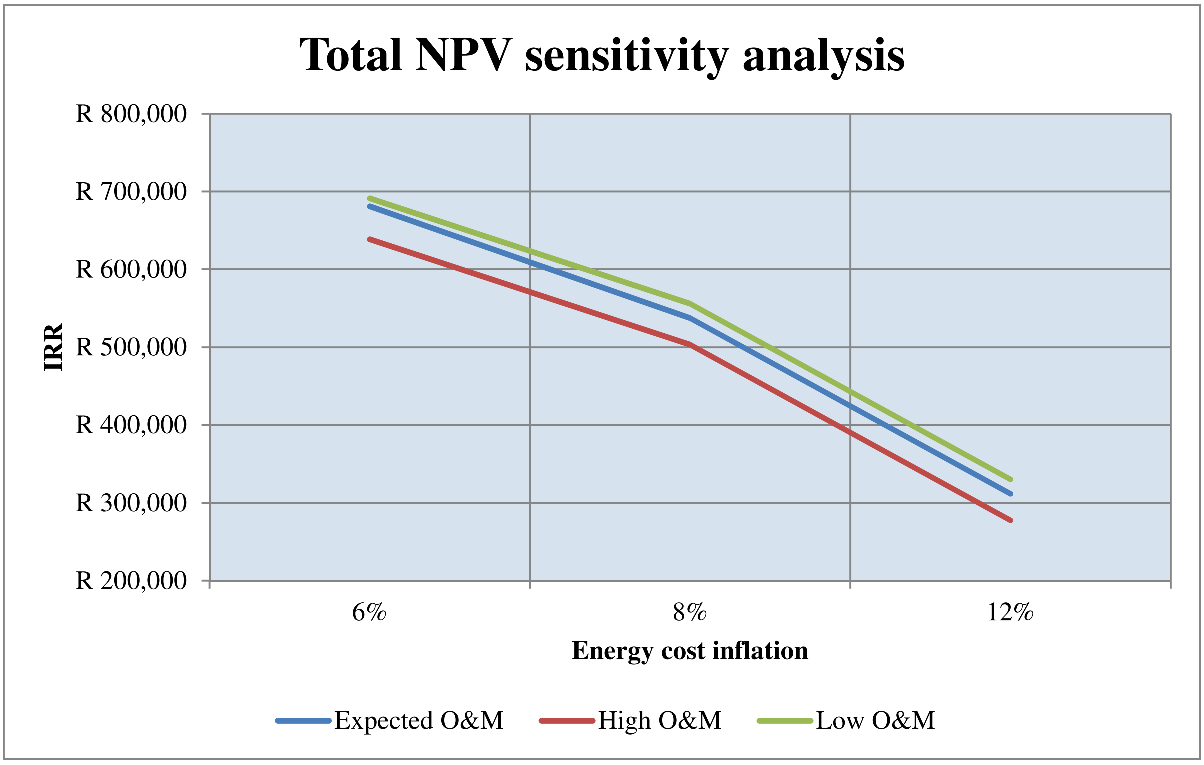

Figure 5-39: Pierre van Ryneveld Phase 3 NPV sensitivity analysis

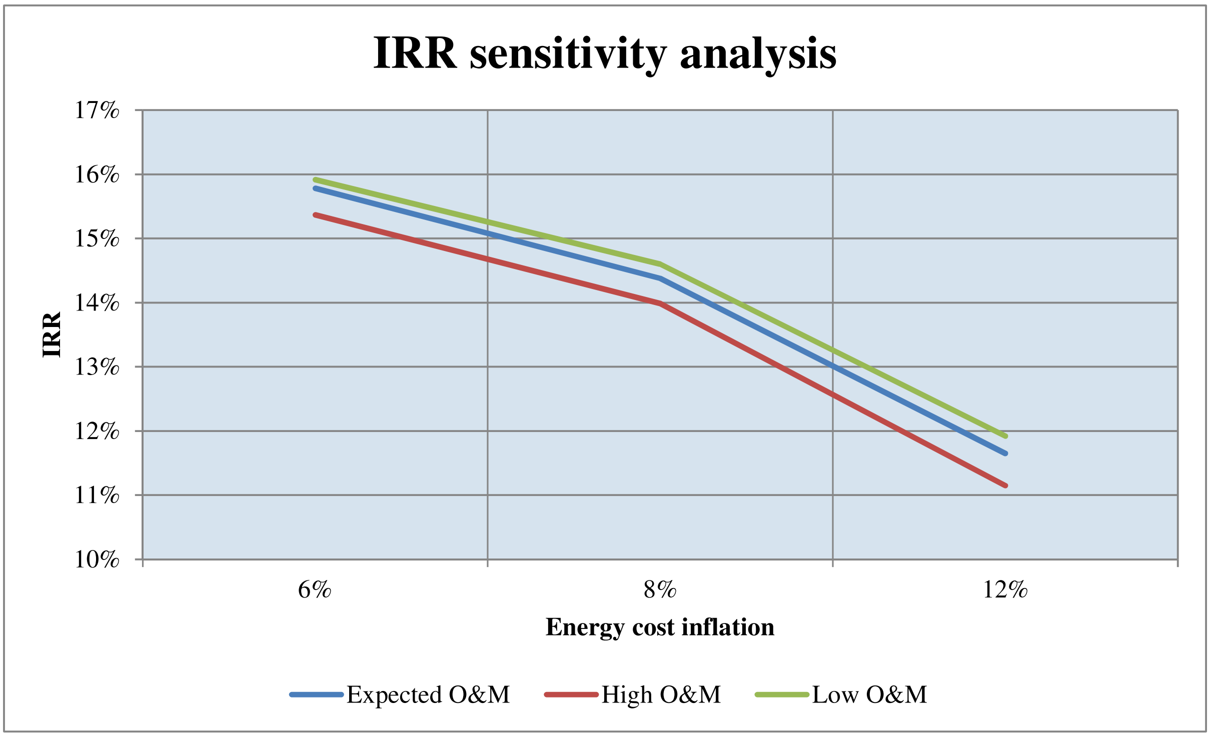

Figure 5-40: Pierre van Ryneveld Phase 3 IRR sensitivity analysis

5.5.6 DISCUSSION OF RESULTS

The analysis of hydropower at the Pierre van Ryneveld Reservoir showed that operational changes to the system may make a pico hydropower plant viable for on-site usage (**Table 5-17**). Since future circumstances at the reservoir and its distribution zone are not certain, a design life of only 15 years was selected. The project will be economically feasible even for this short design life, as shown in **Table 5-23**. A BHG cross-flow turbine with a capacity of 15 kW was selected (**Figure 5-41**), as it was available and applicable to the flow range on site.

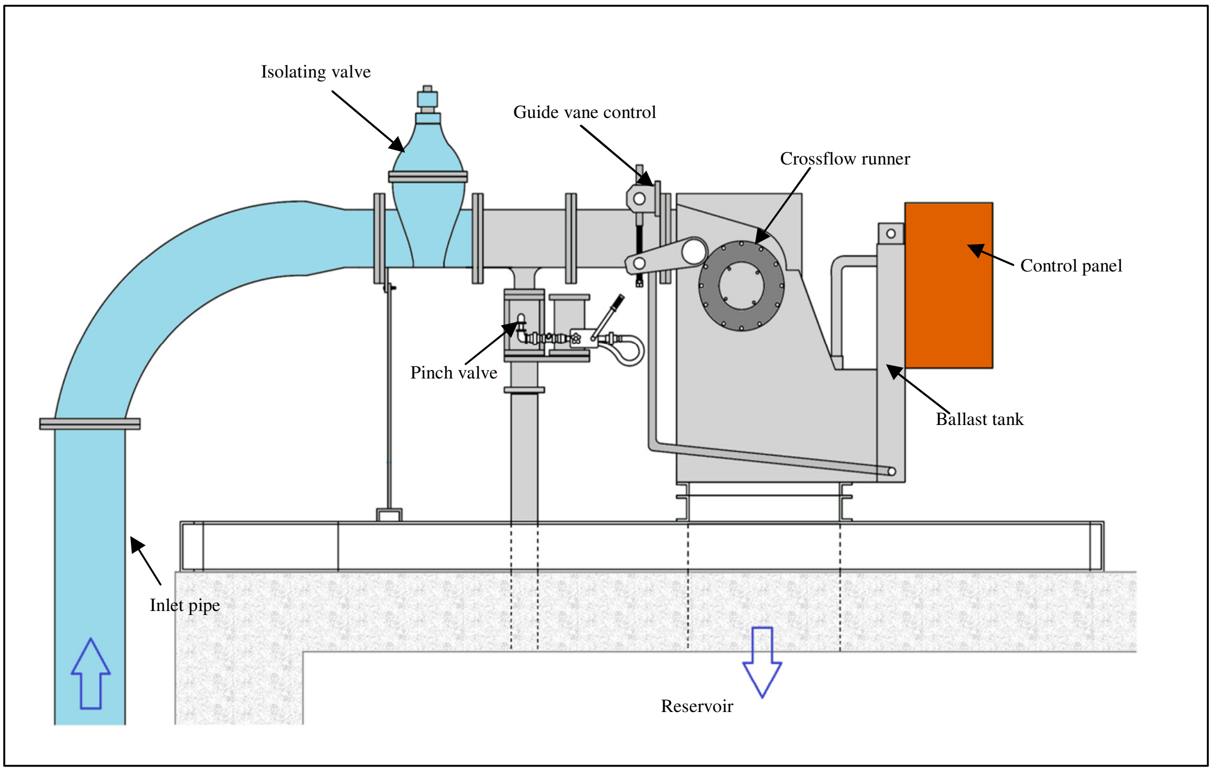

Figure 5-41: BHG cross-flow turbine set-up at Pierre van Ryneveld Reservoir

5.6 CASE STUDY 3: WATERKLOOF RESERVOIR

5.6.1 LOCATION

The Waterkloof Reservoir is located in Argo Place, Waterkloof, City of Tshwane, as can be seen in **Figure 5-42**. The GPS coordinates are 25°47'5.3"S and 28°13'44.9"E and the base of the reservoir is situated at an elevation of 1 465 m amsl.

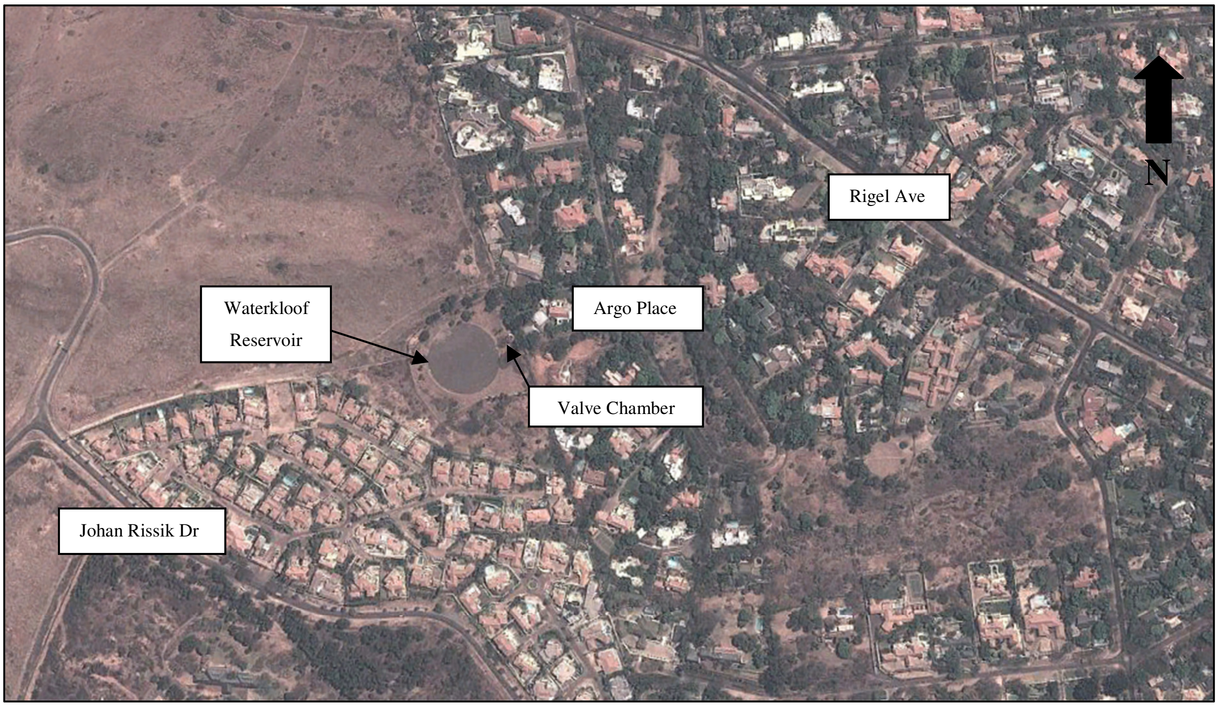

Figure 5-42: Location of Waterkloof Reservoir (Google Earth, 2012)

5.6.2 SITE DESCRIPTION

As is the case in much of the City of Tshwane, water to the Waterkloof Reservoir is supplied by Rand Water. It gravitates from a higher altitude in Johannesburg to a lower elevation in Tshwane. The reservoir supplies potable water to the Waterkloof suburb in Pretoria. **Figure 5-43** shows the reservoir's water-distribution zone. The site consists of one structure with a capacity of 22 750 m^3 and built using post-tensioned reinforced concrete.

The flow meter and pressure gauge were installed at the PRS located in the valve chamber upstream of the reservoir, as indicated in **Figure 5-42**.

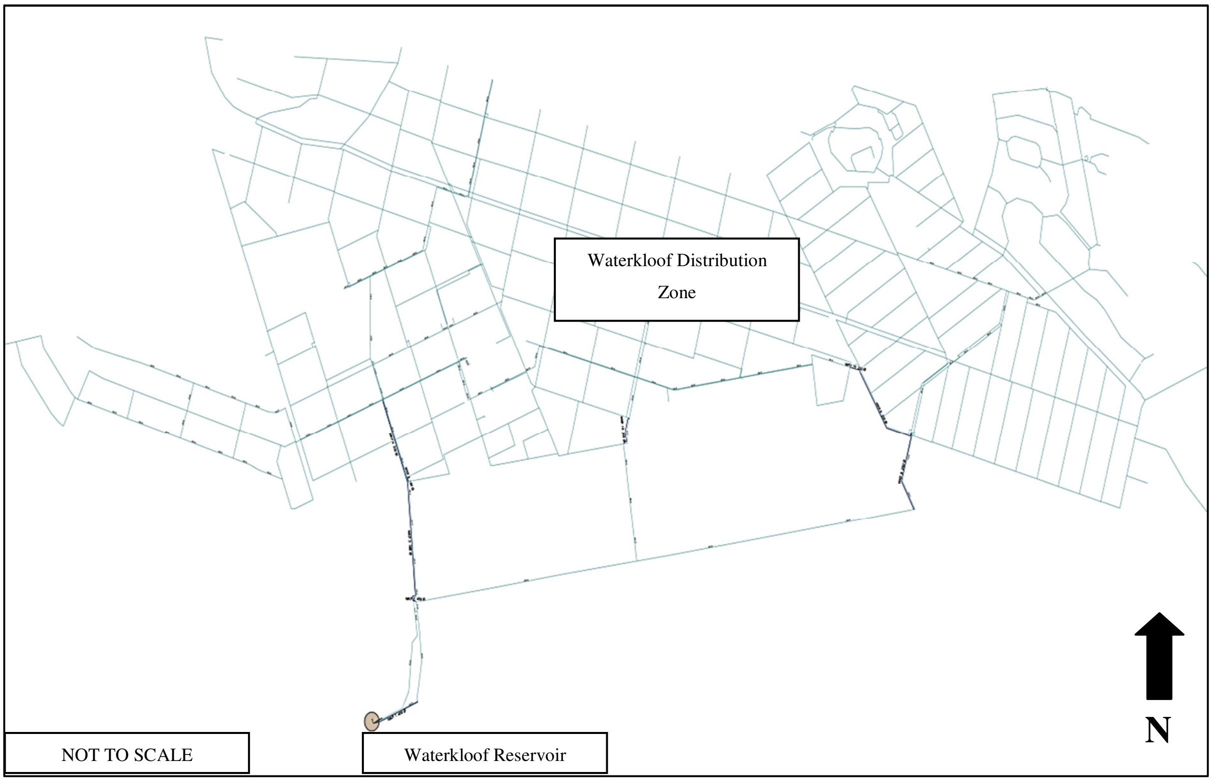

Figure 5-43: Waterkloof Reservoir water-distribution zone (IMQS)

5.6.3 PHASE 1 ANALYSIS AND RESULTS

The information used in the first phase study was obtained from The City of Tshwane Metropolitan Municipality's IMQS (Infrastructure Management Query Station) database. The relevant information can be seen in **Table 5-25**. This information was entered into the CHD Tool for Phase 1, with default values as indicated in **Appendix C** and the output is also shown in **Table 5-25**.

This reservoir supplies water to a developed residential area and little change in future scenarios is expected, as shown in **Table 5-25** by the small increase between current annual average daily demand (AADD) and maximum future possible AADD. Therefore a design life of 30 years was selected.

Table 5-25: Waterkloof Phase 1 analysis summary

DSS step	Description	Value	Unit	Source
	Reservoir name	Waterkloof		IMQS
3	Owner of infrastructure	City of Tshwane		
4	Present average annual daily demand	8 783	kℓ/d	IMQS
	Future average annual daily demand	11 575	kℓ/d	
	Average flow	0.102	m^3/s	CHD Tool
	Static head (pressure head used)	186 (112)	m	IMQS
5	Theoretically available power	77.9	kW	CHD Tool
6	Potential use	Grid connected		Decided
7	Distance to grid	0.08	km	Measured
8	On-site peak energy demand	N/A	kW	N/A
9	Average power/max demand	N/A	%	
10	Design life	30	Years	CHD Tool
	Estimated cost of plant (based on theoretically available power)	3 544 400	Rand	
	NPV of costs	4 748 300	Rand	
	NPV of income	9 644 100	Rand	
	NPV	4 895 700	Rand	
	IRR	12	%	
	Payback period	16	years	
	Economically feasible?	YES		
11	Consider next phase?	YES		

With an IRR of 12% and a positive NPV, the Phase 1 analysis indicated that a full feasibility study may be undertaken, even though the payback period seems long. Operational changes may also have a positive impact on the economic feasibility of the project.

5.6.4 PHASE 2 ANALYSIS AND RESULTS

The first phase hydropower potential analysis indicated economic feasibility and therefore a Phase 2 analysis was also performed. After determining first phase feasibility (CHDSS Step 1), it was necessary to visit the site and assess the practicability of a hydropower plant there.

Considered aspects included: space for the hydropower plant; safety of the turbine and other equipment from theft or vandalism; noise impact on the surroundings; and accessibility to the site by construction equipment. The analysis is summarised in **Table 5-26**.

Table 5-26: Waterkloof Phase 2 site analysis summary

DSS step	Practicability aspect	Discussion	Conclusion
2	Available space	The Waterkloof Reservoir is situated on a small, steep plot on a hill, but sufficient space for a hydropower plant is available on or next to the reservoir roof as shown in **Figure 5-42** and **Figure 5-44**.	Sufficient space exists on site
	Safety	The site is located on locked CoT property within the boundaries of a residential estate, which has 24 hour security.	Sufficient security is present
	Noise impact	As this reservoir is located within a residential area, the impact of noise may be disturbing to residents. However, a PRV is currently installed and no complaints have been received.	Noise impact will be sufficiently low
	Accessibility of site	As shown in **Figure 5-42**, the site is just off Argo Place in Waterkloof. Access to the site by construction vehicles may be gained through the front gate.	Easy accessibility

As the practicability of this site had been established, measuring instrumentation was installed to measure flow and pressure in the system, as recommended in CHDSS Step 3 of Phase 2. Flow and pressure data were collected at the PRV in the valve chamber upstream of the reservoir, as indicated in **Figure 5-42**. Data loggers were installed as shown in **Figure 5-45**.

Figure 5-44: Waterkloof Reservoir roof

Figure 5-45: Pressure and flow measurement at Waterkloof pressure-reducing station

Figure 5-46 shows the unedited measured data for flow rates and upstream pressures. No major gaps were experienced. However, some minor gaps exist in the pressure and flow data. The reason for the gaps is possibly a communication error between the modem on site and the server where information is stored. These gaps were removed before proceeding with the analysis.

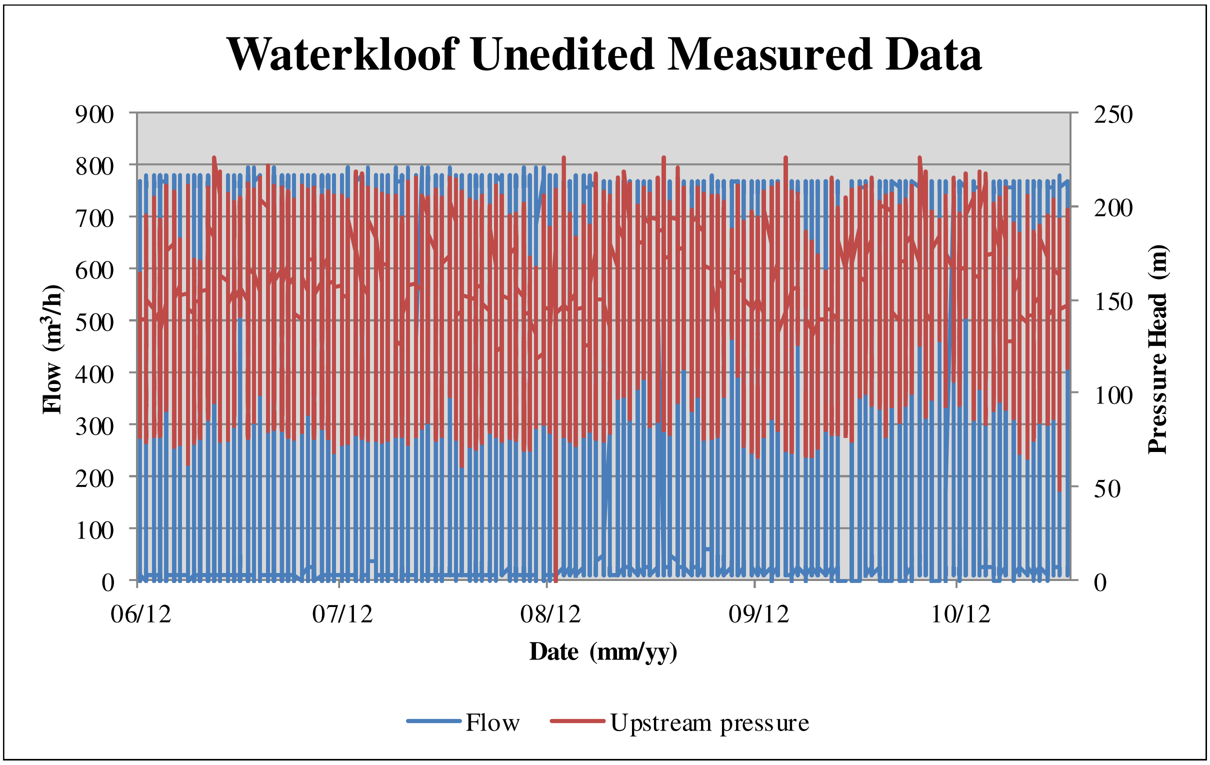

Figure 5-46: Waterkloof unedited measured data

The obtained data set was entered into Phase 2 of the CHD Tool to analyse the records (as per CHDSS Step 4 of Phase 2) and to populate **Table 5-27**. **Figure 5-47**, **Figure 5-48** and **Figure 5-49** were also generated using the CHD Tool.

CHDSS Step 5 was followed, as it was noticed that changing the operational procedure to maintain the average flow rate would generate almost twice as much power on an annual basis, even though a smaller turbine is required. CHDSS Step 6 was not followed for this site, as there is already significant hydropower potential. In Phase 3 allowance will be made for future operation of the plant as the potential increases due to higher flow rates.

Table 5-27: Waterkloof Phase 2 potential analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Waterkloof		IMQS
4	Measured and calculated values	Optimum flow	0.192	m^3/s	Measured
		Pressure head	95.2	m	
		Power rating	125.5	kW	CHD Tool
		Annual energy	506.1	MWh/a	
	Assurance of supply (% of time) (**Figure 5-47**)		N/A	%	N/A
	Initial Design values	Design flow	0.192	m^3/s	CHD Tool
		Pressure head	95.2	m	
		Power rating	125.5	kW	
		Annual energy	506.1	MWh/a	
5	What operational changes could be considered?		The reservoir feeds one distribution zone, so consider constant flow		
4	Design values after operational change	Design flow	0.097	m^3/s	
		Pressure head	126.1	m	
		Power rating (**Figure 5-48**)	83.8	kW	
		Annual energy (**Figure 5-48**)	720.3	MWh/a	
7	Selected turbine (**Figure 5-49**)		Pelton		
8	Electricity use		Grid-connected		Decided
9	Distance from grid connection		0.08	km	Measured
10	On-site power demand		N/A	kW	N/A
	Power rating/max demand		N/A	%	

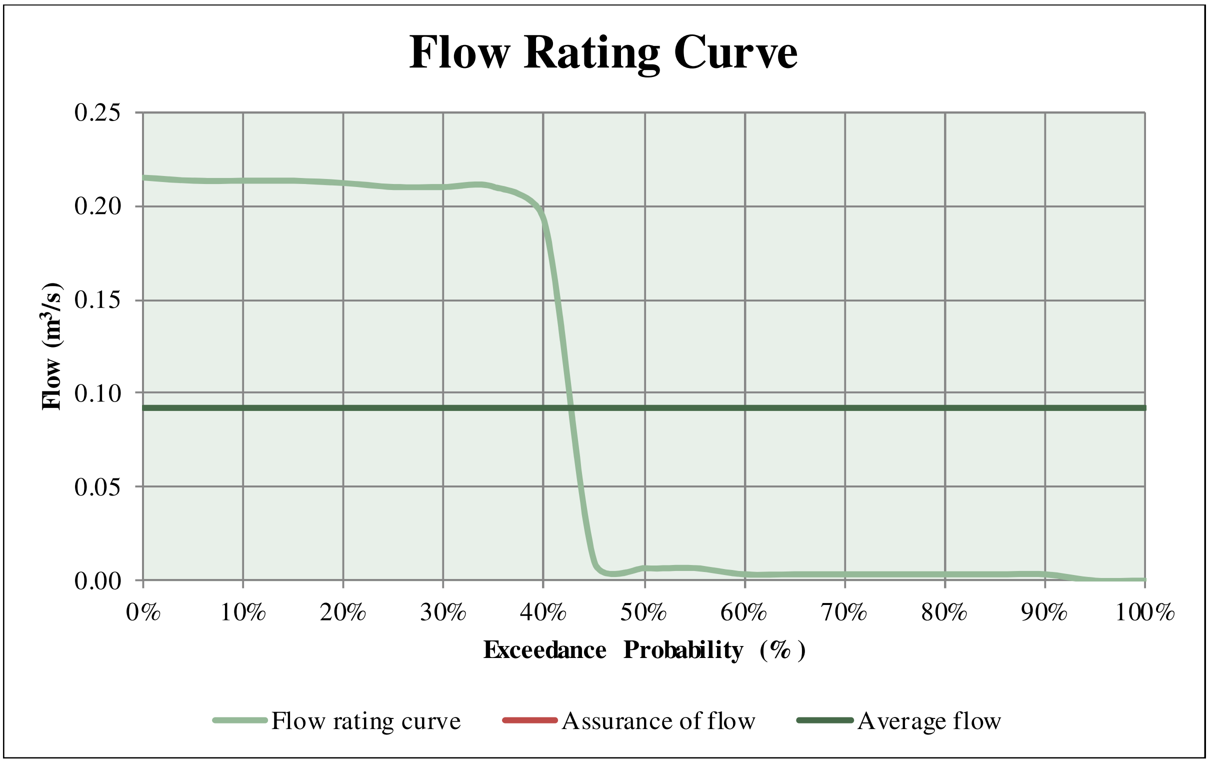

Figure 5-47: Waterkloof Phase 2 flow-rating curve

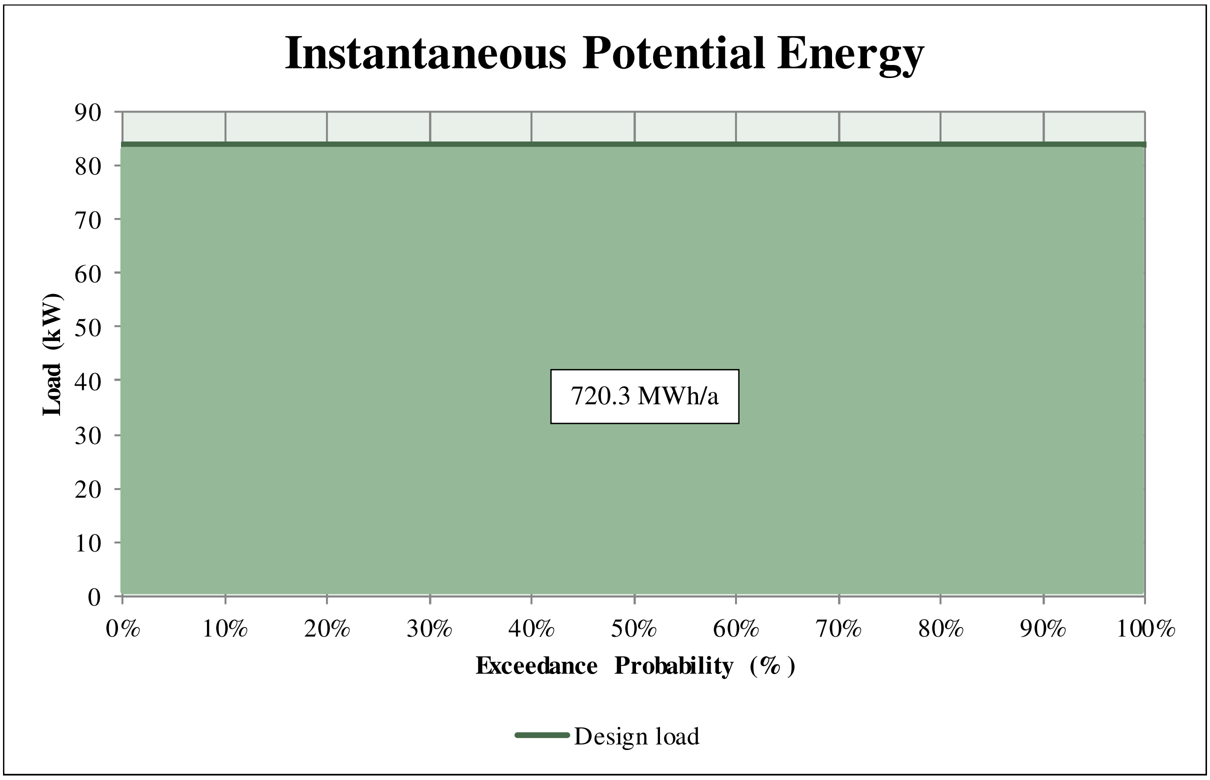

Figure 5-48: Waterkloof Phase 2 instantaneous potential energy

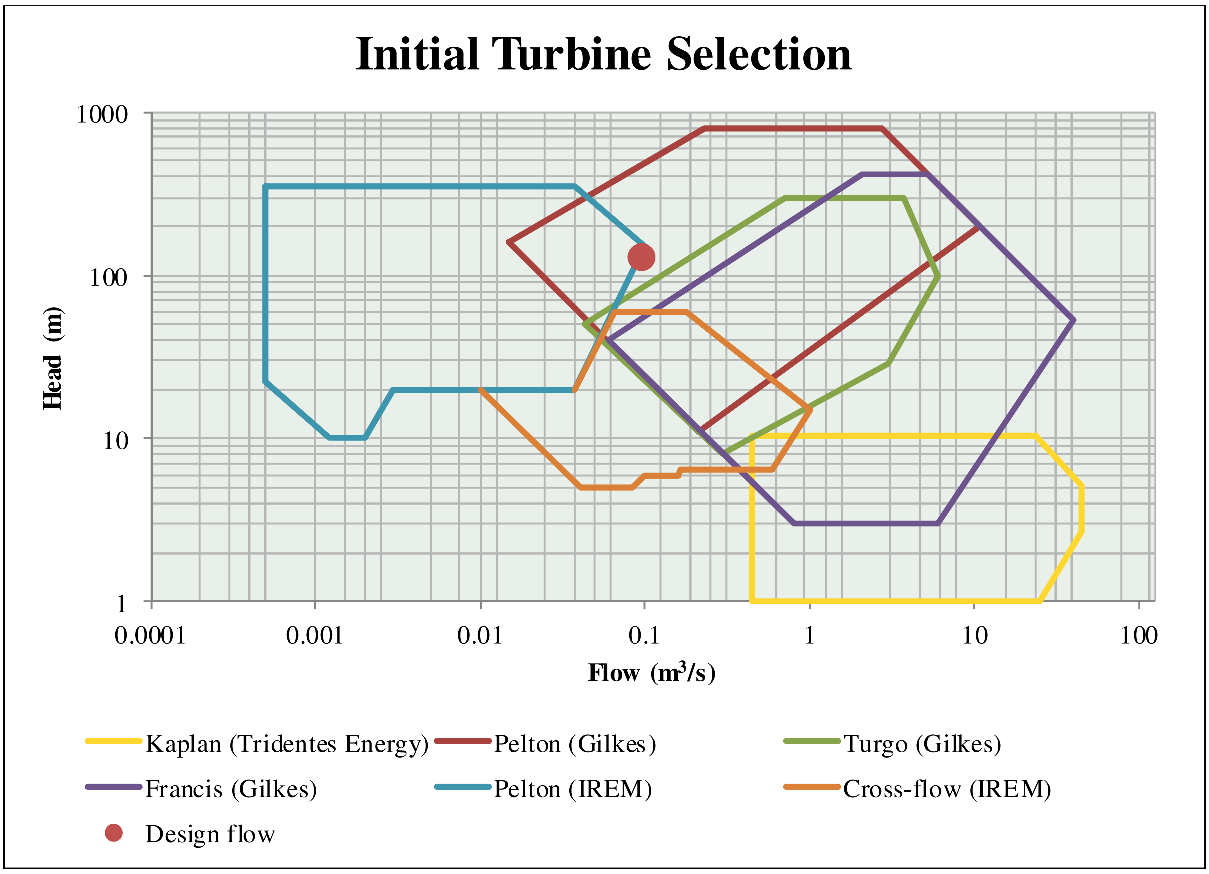

Figure 5-49: Waterkloof Phase 2 initial turbine-selection curve

CHDSS Steps 11-14 deal with regulatory requirements. These steps are summarised in **Table 5-28**.

Table 5-28: Waterkloof Phase 2 regulatory analysis

DSS step	Regulatory aspect	Discussion	Conclusion
11	Environmental studies	All power plant and construction areas are smaller than the minimum sizes for which environmental studies are required, according to the National Environmental Management Act (Act 107 of 1998) (refer to **Table 2-10**)	Neither BA nor EIA required
12	NERSA licence	As the generated electricity would be used fed into the municipal grid and sold commercially, NERSA licensing would be required. An example of a completed generation application form is attached in **Appendix D**.	Generation licence required
13	Water-use licence	Water-use licensing would not have to be obtained, as this project can be seen as a continuation of an existing lawful use under Tshwane's water-use licence.	Not required
14	Social requirements	A public participation process (PPP) would have to be followed wherein a notice board, meeting the requirements set in Government Notice 543 of 18 June 2010, is displayed on the boundary fence. If complaints are received, public hearings should be held.	PPP required

The next step was to perform an economic evaluation for Phase 2. The CHD Tool was used, with default values and cost functions as discussed in **Appendix C**. **Table 5-29** was populated with the input and calculated values.

Table 5-29: Waterkloof Phase 2 economic analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Waterkloof		IMQS
4	Design values	Design flow	0.097	m^3/s	Measured
		Pressure head	126	m	
		Power rating	83.8	kW	CHD Tool
		Annual energy potential	720	MWh/a	
7	Selected turbine		Pelton		
15	Planning cost per MW		1 350 000	R	Industry average
	Planning cost for this site		113 200	R	CHD Tool
	Turbine cost		992 100		
	Capital cost per MW (excluding turbine)		13 300 000	R	Industry average
	Total capital cost for this site (including turbine)		2 107 100	R	CHD Tool
	Annual operation and maintenance cost		39 100	R	
	Annual income		417 800	R	
	Design life		30	years	Decided
	NPV of costs		3 409 700	R	CHD Tool
	NPV of income		17 457 500	R	
	Total NPV		14 047 900	R	
	Internal rate of return		27.96	%	
	Payback period		7	years	

With an NPV of almost R15 000 000 and an IRR of 28%, without considering Eskom SOP tariffs, the Phase 2 economic analysis indicated that a detailed design was warranted. It should be noted that this phase indicated a significantly shorter payback period (6 years) compared to the value calculated in Phase 1 (14 years). The main reason for this is because operational changes to the system resulted in a better load factor (approximately 98% of time), allowing more electricity to be generated annually.

5.6.5 PHASE 3 ANALYSIS AND RESULTS

The Phase 2 economic analysis indicated financial feasibility. Therefore the Phase 3 analysis and detailed design was completed. The first step in this phase was to obtain historical flow and pressure records. Longer historical records (of a year or more) would be useful, as they would improve accuracy. However, as longer records were not available for this site, the same measured flow and pressure records were used as in Phase 2, for Step 2 of Phase 3.

The third step of this phase was to consider the effect of system optimisation. **Figure 5-50** shows the flow rates and corresponding pressures during a representative week in August 2012. From this figure it is clear that flow in the pipe is normally controlled at around 780 m^3/h until the reservoir is full, at which stage the flow in the pipe becomes almost zero. **Figure 5-51** shows that hours with high power potential do not typically correlate well with hours of high electricity value (peak times). Therefore operational changes to ensure better correlation would produce higher income.

As the Waterkloof Reservoir serves only one distribution zone (as shown in **Figure 5-43**), the operational philosophy can be adjusted to obtain a more constant flow, with higher flow values at electricity peak times, all the while ensuring that the reservoir does not run dry. The potential analysis was therefore done for constant flow rates, as shown in **Table 5-30**.

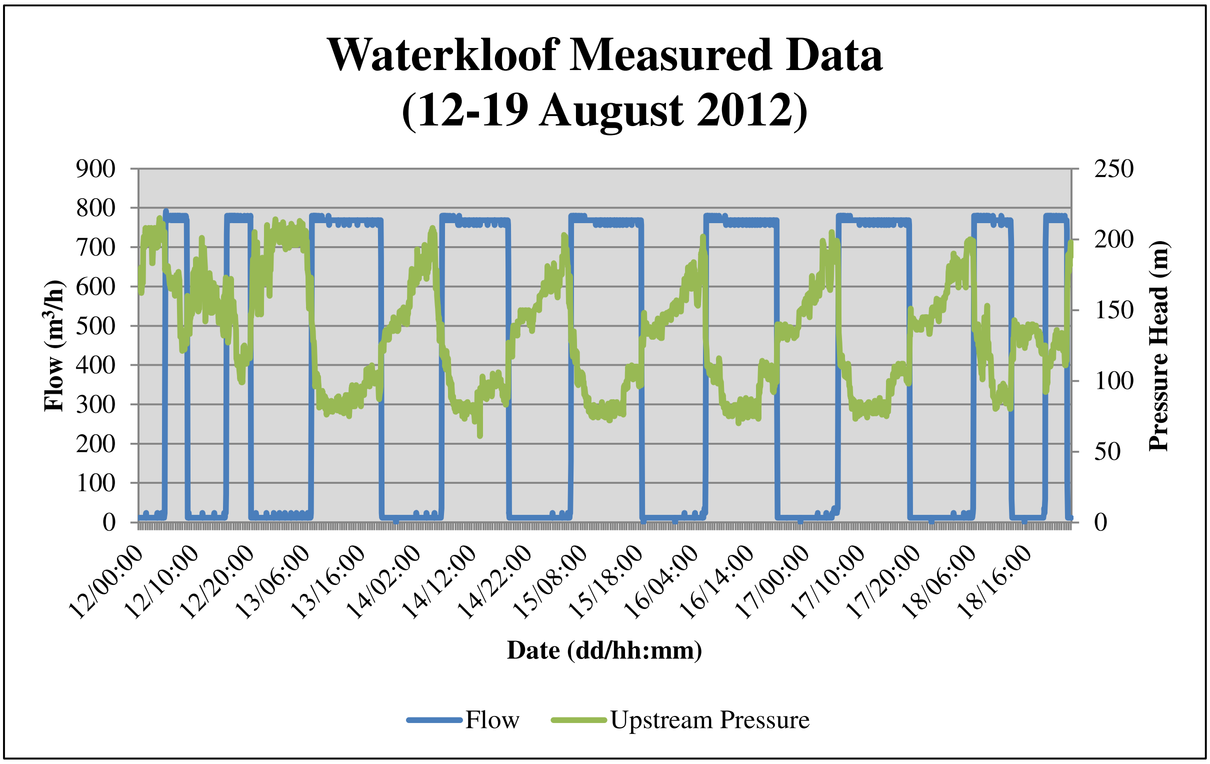

Figure 5-50: Waterkloof measured data for a typical week

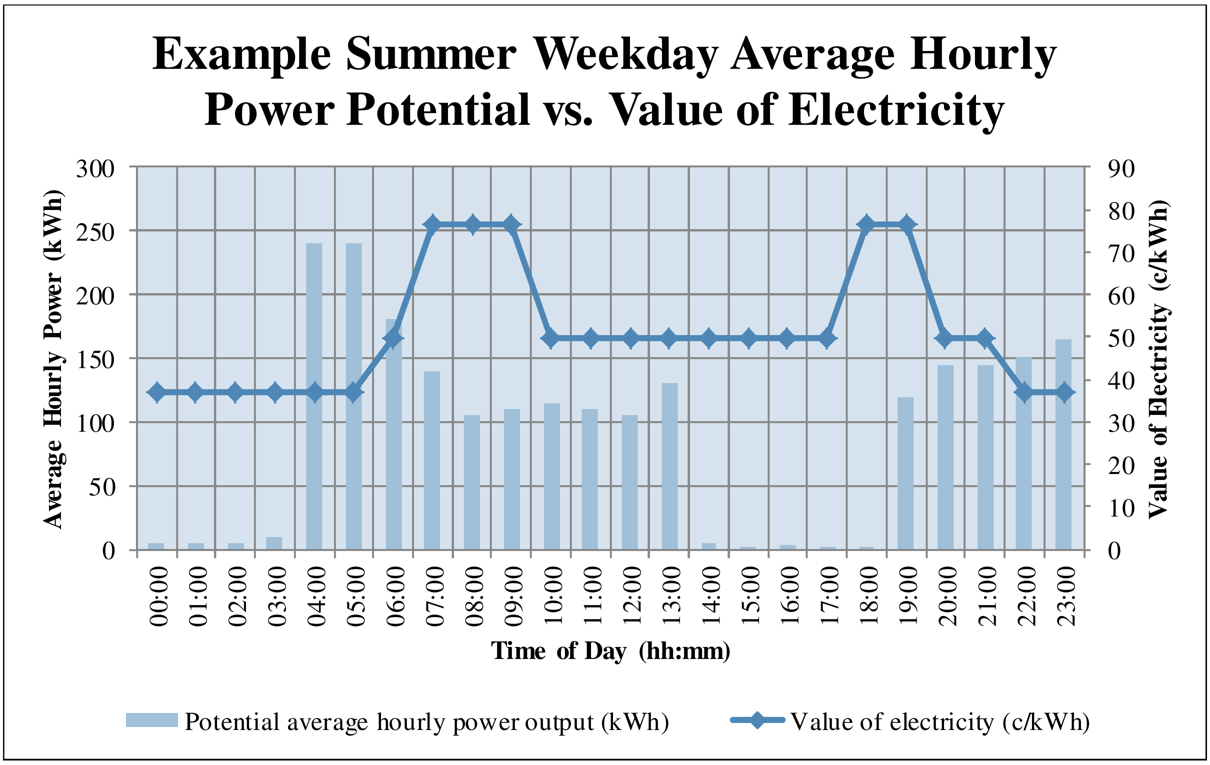

Figure 5-51: Waterkloof typical correlation between power potential and electricity tariffs

Based on information in the IMQS, the maximum future AADD at Waterkloof Reservoir will be approximately 12 000 kℓ/d, which is roughly 30% more than the current AADD of 9 000 kℓ/d. For this analysis it was assumed that operation with the current flow could be manipulated so that an above-average current flow (equal to the future average flow) could be maintained during peak energy tariff hours, with a slightly below-average flow in off-peak times (**Figure 5-52**). In this way a turbine with a capacity to match future flow rates can be installed now and future expansion would not be necessary. A flow range including the current and future average flows was therefore used, as seen in **Table 5-30** and **Figure 5-53**.

Table 5-30: Waterkloof Phase 3 potential analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Waterkloof		IMQS
3	Measured and calculated values	Current design flow	0.097	m^3/s	Average of measured values
		Pressure head	126	m	
4		Power rating	98.2	kW	CHD Tool
		Annual energy potential	843.8	MWh/a	
5 (4)	Estimated future values	Estimated future design flow	0.126	m^3/s	Described
		Pressure head	126	m	(Conservative)
		Power rating	130.9	kW	CHD Tool
		Annual energy potential	1124.9	MWh/a	
6	Required turbine range for current flow (**Figure 5-52**)		95-135	kW	CHD Tool
7	Selected turbine for current flow (**Figure 5-53**)		Gilkes Pelton		Product catalogue
8	Turbine efficiency for current flow		82	%	Product catalogue
6	Required turbine range for future flow		95-135	kW	CHD Tool
9	Additional turbines for future flow		None		Product catalogue
8	Turbine efficiency for future flow		84	%	Product catalogue
10	Electricity use		Grid-connected		
11	Distance from grid connection		0.08	km	Measured
12	Grid-connection requirements		**Appendix A**		
14	Do supply-and-demand patterns correlate?		N/A		N/A
	Is there sufficient demand for the installation size?		N/A		

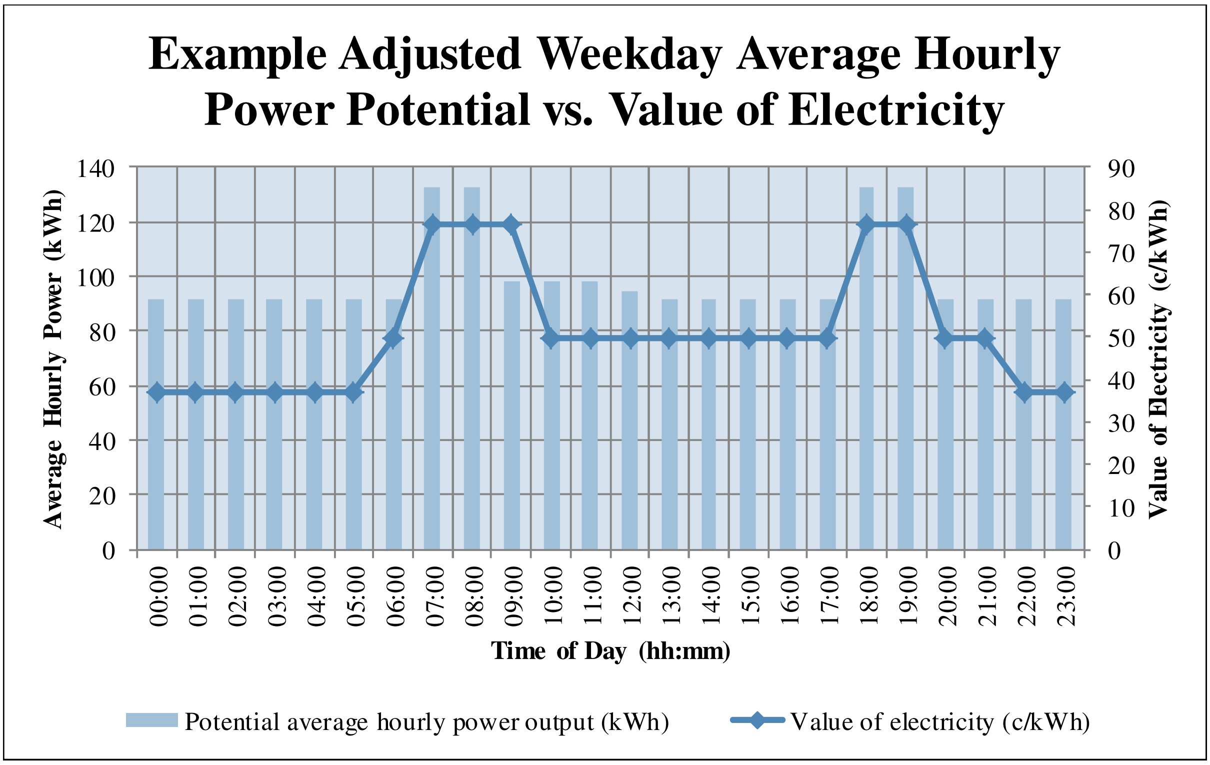

Figure 5-52: Waterkloof Phase 3 adjusted operation

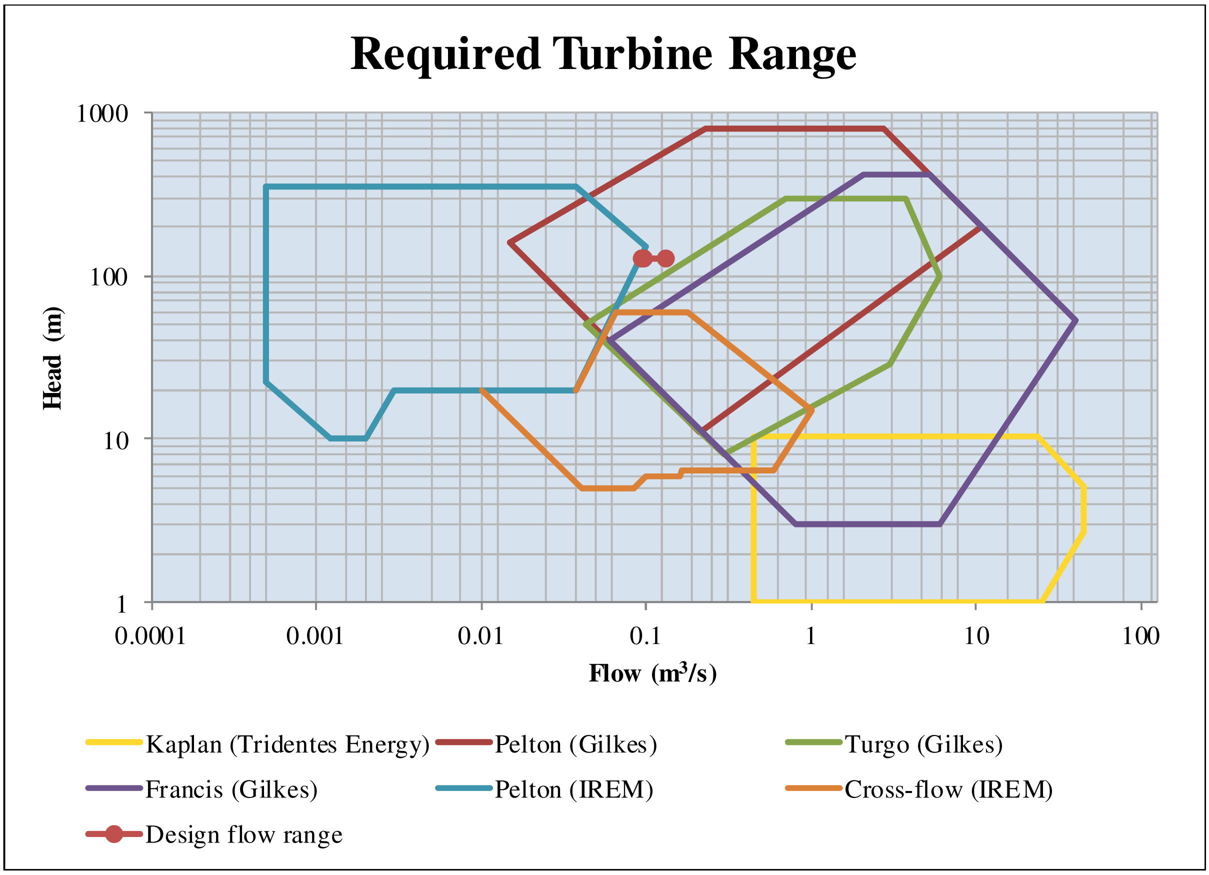

Figure 5-53: Waterkloof Phase 3 turbine selection

The next set of steps involved the detailed design of all the components of the conduit hydropower plant. Due to time constraints, a detailed design was not done for the Waterkloof development. However, a detailed design was done for the Pierre van Ryneveld Reservoir and can be seen in **Chapter 5.5.5**.

A detailed economic evaluation was conducted with obtained costs, where applicable. The results can be seen in **Table 5-31**. The future flow scenario was applied from 2029 (15 years from project commencement). A sensitivity analysis was also conducted to determine the sensitivity of project feasibility when considering alternative inflation rates. The results of this analysis are summarised in **Table 5-32**.

Table 5-31: Waterkloof Phase 3 economic analysis

DSS step	Description		Value	Unit	Source
	Reservoir name		Waterkloof		IMQS
4	Design values	Design flow	0.09-0.126	m^3/s	CHD Tool
		Pressure head	126	m	
		Power rating	91-133	kW	
		Current annual energy potential (future)	869 (1 147)	MWh/a	
6	Selected turbine		Gilkes Pelton		
19	Costs	Planning and design	235 000	R	Industry average
		Preliminary and general	80 000	R	
		Turbine	1 317 000	R	
		Other electrical and mechanical	300 000	R	
		Civil and construction	200 000	R	
		Transformer	352 000	R	
		Transmission	48 000	R	
		Contingencies	100 000	R	
		Disposal (present value)	0	R	
		Annual O&M (for year 1)	58 800	R	
	Annual income (for year 1)		520 800	R	
	Annual income (for year 15, PV in year 1)		652 200	R	
	Design life		30	years	Decided
	Total initial cost (planning and capital)		3 292 100	R	CHD Tool
	NPV of costs		5 080 200	R	
	NPV of income		24 451 000	R	
	Total NPV		19 370 700	R	
	Internal rate of return		24.81	%	

Step 21 of the CHDSS concerns funding of the project. Since this project has a projected capital expenditure of just over R3 000 000, no external funding is required and the municipality can source funds from their own internal budget.

A sensitivity analysis was done to determine the impact of different future inflation rates. The results are shown in **Table 5-32**, **Figure 5-54** and **Figure 5-55**. It is clear that the current uncertainty about future changes in the value of electricity is likely to cause a more significant impact on the net present value (NPV) of the project than operation and maintenance inflation, with an NPV of between R23 719 000 for high average electricity tariff inflation (12% from 2017 to 2027) and R13 160 000 for low average electricity tariff inflation (6% from 2017). The expected NPV is R19 371 000, as determined in the economic analysis. The internal rate of return (IRR) of the project was found to have a range of between 22.25% (for low electricity inflation) and 26.24% (for high electricity inflation).

It can therefore be assumed that this project should be feasible even if inflation rates are not as expected.

Table 5-32: Waterkloof Phase 3 sensitivity analysis summary

DSS step			Electricity inflation		
			High (12%)	**Expected (8%)**	**Low (6%)**
22	**IRR**				
	Operation and maintenance inflation	**Expected (6%)**	26.08%	24.81%	22.25%
		High (9%)	25.77%	24.46%	21.79%
		Low (4%)	26.24%	24.99%	22.47%
	NPV				
	Operation and maintenance inflation	**Expected (6%)**	R 23,271,155	R 19,370,737	R 13,159,722
		High (9%)	R 22,207,646	R 18,307,228	R 12,096,213
		Low (4%)	R 23,718,901	R 19,818,483	R 13,607,468

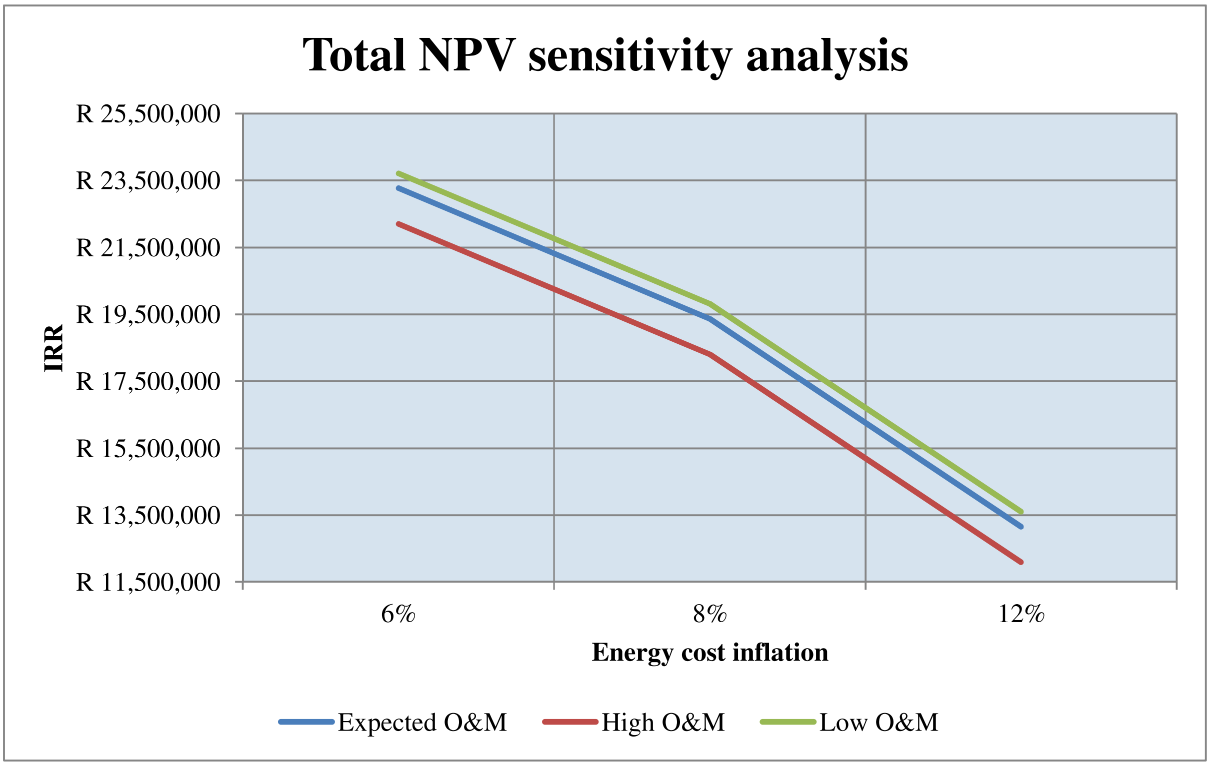

Figure 5-54: Waterkloof Phase 3 NPV sensitivity analysis

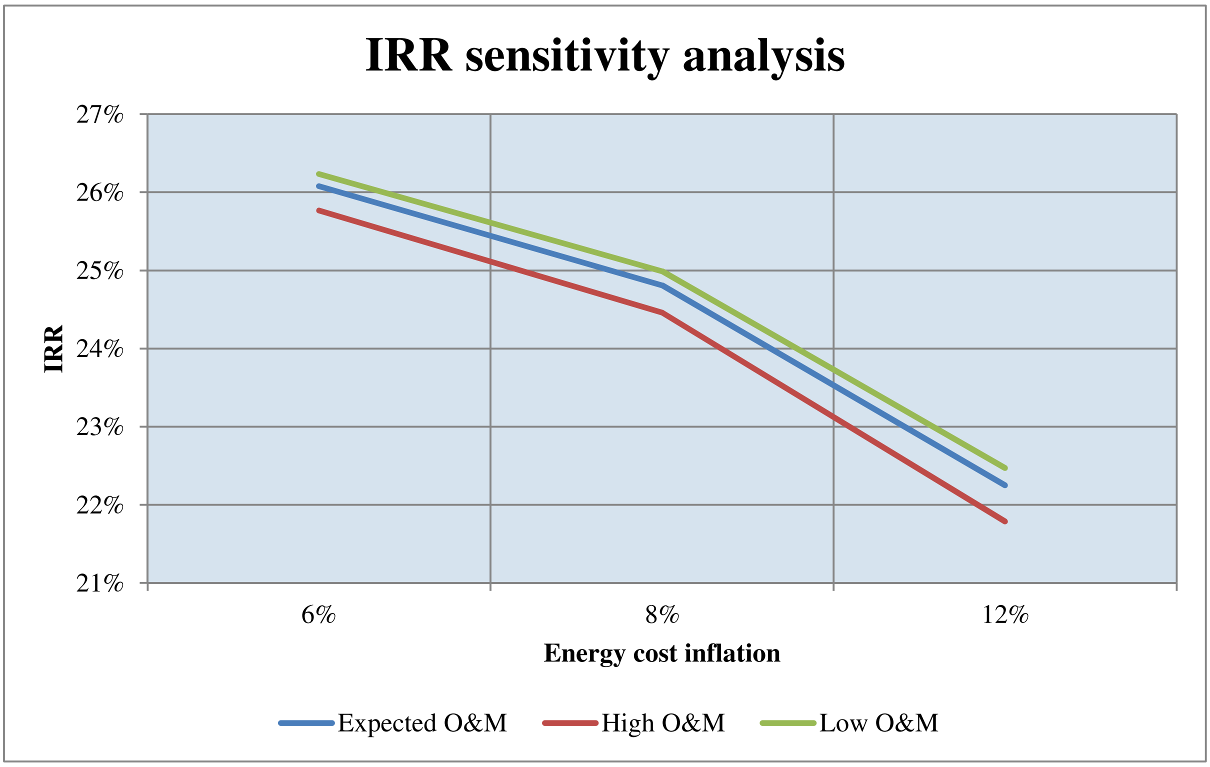

Figure 5-55: Waterkloof Phase 3 IRR sensitivity analysis

5.6.6 DISCUSSION OF RESULTS

The analysis of hydropower at the Waterkloof Reservoir showed that there is economically exploitable potential at this site, especially if operational changes are made, as shown in **Figure 5-52**. It is proposed that a 135 kW grid-connected Gilkes Pelton (**Figure 5-56**) turbine be installed for current use, with operational changes made to accommodate average flow for future use.

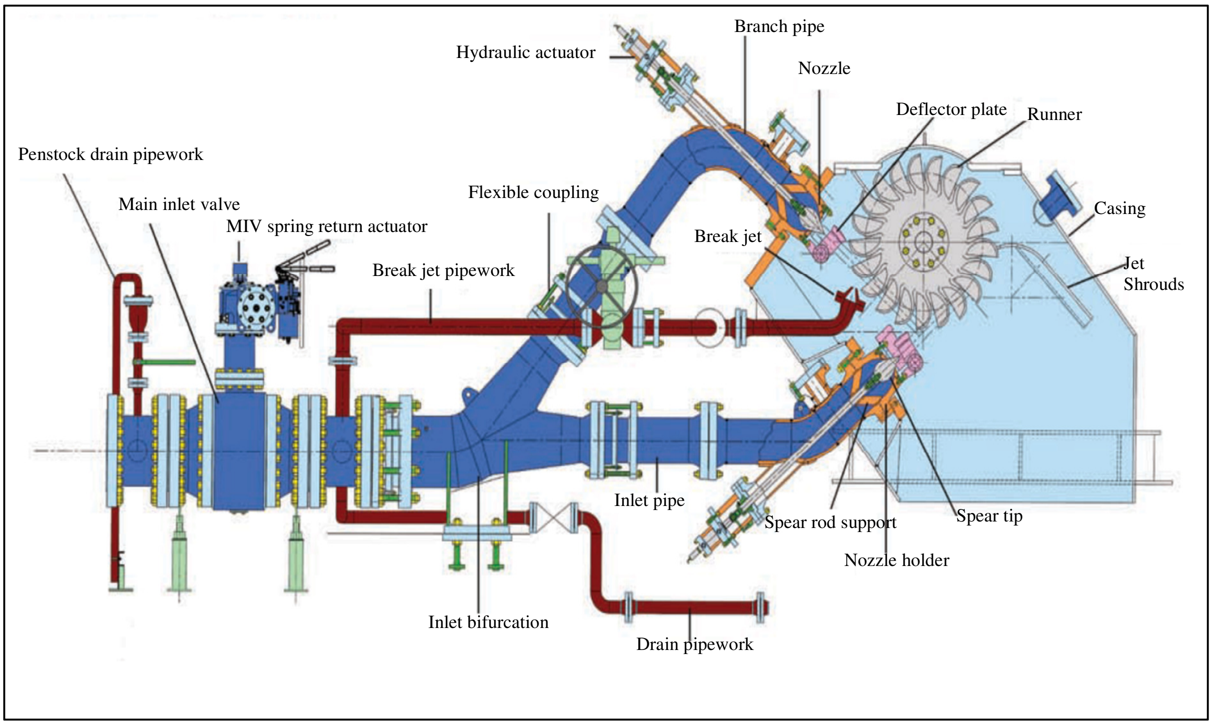

Figure 5-56: Typical Gilkes Pelton layout (Gilkes, 2012)

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This dissertation documented the development and testing of a Conduit Hydropower Decision Support System (CHDSS) and Conduit Hydropower Development (CHD) Tool that can be used to assist municipalities and engineers in reviewing conduit hydropower potential in South Africa, as well as provide proper guidance for the development of identified sites.

This was achieved by first conducting a literature review to ascertain the current level of knowledge and developments in the field of conduit hydropower. The information gathered in the literature review was included in a procedural approach (the CHDSS) taking into account all relevant practical, technical and economic aspects of conduit hydropower. This procedural approach was communicated visually in a series of flow diagrams that can be seen as a summary of the CHDSS. The CHDSS was divided into the following three phases:

- First Phase: Pre-Feasibility Investigation
- Second Phase: Feasibility Study
- Third Phase: Detailed Design

Secondly, a Microsoft Excel-based Conduit Hydropower Development Tool (CHD Tool) was developed to facilitate the calculations necessary for successful conduit hydropower development. This tool focuses on the review of hydropower potential and the review of economic feasibility.

Thirdly, all the aspects of the CHDSS were discussed in a guideline format. Each section of the guideline was linked to a correlating step in one of the procedural CHDSS flow diagrams. This guideline detailed the necessary steps of the process with the aim of guiding users in the application of these steps.

Finally, the CHDSS was tested using three sites in the City of Tshwane Metropolitan Municipality. The three case-study sites were selected to represent a variety of circumstances that would enable comprehensive testing of the procedural method.

The first case study was carried out on the Garsfontein Reservoir, where 730 kW of exploitable hydropower potential exists. This is a bulk reservoir in the water-distribution network to a significant portion of the eastern parts of the Tshwane Metropolitan area. Therefore, operational changes to increase hydropower generation were not made, as water-supply reliability is the primary concern.

The second case study was the Pierre van Ryneveld Reservoir. This site has potential for about 23 kW, of which only 12.5 kW could be utilised on site. As it was easy to procure a 15 kW cross-flow turbine, this was installed.

The Waterkloof Reservoir was used for the third case study. The initial analysis considered the system without operational changes, but changing the operational procedure to maintain the average flow rate into the reservoir would generate almost twice as much power on an annual basis, even though a smaller turbine was required. As this reservoir serves only one distribution zone with predictable water demand, operational changes were incorporated in the design. A 135 kW Pelton turbine was chosen to incorporate both current and future flow rates, as future scenarios at this turbine do not differ significantly from the present.

The CHDSS was therefore tested and validated using a range of circumstances and found to be applicable to all the tested scenarios.

This study successfully addressed the need for a system that can be used to identify conduit hydropower potential in South Africa. A user-friendly CHDSS was produced, facilitating the process of conduit hydropower development in South Africa. The CHDSS was structured to guide potential power producers through the necessary developmental requirements in a step-by-step manner. It was illustrated using process flow diagrams and supported by a CHD Tool to simplify the necessary calculations.

6.2 RECOMMENDATIONS

It is recommended that this CHDSS and CHD Tool be used by engineers in municipalities to identify and develop the untapped hydropower potential present in South Africa's water-distribution systems.

Recommendations for subsequent studies include:

- More case studies may be done as part of final-year projects to consider an even wider range of possible conduit hydropower scenarios.
- Operation and maintenance guidelines should be compiled for conduit hydropower applications.
- Optimisation guidelines should be compiled for conduit hydropower applications in complex distribution systems.
- The potential for low-head installations in distribution systems, for example at wastewater treatment plants and in canals, should be investigated.
- If sufficient low-head potential exists, a DSS for low-head hydropower should be developed.

- Mining and industrial applications should be investigated and the DSS should be adapted for these applications, if sufficient potential exists.

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Legislation

Energy Regulation Act (Act 4 of 2006)

National Water Act (Act 36 of 1998)

National Environmental Management Act (Act 107 of 1998)

APPENDICES

A. NERSA AND ESKOM APPLICATION FORMS

A.1 INTRODUCTION

Various application forms and specifications are applicable if a hydropower plant is planned; especially when it will be connected to a local or national grid. This appendix provides a list of relevant documents, as well as examples of the documents on the attached CD.

A.2 DOCUMENTS INCLUDED ON CD

The following documents are included on the attached CD:

A1. NERSA – APPLICATION FOR AN ELECTRICITY GENERATION LICENCE IN TERMS OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006)

A2. NERSA - APPLICATION FOR AN ELECTRICITY DISTRIBUTION LICENCE OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006)

A3. ESKOM – APPLICATION FOR A CONNECTION OF A GENERATOR TO THE ESKOM NETWORK

A4. ESKOM – DISTRIBUTION STANDARD FOR THE INTERCONNECTION OF EMBEDDED GENERATION

A5. ESKOM – GUIDE FOR IPP GRID APPLICATION PROCESS

A6. CITY OF TSHWANE ENERGY AND ELECTRICITY – STANDARD SPECIFICATIONS FOR MUNICIPAL ELECTRICAL ENGINEERING WORKS

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

APPLICATION FOR AN ELECTRICITY GENERATION LICENCE IN TERMS OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006).

Please return completed form to:

HOD: Electricity Licensing and Compliance
National Energy Regulator of South Africa
Kulawula House, 526 Vermeulen Street
Arcadia, 0083
Pretoria

Or:

HOD: Electricity Licensing and Compliance
National Energy Regulator of South Africa
P.O. Box 40343
Arcadia
0007

Tel (012) 401 - 4600
Fax (012) 401 - 4700

SECTION A PARTICULARS OF APPLICANT

A1 Full name of applicant (business name) and business registration number

____

____

____

A2 Address of applicant, or in the case of a body corporate, the registered head office

Physical address

____

____

____

Postal address

____

____

____

A3 Telephone number of applicant

(______)____

A4 Fax number of applicant

(______)____

A5 Email address of applicant

____

A6 Contact person

First name ____

Surname ____

Telephone No ____

Mobile No ____

Fax No. ____

Email address ____

A7 Legal form of applicant

Note to Section A

1) State whether the applicant is a local government body, a juristic person established in terms of an act of parliament, a department of state, a company or other legal body.

2) If the applicant is a local government body, attach a copy of the proclamation establishing such body. Where the applicant is a company, the full names of the current directors and the company registration number are required.

SECTION B COMMENCEMENT DATE OF LICENCE

B1 Desired date from which the licence (if granted) is to take effect

____

____

____

Note to Section B

3) The normal processing time for a licence application is 120 days once all relevant information has been provided and there are no objections received.

4) If the applicant intends operating more than one generation station under the proposed licence, please complete separate application forms for each generation station.

SECTION C PARTICULARS OF PROPOSED GENERATION STATION

C1 Name of generation station

____
____

C2 Geographical location of generation station (please attach maps)

____
____

C3 Address of generation station

____
____
____

C4 Contact person at generation station

First name and Surname ____________________________________
Telephone No ____________________________________
Mobile No ____________________________________
Fax No ____________________________________
Email address ____________________________________

C5 Type of generation station (thermal, nuclear, hydro, pumped storage, gas turbine, diesel generator or other)

____
____
____

C6 Expected commissioning date for a proposed generation station or at which the station was commissioned (if an existing station).

____
____

C7 The installed capacity (existing and/or planned) of each unit within the generation station (MW)

Existing Capacity

____
____
____

Planned Capacity

____
____
____

C8 Maximum generation capacity (MW) expected to be available from the generation station and energy to be produced (MWh) over the next 5years of operation. These estimates should be based on modelling of how the power station will fit into the demand profile of its customers, taking into account the least cost energy purchase consideration and demand management options of customers.

YEAR	**Max MW**	**Total MWh**	**Own use MWh**	**Export (Sales) MWh**

C9 Estimate of the energy conversion efficiency of the generation station.

____

____

C10 Expected future life of the generation station.

____

____

SECTION D PARTICULARS OF LONG TERM ARRANGEMENTS WITH PRIMARY ENERGY SUPPLIERS

D1 Name of primary energy supplier/s (mining house, colliery or other fuel supplier)

____

____

D2 Particulars of the contractual arrangements with primary energy supplier

____

____

____

____

Notes to Section D

5) Please provide brief particulars of any long term agreements entered into with fuel suppliers and copies of such contracts (Signed Fuel Supply Agreements).

SECTION E MAINTENANCE PROGRAMMES AND DECOMMISSIONING COSTS

E1 Details of any proposed major maintenance programmes, including the expected cost and duration thereof, covering the next six years. Project proposals to state the expected availability, planned outage rate and forced outage rate of the plant over the first five years of operation.

E2 Details of any major decommissioning costs expected during the life span of the power station and provided for in the project feasibility study.

E3 Details of major generation station expansion and modifications planned for in the feasibility study (Dates, Costs in Rands (state year) and description)

SECTION F CUSTOMER PROFILE

F1 Particulars of the person or persons to whom the applicant is providing or intends to provide electricity from the generation station

____
____
____
____

F2 Network connection details (connection points, voltages, wheeling arrangement, single line diagram)

____
____
____
____

F3 Provide summary details of Power Purchase Agreements with customer including purchasing price etc. (Please attach Power Purchase Agreements).

____
____
____
____

Notes to Section F

6) For example, supply to ESKOM or supply to local government distribution system. Please include the details of power purchase agreements entered into and the price structure of the contract.

SECTION G FINANCIAL INFORMATION

G1 Submit projections of and current statements of the accounts in respect of the undertaking carried on by the applicant, showing the financial state of affairs of the most recent period, together with copies of the latest audited annual accounts where such have been prepared.

G2 Submit annual forecasts for the next five years of costs, sales and revenues generated by the project, stating the assumptions underlying the figures.

G3 Estimates of net annual cash flows for subsequent periods (5 years; 10 years; 15 years) sufficient to demonstrate the financial security and feasibility of operating the generation station.

G4 Project financing: Who will finance the project, how is funding split between debt and equity, and what is the terms and conditions of the funding agreements.

Notes to Section G

7) The financial projections should be based on a production plan for the generation station and the revenue generated by participating in the electricity market and by bilateral contracts (Power Purchase Agreements) with customers. Reference to the latest version of National Integrated Resource Plan (IRP) is required to demonstrate that the proposed power purchase agreement is the least cost solution available to the electricity purchaser.

SECTION H HUMAN RESOURCES INFORMATION

H1 Submit details of the number of staff and employees and their categories in the service of the applicant at the generation station and in any support services separate from the generation station. Also provide information regarding relevant qualifications and experience in critical areas e.g. Professional registration (Engineering Council of South Africa ï ECSA), Government Certificate of Competency.

SECTION I PERMISSION FROM OTHER GOVERNMENT DEPARTMENTS OR REGULATORY AUTHORITIES

I1 What progress has been made to obtain the required permits and approvals for the generation project? Please provide copies of permits issued by the relevant environmental and safety agencies in respect of the operation of the generation station.

SECTION J BROAD-BASED BLACK ECONOMIC EMPOWERMENT

J1 Please provide information in terms of the following categories:

COMPONENTS	POINTS	0.5	0.75	1
Direct Empowerment	Black Ownership	10% to <20%	20% to 50%	>50%
	Black Management	20% to <35%	35% to 50%	>50%
	Black Female Management	1% to <5%	5% to 10%	>10%
Human Resource Development	Black Skilled Personnel as % of payroll	20% to <35%	35% to 50%	>50%
	Skills Development Programs as % of payroll	1% to <5%	5% to 10%	>10%
	Employment Equity i.e. Women Representation	20% to <35%	35% to 50%	>50%
Indirect Empowerment	Procurement from Black/BEE Suppliers	20% to <35%	35% to 50%	>50%
	Enterprise Development i.e. Monetary Investment or quantifiable non-monetary support in SMME with BEE contributions as % of Net Asset Value/ EBITDA/Total Procurement	10% to <20%	20% to 25%	>25 %
	Industry specific initiatives to facilitate the inclusion of black people in the sector as % of net profit	1% to <5%	5% to 10%	>10%
NERSAôs Discretionary Points	Based on skills transfer and fulfilment or acceleration of other national objectives e.g. employment of disabled personnel robust implementation of mechanisms to verify the BEE status of suppliers reported under preferential procurement and utilization of DTI approved accreditation agencies and so on.	1% to <5%	5% to 10%	>10%

SECTION K ADDITIONAL INFORMATION

Provide any other relevant information related to this application

SECTION L DECLARATION

On behalf of the applicant, I hereby declare that:

(a) the applicant shall at all times comply in every respect with the conditions attached to any licence that may be granted to the applicant;

(b) the applicant shall at all times comply with lawful directions of the National Energy Regulator of South Africa;

(c) the information provided by me on behalf of the applicant is accurate and complete in all respects; and

(d) I am authorised to make this declaration on behalf of the applicant.

Signed:

Full name(s) of Signator(y/ies):

Position held (if the applicant is a company, co-operative, partnership, unincorporated association or any other body corporate):

Date:

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

APPLICATION FOR AN ELECTRICITY DISTRIBUTION LICENCE OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006).

Please return completed form to:

National Energy Regulator
HoD: Licensing and Compliance Department
4th Floor, Kulawula House
526 Vermeulen Street
Arcadia
Pretoria

P O Box 40343
Arcadia
0007
South Africa

Tel: 012 401 4600
Fax: 012 401 4700

PREAMBLE

Section 4 of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) provide for the Regulator to issue licences for operation of electricity distribution facilities. Rules as determined by the Regulator specify that anyone owning and operating an electricity distribution facility requires to be licensed by the Regulator.

SECTION A PARTICULARS OF APPLICANT

A1 Full name of applicant

____
____
____

A2 Address of applicant, or in the case of a body corporate, the registered head office

____
____
____

A3 Telephone number of applicant

(_____)__________________

A4 Fax number of applicant

(_____)__________________

A5 Contact person of applicant

Name ____

Telephone No ____

Fax No. ____

A6 Legal form of applicant

____
____
____

A7. In the case of a local government body, please state the grading of that authority

____

Note to Section A

State whether the applicant is a local government body, a juristic person established in terms of an act of parliament, a department of state, a company or other legal body.
If the applicant is a local government body, attach a copy of the proclamation establishing such body. Where the applicant is a company, the full names of the current directors and the companies registered number are required.

SECTION B COMMENCEMENT DATE OF LICENCE

B1 Desired date from which the licence (if granted) is to take effect

SECTION C AREA OF OPERATION TO WHICH THE APPLICATION RELATES

C1 Please provide a sufficient description of the area of operation to which the application relates

____

C2 Please provide a sufficient description of the purpose of the distribution system and the users of the distribution system

____

SECTION D DETAILS OF THE DISTRIBUTION SYSTEM

D1 Please provide an overview of the current system and prospects for the next five years, which includes:

D.1.1 The Physical system

- Supply points connected to existing generators (Eskom and municipal power stations, neighbouring utilities) and transmission systems
- Delivery points connected to existing distributors and special customers
- Total kilometres per voltage of distribution lines[1]
- Summary of large scale map showing geographical location of substations and routes of distribution lines
- Single line diagram of the distribution system
- Table showing all transformers, lines and substations also indicating the replacement values of such equipments as below:

Transformers

HV	LV	Number of transformers	MVA	Replacement value (R'000)

List of substations

Substation name	Voltages	Number of transformers	Total MVA	Replacement Value (R'000)

D.1.2 System characteristics

- Maximum demand
- Energy entering the system at supply points
- Energy leaving the system at delivery points
- Electrical losses, breakdown of causes and prospects

D.1.3 Grid code (Transmission and Distribution) compliance

- Adequacy of internal policies for grid code compliance

Note1: Lines and any other assets that are above 132 kV for historic reasons but utilised for distribution purposes are deemed as distribution assets and must be reported. For any future modifications/extensions of these assets, a pre- approval from the Regulator will be required.

Note 2: Updated Section D will be reported annually to the Regulator.

SECTION E MAINTENANCE PROGRAMMES

E1 Details of any proposed major maintenance programmes, including the expected cost and duration thereof, covering the next six years. Project proposals to state the expected availability, planned outage rate and forced outage rate of the disitribution system over the next five years of operation.

____
____
____
____
____

E2 Please provide the actual (total) maintenance cost as a percentage of the replacement value (total).

____
____
____
____

E3 Provide details of person/body that will operate the distribution and co-ordinate with national transmission system. Also provide any agreements with National Control.

____
____
____
____

Note to Section E

Updated Section E will be reported annually to the Regulator.

SECTION F **CUSTOMER PROFILE**

F1 Provide particulars of the person or persons to whom the applicant is providing or intends to provide electricity transmission services to. Also provide details of proposed tariffs for the distribution services.

SECTION G FINANCIAL INFORMATION

G1 Submit projections of and current statements of the accounts in respect of the undertaking carried on by the applicant, showing the financial state of affairs of the most recent period, together with copies of the latest audited annual accounts where such have been prepared.

G2 Submit annual forecasts for the next five years of costs, sales and revenues generated by the project, stating the assumptions underlying the figures. (Separate direct operating costs and overheads)

G3 Estimates of net annual cash flows for subsequent periods (5 years; 10 years; 15 years) sufficient to demonstrate the financial security and feasibility of importing/exporting activities.

G4 Project financing: Who will finance the project, how is funding split between debt and equity, and what is the terms and conditions of the funding agreements.

G5 Fixed Assets – Provide summary of total assets of all distribution plant

SECTION H HUMAN RESOURCES INFORMATION

H1 Submit details of the number of staff and employees and their categories in service of the applicant and in any support services separate from the operation of the distribution system. Also provide information regarding relevant qualifications and experience in critical areas e.g. High voltage and low voltage regulations, switching, etc. Please provide any contracts in this regard.

SECTION I PERMISSION FROM OTHER GOVERNMENT DEPARTMENTS OR REGULATORY AUTHORITIES

I1 Please provide of copies of the permits issued by other government departments or regulatory authorities in respect of erecting and operating the distribution system, including any environmental and safety approvals.

SECTION J BROAD-BASED BLACK ECONOMIC EMPOWERMENT

J1 Please provide information in terms of the following categories:

COMPONENTS	POINTS	0.5	0.75	1
Direct Empowerment	Black Ownership	10% to <20%	20% to 50%	>50%
	Black Management	20% to <35%	35% to 50%	>50%
	Black Female Management	1% to <5%	5% to 10%	>10%
Human Resource Development	Black Skilled Personnel as % of payroll	20% to <35%	35% to 50%	>50%
	Skills Development Programs as % of payroll	1% to <5%	5% to 10%	>10%
	Employment Equity i.e. Women Representation	20% to <35%	35% to 50%	>50%
Indirect Empowerment	Procurement from Black/BEE Suppliers	20% to <35%	35% to 50%	>50%
	Enterprise Development i.e. Monetary Investment or quantifiable non-monetary support in SMME with BEE contributions as % of Net Asset Value/ EBITDA/Total Procurement	10% to <20%	20% to 25%	>25 %
	Industry specific initiatives to facilitate the inclusion of black people in the sector as % of net profit	1% to <5%	5% to 10%	>10%
NERSA's Discretionary Points	Based on skills transfer and fulfilment or acceleration of other national objectives e.g. employment of disabled personnel robust implementation of mechanisms to verify the BEE status of suppliers reported under preferential procurement and utilization of DTI approved accreditation agencies and so on.	1% to <5%	5% to 10%	>10%

SECTION K ADDITIONAL INFORMATION

Please provide any other relevant information that the applicant wishes to include with this application

Eskom

APPLICATION FOR A CONNECTION OF A GENERATOR TO THE ESKOM NETWORK

Revision 06
20 September 2011

Introduction

(This form should be completed if the generator in question will be synchronised with the Eskom grid.)

This application form outlines the minimum information required by Eskom to conduct an evaluation of the feasibility of connecting generators within Eskom's networks.

This application form is in two parts.

1. Part 1 must be filled in for Eskom to provide an (non-binding) estimate of the cost of connection.
2. If the required conditions are met to proceed with a budget quotation, Eskom will request Part 2 of the application form to be completed for the detailed interconnection and power system studies.

All of the information stipulated in this application form must be provided prior to the commencement of any cost estimates and ultimately if approved, cost quotations. The technical cost of connection as well the network charges are determined for the applicant from the information supplied in this document. Technical findings and constraints derived from the provided information shall also be communicated to the relevant applicant.

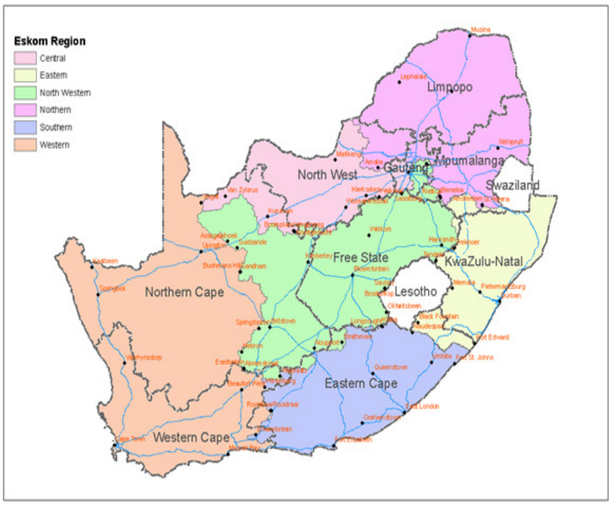
If applicable, should the import capacity required by the site during start up, result in a demand being required or an existing plant's notified maximum demand being exceeded, an application for the demand shall also be submitted to Eskom. Applicants shall also note that an application for a temporary construction supply or for an increase in demand is separate from this application, and the applicant is required to follow the standard Eskom application process.

It should be noted that it is the applicant's responsibility to comply with the applicable technical, design and operational standards detailed in the South African Grid Code and the South African Distribution Code. Copies of the codes may be downloaded from NERSA's website www.nersa.org.za.

Eskom Distribution's specific technical requirements for the interconnection of embedded generation are described in a separate document, i.e. "Distribution standard for the interconnection of embedded generation" (DST 34-1765). A copy of this standard will be provided on request. This application form may be completed as a hard copy or as a soft copy together with all supporting documentation. An electronic (soft copy) submission is preferred and can be submitted to the following email addresses:

are.vanzyl@eskom.co.za	Western Region
valmon.muller@eskom.co.za	Central Region
FerreiPJ@eskom.co.za	North West Region
eddie.leach@eskom.co.za	Southern Region
helen.bezuidenhout@eskom.co.za	Northern Region
Ravi.moonsamy@eskom.co.za	Eastern Region

See map for the Eskom Regions →



You will be contacted to confirm receipt of your application and provided with a reference number.

---o---

For office use

Received by	
Date received	
Allocation of tracking GTX or project number	

Eskom application form for a generator connection

Important information

Note 1: Eskom will provide a cost estimate letter after the following conditions are complied with:

- Completion of Part 1 of the application form
- Reasonable assurance of the right to develop on a proposed site, e.g. letter from landowner.
- EIA activities initiated, acknowledgement by DEA of application

Note 2: Once the application has been submitted Eskom may contact you to discuss the following:

- Where should facility be connected
- Grid configuration and voltages to use
- Estimated costs of connection – based on proper network configuration and equipment boundaries and details
- Grid capacity available at nearest network
- Fault levels at nearest network
- Define need to coordinate projects, determine requirements / risks for shared networks
- Any potential Eskom plans that may impact on project proposals
- Any impact (e.g. lead times) on requested timetable
- Eskom to determine interdependent projects in public domain (as far as possible) (liaising with EIA consultants, DEA, NERSA, etc.)

Note 3: Eskom will request Part 2 of this application form to be filled in and proceed with a budget quote only after the following conditions have been complied with, namely:

- Where the IPP intends to submit bids in a regulated IPP purchase programme:
  - ➢ The entity responsible for procurement has to first pre-qualify the application
- For IPP applications that do not intend to be part of a regulated bid programme:
  - ➢ Letter from NERSA indicating engagement on an application for a licence
  - ➢ Acceptance of the cost estimate conditions and the payment of the quotation fee
  - ➢ Completion of Part 2 of the application form
  - ➢ Proof of land ownership/permission to use the land obtained
  - ➢ EIA progress, i.e. appointment of EIA consultant and confirmation from DEA approving the Scoping Report or Basic Assessment Report as may be applicable
  - ➢ Proof of reasonable viability of the proposed technology regarding the primary energy source

Note 4:

In order to expedite your connection, you are advised to as far as possible integrate the EIA for the generation plant with the EIA for the Eskom connection assets. You need to discuss the requirements and coordination of the EIA for the Eskom connection assets with Eskom, e.g. route selection, design, evaluation and ranking of alternatives, EMP for the construction and operational phase(s), servitude conditions.

Part 1

DETAILS OF APPLICANT	
1. Full name of applicant(s) / lead developer Note that if there is more than one developer as much information as possible should be provided	
2. Date of submission	Y E A R M M D D
3. Do you intend to submit a bid in terms of a regulated power purchase procurement process (e.g REFIT)	YES / NO
4. If YES, provide the name of the programme	
5. If NO, indicate if its for own use and/or a wheeling transaction or other	
6. Address of the application(s) or in the case of a company or corporate body, the registered address	
Street:	
Street:	
Suburb:	
City:	
Post Code:	
7. Postal address P O Box:	
City and Country:	
Postal Code:	
8. Name of contact person	
9. Telephone number	
10. Alternative telephone number	
11. Fax number	
12. Email	

13. Contact address if different from above	
Street:	
Street:	
Suburb:	
City:	
Post Code:	
14. Please nominate a preferred name for this project/facility. Eskom will take this preferred name into consideration when determining the facilities station name but reserves the right to change it in order to avoid any potential for confusion with other projects or stations. Please use single word or short name for use in databases – to avoid potential abbreviations.	
GENERAL DETAILS	
15. Has the applicant previously had a study regarding this facility completed by Eskom.	YES.. ☐ NO.. ☐
16. If yes, please specify the title, date of issue and issuing department of the pre-feasibility study(s)	
17. Target connection date (this date will be used for connection assessment)	Y E A R M M D D
18. Provide preference in terms of construction of assets:	Eskom to construct assets.............................. ☐ Negotiated self-built project transferring assets to Eskom... ☐ Negotiated self-built project with developer retaining ownership of assets.......................... ☐

MAPS AND DIAGRAMS

19. Please indicate coordinates for on-site grid electrical connection. Use WGS84 datum coordinates in following format: dd°mm'ss.s" (Degrees, Minutes, Seconds)	**Generator facility:** Latitude S d d ° m m ' s s . s Longitude E d d ° m m ' s s . s **Electrical connection point (where known):** Latitude S d d ° m m ' s s . s Longitude E d d ° m m ' s s . s
20. Please provide reasonable assurance of the right to develop on a proposed site, e.g. letter from landowner	
21. Please provide a map, with the location of the facility, and relationship to an identifiable landmark clearly marked. The electrical connection (where known) must be clearly marked. Or provide the farm name(s), farm number and portion number – e.g. MyFarm 123/0, YourFarm 124/1 (Indicate multiple farm numbers as required. **Name of map attachment (soft copy)**	*If GIS shape files are available, that might be submitted as well (*.shp, *.shx, *.dbf, *.prj) Minimum file requirements might have to be listed.*
22. If known please provide the name of the Eskom substation from which existing supply (if applicable) is taken. Alternatively please provide the existing customer account number or nearest pole number.	
23. Please provide an electrical Single Line Diagram of the proposed facility detailing all significant items of plant including: a) Relevant voltage levels b) Interlocking c) Breakers d) Line/cable types and lengths e) Buscouplers f) Normally open points g) Earthing and synchronizing arrangements h) Protection Relay functions i) CT/VT ratios j) Generator transformer(s) k) Power factor correction devices	*If not available during initial application, Eskom may need to discuss boundaries and determine full requirements before quote can be prepared, otherwise Eskom will quote nearest HV bulk supply*

l) Location of in-house load feeders m) Grid connected transformer(s) n) Large motor loads (>1MVA) **Name of single line diagram attachment (soft copy)**	
TECHNICAL DATA	
24. Please indicate the required reliability of the connection, e.g. n-1	
25. Maximum Export Capacity (MEC) required. This is the maximum capacity, in MW to be injected into the Eskom system at the point(s) of connection determined as the net equivalent of the maximum generating capacity less the plant load.	_______________ MW _______________ Power Factor
26. Do you intend to construct the generation facility in phases? If so, please indicate the phases and the additional MEC required at each phase, e.g. Phase 1: 10 MW & Phase 2: 5 MW	
27. Indicate auxiliary supply requirements, e.g. CSP plant may require X% of peak production load e.g 5 MW Auxiliary for 50 MW generation.	
28. For an existing load provide the notified maximum demand (NMD) (typically for co-generation) of the load.	
29. State number of existing connecting circuits to the Distribution System	
30. Please provide details of load factor and the expected running regime (e.g. base load, peaking etc), including details of seasonal variances, if any.	

31. Please provide details of the technology type and number of generators units

Technology	No. of units	MW size	Total
Wind			
CSP trough			
CSP tower			
PV			
Concentrating PV			
Landfill			
Biomass			
Biogas			
Hydro or small Hydro			

	Coal			
	Gas			
	Specify Other			
32. EIA status	No EIA process yet……………………………… ☐ EIA initiated………………………………………. ☐ EIR / BA submitted for approval………………….. ☐ Environmental Authorisation received…………… ☐			

Part 2

Eskom will contact you to request this section of the application form to be completed once all the required conditions are fulfilled. This section is to be completed in order for Eskom to proceed with a Budget Quote.

Need to ensure different technology requirements are addressed, revision might have to follow.

ENVIRONMENTAL INFORMATION	
33. Is a waste license required and if so what is the status of the application?	
34. Is an emissions license required and if so what is the status of the application?	
35. Is an Integrated Water Use License required and if so what is the status of the application?	
36. Are there appeals and/or legal review against any environmental authorisation? If so, what is the status?	
37. Does the EIA application include all associated activities including that for the power line connection to the Eskom grid (state all listed activities applied for)	
38. If EIA and/or other environmental authorisations (waste, water, air quality) initiated, please provide name of environmental consultant.	
39. Proof of Land owner consent, to avoid requests for duplicate quotes on same land or very close proximity.	
40. Highlight potential risks of project, e.g. wetlands, proximity to airports, etc	
SITE DATA	
41. Status of negotiation for the acquisition of servitudes for power line route	
42. Please provide a site plan in an appropriate scale. This site plan	

should indicate: a) The proposed location of the connection point (normally at the HV bushings of the grid connected transformer) b) Generators c) Transformers d) Site buildings **Name of site plan attachment (soft copy):**	
PROJECT PHASES	
43. Provide project phases / time lines. Indicate short term and long term MW phasing of the project e.g. phase 1 a total of 50 MW with 1st turbine being commissioned in 2014 and final commissioning by 2016, phase 2 a total of 100 MW with 1st turbine being commissioned in 2016 and final commissioning by 2018. This will help to determine required network capacities and highlight potential development risks.	
CAPACITY REQUIREMENTS	
44. Provide details of construction supply requirements in kVA, voltage and location Please note that a separate application for the supply will be required in this regard.	
QUALITY OF SUPPLY	
45. The level of quality of supply / reliability to be indicated, e.g. n-1 requirements for lines and transformers. Developers are requested to be clear on this issue, as it will impact the costs and scope of the quote. Otherwise Eskom will assume a standard supply case with no redundancy. Redundancy requirements should be discussed with Eskom to ensure both parties have a common understanding of requirements and associated implications.	

FUEL SOURCE	
46. Proof of fuel source availability independently verified measurements is to be provided: • For wind, at least 1 year's worth of wind measurements • For coal, verified quantities/suppliers and security of water supply • For hydro, water source and levels. • For solar, DNI levels *Soft copy to be attached*	

GENERATOR DATA

Generator capabilities must comply with the South African Grid and/or Distribution Codes.

Please provide generator data for all **EXISTING and NEW** generators

Generators	**Unit 1**	**Unit 2**	**Unit 3**
47. Is the generator new or existing			
48. Manufacturer			
49. Type of generation plant (hydro, combined cycle, etc)			
50. Type of generator (synchronous/ asynchronous, salient pole/cylindrical rotor)			
51. Number of generators of type			
52. Generator voltage (kV)			
53. Generator rated MVA			
54. Maximum MVAR limit			
55. Rated Power Factor			
56. Expected generating capacity (while synchronised to the grid)			
57. Xd – synchronous reactance (p.u)			
58. X_d'' – Generator Direct Axis Subtransient reactance (unsaturated): (pu machine MVA base)			

59. X2 – Negative sequence reactance (p.u)			
60. X0 – Zero sequence reactance			
61. rstr – stator resistance (p.u)			
62. Inertial Constant			
63. Earthing of generator neutral (isolated, solidly earthed or resistively earthed)			
64. Neutral to Earth Resistance in Ohms			

MOTOR DATA

Please provide data for all existing motors rated above 1 MW (or several smaller motors rated more than 1 MW in total).

Motors	**Unit 1**	**Unit 2**	**Unit 3**
65. Type of motor (synchronous, asynchronous)			
66. Type of motor starting			
67. Number of motors of type			
68. Motor voltage (kV)			
69. Motor rated kVA			
70. For all synchronous motors: X_d'' – Motor direct axis Subtransient reactance (unsaturated), (p.u. machine MVA base)			
71. For all asynchronous motors: Locked rotor current (p.u. machine kVA base)			

GRID CONNECTION TRANSFORMER DATA

There are many types of transformers. This application form specifies two and three winding transformers. Please fill in relevant section. All impedances should be stated in % on transformer MVA base (for other winding configurations please specify on a separate page at least the information requested below).

Please note that the connection voltage is determined by Eskom taking into account the particulars of each development. If the connection voltage differs to that specified in the Application, Eskom will request new data corresponding to the new voltage level.

TWO WINDING TRANSFORMERS	**Transformer 1**	**Transformer 2**	**Transformer 3**
72. Is the transformer new or existing?			
73. Transformer rated MVA			
74. Transformer voltage ratio HV/LV (kV)			
75. Transformer vector group			
76. Earthing arrangement of star points (isolated, solidly earthed or resistively earthed & if resistively earthed – provide the resistance value) Note that this information is to be provided for each star point. If NEC/R earthing is used then the details of the NEC/R impedance is to be provided.			
77. Transformer positive sequence resistance (R,%)			
78. Transformer positive sequence reactance (X,%)			
79. Transformer zero sequence resistance (R_0%)			
80. Transformer zero sequence reactance (R_0%)			
81. Tap changer available(Y/N). If yes, provide the tap changer range and step size [±%]			
THREE WINDING TRANSFORMER			
Transformer 1	Is the transformer new or existing?		
	HV Winding	**MV Winding**	**Tertiary Winding**
82. Transformer rated MVA			
83. Transformer rated voltage (kV)			

84. Transformer vector group			
85. Earthing arrangement of star points (isolated, solidly earthed or resistively earthed & if resistively earthed (NEC or direct) specify and provide the resistance value)			
Transformer 2	Is the transformer new or existing?		
	HV Winding	**MV Winding**	**Tertiary Winding**
86. Transformer rated MVA			
87. Transformer rated voltage (kV)			
88. Transformer vector group			
89. Earthing arrangement of star points (isolated, solidly earthed or resistively earthed & if resistively earthed (NEC or direct) specify and provide the resistance value)			
	MVA Base	**Transformer 1**	**Transformer 2**
90. Transformer positive sequence resistance (R_{1HM}%) between HV/MV			
91. Transformer positive sequence reactance (X_{1HM}%) between HV/MV			
92. Transformer zero sequence resistance (R_{0HM}%) between HV/MV			
93. Transformer zero sequence reactance (X_{0HM}%) between HV/MV			
94. Transformer positive sequence resistance (R_{1HT}%) between HV/Tertiary			
95. Transformer positive sequence reactance (X_{1HT}%) between HV/Tertiary			
96. Transformer zero sequence resistance (R_{0HT}%) between HV/Tertiary			
97. Transformer zero sequence reactance (X_{0HT}%) between HV/Tertiary			
98. Transformer positive sequence resistance (R_{1MT}%) between MV/Tertiary			
99. Transformer positive sequence reactance (X_{1MT}%) between MV/Tertiary			

100. Transformer zero sequence resistance (R_{0MT}%) between MV/Tertiary			
101. Transformer zero sequence reactance (X_{0MT}%) between MV/Tertiary			
102. Transformer positive sequence resistance (R_{1HMT}%) between HV/(MV + Tertiary)			
103. Transformer positive sequence reactance (X_{1HMT}%) between HV/(MV + Tertiary)			
104. Transformer zero sequence resistance (R_{0HMT}%) between HV/(MV + Tertiary)			
105. Transformer zero sequence reactance (X_{0HMT}%) between HV/(MV + Tertiary)			
106. Tap changer available (Y/N). If yes, provide the tap changer range and step size [±%]			

CONSUMPTION DETAIL	
107. Provide expected consumption details for both during construction and operation phases as well as requirements during ramp up phase.	

EXPANSION PLANS	
108. Provide Future Site Development Plans where available.	

Eskom Distribution

STANDARD

Document Classification: Controlled Disclosure

Title: **DISTRIBUTION STANDARD FOR THE INTERCONNECTION OF EMBEDDED GENERATION**

Reference:	**34-1765**
Document Type:	**DST**
Revision:	**0**
Published date:	**MARCH 2008**
Total pages:	**38**
Review date:	**MARCH 2011**

COMPILED BY	APPROVED BY	FUNCTIONAL RESP	AUTHORISED BY
		2008/03/07	*Signed*
S J VAN ZYL	**B MATJILA**	**P R GROENEWALD**	**MN BAILEY**
DT CT	DT CT Integration	for TESCOD	**CMDT for MD (Dx)**

Contents

Page

Foreword

This standard sets out the minimum technical and statutory requirements for the connection of Embedded Generators to Eskom Distribution's electrical networks.

This standard serves to fulfil Eskom Distribution's obligation under Section 8.2 (4) of the South African Distribution Code: Network Code:

> "The Distributor shall develop the protection requirement guide for connecting Embedded Generators to the Distribution System to ensure safe and reliable operation of the Distribution System".

For information on pricing and contractual requirements with regard to the connection and operation of Embedded Generators, the user is referred to Distribution Policy *34-193: Purchasing of energy from embedded distribution generators*.

In this document, references to "Eskom" shall mean the Distribution Division of Eskom Holdings Ltd. In some instances, the term "Distributor" has been used in place of "Eskom" in anticipation of the standard's broader application in the electricity distribution industry in South Africa. In this context, "Distributor" includes Eskom Distribution, and any municipal entity that might adopt this standard.

Revision history

Date	Rev.	Compiler	Remarks
Sept 2007	A	S.J. van Zyl	Original issue for work-group comments.
Nov 2007	B	S.J. van Zyl	Extensive revision to incorporate work-group feedback.
Nov 2007	C	S.J. van Zyl	Revised Section 4.5.4.2 (SCADA Controls) to indicate possible requirement of Eskom remote control of interconnection circuit-breaker.
			Rewrote Section 4.6.2 (Quality of Supply).
Dec 2007	D	S.J. van Zyl	Rewrote Section 4.5.3 (Metering).
			Document issued for TESCOD comments.
Feb 2008	E	KEC	Incorporated changes agreed upon by work-group and KEC.
Mar 2008	0	S.J van Zyl	Document published.

Authorisation

This document has been seen and accepted by:

Name	Designation
M N Bailey	Corporate Manager - Divisional Technology
P R Groenewald	Technology Development Manager - Control Technologies
V Singh	Technology Development Manager - Power Plant
K Krafft	Distribution Network Operations Committee Chairman

This standard shall apply throughout the Distribution Division of Eskom Holdings Limited.

Acknowledgement / Development team

This document is based upon Eskom Guideline ESKAGAAG2 "Minimum requirements for the connection of non-Eskom generating plant to the Eskom electrical networks" that was compiled in 1995 by a working group led by Graeme Topham. ESKAGAAG2 in turn was based upon Engineering Recommendation G.59 "Recommendations for the connection of private generating plant to the Electricity Boards' Distribution Systems" issued by the Electricity Council, and prepared for use in relation to the United Kingdom's system.

The present document constitutes a complete revision of the old document, with contributions made by the following working group members:

Mobolaji Bello	IARC Planning
Chris Billingham	Southern region Network Optimisation
Derrick Boltt	Southern region system support (Hydro gen)
Kenneth Brown	IARC Control Technologies - Telecontrol
Teresa Carolin	System Operator
Clinton Carter-Brown	IARC Planning
Johan Crous	Transmission
Hendri Geldenhuys	IARC Technology Development
Henri Groenewald	IARC Control Technologies - Metering
Thomas Jacobs	IARC Control Technologies - DC & Auxiliary
Brett Matjila	IARC Control Technologies - Integration/Telecontrol
Reggie Moleko	North West region Project Management
Avinash Ramdhin	Eastern region Planning
Melanie Schilder	ERID, Quality of Supply
Faans van Zyl	Northern region Planning
Stuart van Zyl	IARC Control Technologies - Protection
Machiel Viljoen	Generation technology
Frans Wahl	Northern region T&Q

Significant contributions made by consulting engineers representing KE Consortium are also acknowledged:

Ron Coney

Geoffrey Lee

Izak van der Merwe

Keywords

Embedded Generator, Co-generator, Interconnection

Bibliography

Fieldstone report for NERSA. Development of Regulatory guidelines and qualifying principles for co-generation projects. November 2006.

IEEE 1547: 2003, Standard for Interconnecting Distributed Resources with Electric Power Systems.

N. Jenkins, R. Allan, P. Crossley, D Kirschen, G Strbac. *Embedded Generation*. IEE Power and Energy series 31. 2000.

Network Protection & Automation Guide, Alstom, July 2002.

ESB Networks, Conditions Governing Connection to the Distribution System, Doc Ref: DTIS-250701-BDW, March 2006.

ESKASACL2 Rev.4, Terminology relating to the direction of power flow.

ESKASACL3 Rev.2, Functional measurement requirements for network management.

1. Scope

This standard sets out the minimum technical and statutory requirements for the connection of Embedded Generators to the Eskom Distribution Medium Voltage and High Voltage electrical networks.

This document applies to systems where the generating plant may be paralleled with the Eskom Distribution network either permanently, periodically or temporarily. This document does not apply to generating plant that does not operate in parallel with the Eskom grid (e.g. own use customer generators or stand-by generators). Eskom's requirements for stand-by generators are detailed in ESKAGAAG2. Requirements of ESKAGAAG2 pertaining to generators that are operated in parallel with the Eskom Distribution network are superseded by the requirements of this document.

The intention is that this interconnection standard, or one of broadly similar requirements, shall also apply to Embedded Generators connecting to municipal electricity networks which, in turn, are supplied by Eskom. This way, technical requirements for the point of connection between the supply authority and the Embedded Generator need not be replicated between Eskom and the supply authority.

The current revision of this standard does not apply to generator interconnections at Low Voltage, or generators of capacity less than 100kW. Any sources of generation, that are not covered in this standard, seeking parallel connection to the Distributor, shall be subject to special application.

The standard provides for generic interconnection requirements and shall be applicable to all different types of generators, prime movers etc. In certain cases (e.g. wind generating technology) it may be necessary to supplement the requirements of this standard with additional technology-specific requirements.

For information on pricing and contractual requirements with regard to the connection and operation of Embedded Generators, the user is referred to Distribution Policy 34-193: *Purchasing of energy from embedded distribution generators*.

2. Normative references

Parties using this standard shall apply the most recent edition of the documents listed below:

South African Legislation:

Electricity Regulation Act 6 of 2006.

Occupational Health and Safety Act No 85 of 1993.

South African Distribution Code (all parts).

South African Grid Code (all parts).

International and National Standards:

IEC 62271-100: High-voltage alternating-current circuit-breakers.

IEEE 1547.1, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

NRS 029, Current transformers for rated a.c. voltages from 3,6kV up to and including 420kV.

NRS 030, Electricity distribution – Inductive voltage transformers for rated a.c. voltages from 3,6kV up to and including 145kV for indoor and outdoor applications.

NRS 031, Alternating current disconnectors and earthing switches (above 1000V).

NRS 037-1, Telecontrol Protocol for stand-alone remote terminal units.

NRS 048-2, Electricity Supply – Quality of Supply Part 2: Voltage characteristics, compatibility levels, limits and assessment methods.

NRS 048-4, Electricity Supply – Quality of Supply Part 4: Application guidelines for utilities.

NRS 054, Rationalized User Specification – Power Transformers.

NRS 057-4, Electricity metering Part 4: Code of practice

SANS 1019, Standard voltages, currents and insulation levels for electricity supply.

International and National Standards (Protective Relays):

IEC 60068-2-1, Environmental testing — Part 1 Cold.

IEC 60068-2-2, Environmental testing — Part 2 Dry Heat.

IEC 60068-2-30, Environmental testing — Part 30 Damp heat, cyclic (12h + 12h cycle).

IEC 60255-30, Electrical relays Part 3: Single input energizing quantity measuring relays with dependent and independent time.

IEC 60255-6, Electrical relays Part 6: Measuring relays and protection equipment.

IEC 60255-21, Electrical relays Part 21 Vibration, shock, bump and seismic tests on measuring relays and protection equipment (All sections).

IEC 60255-22, Electrical relays Part 22 Electrical disturbance tests for measuring relays and protection equipment (All sections).

SANS IEC 60529, Degrees of protection provided by enclosures (IP Code).

SANS IEC 61000-4, Electromagnetic compatibility (EMC): Test and measurement techniques (All sections).

Eskom Standards:

ESKPVAAN6, *Apportioning of quality of supply parameters*.

ESKASAAW2, *Generator excitation system standard for power station*.

Distribution Standards:

Note: in cases where documents are still to be re-published using the revised document numbering system, the future document classification and number is indicated in brackets following the existing reference code.

SCSASAAL9, MV and LV Reticulation Earthing.

SCSASACB6 (DST 34-906), Medium Voltage Earthing Practice.

DSP 34-392, Specification for digital transducer based measurement system for electrical quantities.

DST 34-462, Standard design for Distribution protection schemes.

DST 34-540, Distribution Standard for the application of Sensitive Earth Fault protection.

DST 34-542, Distribution voltage regulation and apportionment limits.

Distribution Test and Maintenance Procedures:

Note: in cases where documents are still to be re-published using the revised document numbering system, the future document classification and number is indicated in brackets following the existing reference code.

SCSPVAAS9 (DPC 34-1039), Procedure for the maintenance of d.c. supply equipment.

DISPVAEB6 (DPC 34-1033), Voltage transformer test procedure.

DISPVAEC6 (DPC 34-1035), Current transformer test procedure.

DISPVAED1 (DPC 34-1395), Over current and Earth fault relay test procedure.

DISPVAEF9 (DST 34-1043), Maintenance of vantage nickel cadmium cells.

DISPVAEG1 (DST 34-759), Maintenance of L/M/H range nickel cadmium batteries.

DISPVAEQ6 (DPC 34-1036), Procedure for testing of Circuit-Breakers.

DPC 34-1034, Isolator test procedure.

3. Definitions and abbreviations

3.1 Definitions

3.1.1 Co-generator: a source of electrical power that complies with types **I**, **II** or **III** below:

Type I: Projects utilizing process energy which would otherwise be underutilized or wasted (e.g. waste heat recovery).

Type II: Primary fuel based generation projects which produce, as part of their core design, other usable energy in addition to electricity (e.g. Combined Heat and Power projects).

Type III: Renewable fuel based projects where the renewable fuel source is both the primary source of energy, and is a co-product of an industrial process (e.g. use of bagasse and/or forestry waste from the sugar and paper industries).

3.1.2 Distributor: Eskom Distribution and any public electricity supply utility (e.g. municipality) that might adopt this standard.

3.1.3 DNP3: (Distributed Network Protocol) is the preferred communications protocol used for the control of electricity on transmission and distribution networks as per NRS 037-1.

3.1.4 Embedded Generator's authorized person: The person appointed by the Embedded Generator in terms of the appropriate act to sanction the return to service of plant after major maintenance or repair.

3.1.5 Embedded Generator's responsible person: The person appointed by the Embedded Generator in terms of the appropriate act to receive communications and take necessary action in accordance with instructions from the system controller.

3.1.6 Embedded Generator: a legal entity that operates or desires to operate a generating plant that is or will be connected to the Distribution network. This definition includes all types of connected generation, including co-generators and renewables. Alternatively, the item of generating plant that is or will be connected to the Distribution network.

3.1.7 High voltage: the set of nominal voltage levels greater than 44 000V and up to and including 220 000V. [SANS 1019]

3.1.8 Island: a portion of the utility's distribution network energized solely by one or more Embedded Generators.

3.1.9 Loss-of-grid protection: Relay protection designed to detect the loss of connection to the utility network and trip the Embedded Generator to prevent it from energizing an island.

3.1.10 Low voltage: nominal voltage levels up to and including 1kV. [SANS 1019]

3.1.11 Medium voltage: the set of nominal voltage levels greater than 1 000V and up to and including 44 000V. [SANS 1019]

3.1.12 Point of Common Coupling (PCC): The electrical node on the Distributor's network, electrically nearest to a particular Embedded Generator's installation, at which more than one customer is or may be connected or metered.

3.1.13 Point of Utility Connection (PUC): The circuit-breaker and associated ancillary equipment (instrument transformers, protection, isolators) that connects the Embedded Generator facility to the Distribution network. The PUC forms the point of demarcation between the assets of the Distributor, and those of the Embedded Generator.

3.1.14 Point of Generator Connection (PGC): The circuit-breaker and associated ancillary equipment (instrument transformers, protection, isolators) that connects a generator to any electrical network. Where more than one such circuit-breaker exists, the PGC shall be the circuit-breaker electrically closest to the generator.

3.1.15 Secure Supply Point (SSP): That point on the Distributor's network at which a single upstream contingency will not result in the islanding of an Embedded Generator with a portion of the supply network.

3.1.16 Stand-by generator: a legal entity that operates or desires to operate a generating plant so as to provide a stand-by supply in the event of a loss of the grid electricity supply. The stand-by generator's plant will only be connected to the Distribution network for maintenance load testing, and only if the requirements of this standard have been fulfilled.

3.1.17 System controller: The person on shift at the Eskom Control Centre.

3.2 Abbreviations

3.2.1 ac: Alternating Current

3.2.2 ARC: Auto Reclose

3.2.3 CB: Circuit-Breaker

3.2.4 CT: Current Transformer

3.2.5 DC or **dc**: Direct Current

3.2.6 EG: Embedded Generator

3.2.7 HV: High Voltage

3.2.8 LV: Low Voltage

3.2.9 MCOV: Maximum Continuous Over Voltage

3.2.10 MV: Medium Voltage

3.2.11 NEC/R: Neutral Earthing Compensator with Resistor

3.2.12 PCC: Point of Common Coupling

3.2.13 PGC: Point of Generator Connection

3.2.14 pu: per unit

3.2.15 PUC: Point of Utility Connection

3.2.16 QOS: Quality of Supply

3.2.17 SCADA: Supervisory Control and Data Acquisition

3.2.18 SSP: Secure Supply Point

3.2.19 SEF: Sensitive Earth Fault

3.2.20 ROCOF: Rate of Change of Frequency (protection)

3.2.21 RTU: Remote Terminal Unit

3.2.22 VT: Voltage Transformer

4. Requirements

4.1 General requirements

By way of introduction to the detailed technical requirements of subsequent sections, this section serves to outline the broad principles on which the standard is based.

4.1.1 Open access to networks for safe operation

An Embedded Generator (EG) may connect to the utility network at any time provided safety can be assured.

EGs are required to operate within legal power quality limits. Eskom and the Municipalities are held liable for deviations from legal power quality limits that their customers may experience. Therefore no EG shall continue to energise any portion of the network that has been unintentionally islanded on a section of the Distributor’s network. Disconnection shall occur at the PUC upon detection of an unintentional island. The primary concern is for human safety, plant protection and power quality, in that order.

The Eskom National System Operator and/or Regional Control Centres reserve the sole right to permit the operation of intentional islands within the Eskom Distribution network. EGs permitted to operate intentional islands shall adhere to the procedures and operating requirements as stipulated by the System Operator/Regional Control Centre.

The EG shall be responsible for protecting his/her own assets. Notwithstanding this, unnecessary tripping of EGs presents quality of supply and network stability problems and should be avoided where possible.

Safe operation of the distribution network, power system stability and security of supply are paramount and require that the Distributor be responsible for specifying predetermined minimum protection, measurements and SCADA requirements to the EG.

It is the responsibility of the EG to establish synchronism between the EG’s network and the Distributor’s grid supply prior to paralleling the two networks. Detailed technical and statutory requirements for synchronising onto the power network are stipulated in Section 4.4.2.

The neutral earthing philosophy to be applied shall be in accordance with Section 4.5.3. The neutral points of generator transformer windings galvanically connecting the EG to a Distributor at HV shall be solidly/effectively earthed, while those of MV connected generators/transformers will not be earthed.

NOTE: Partially graded neutral insulation may not be used for generator transformers for connection to a utility network at MV.

Where it is necessary for Eskom to provide any electrical lines, or other electrical plant, or for any other works to be carried out to enable the connection of embedded generation to its networks, Eskom may require payments in respect of any expenditure incurred in carrying out this work.

4.1.2 Redundancy

The failure of any single component or system will not result in unsafe operation. Thus:

a) No generator shall be connected to the Distributor’s network via a single circuit-breaker.

b) Primary system protection provided at the PUC shall be duplicated elsewhere within the EG’s facility. Refer to Section 4.6.2.1.

c) Primary loss of grid protection shall be provided at the PUC, but this protection shall be backed-up elsewhere in the Distributor's network (e.g. live-line close blocking).

d) The DC supplies at the Point of Utility Connection (PUC) and Point of Generator Connection (PGC) shall be independent of one another and shall be subject to continual monitoring.

4.1.3 Ownership

PUC represents the point of demarcation between the Distributor and the EG, examples of which are given in Annex A. This standard does not stipulate the specific ownership of plant used at the PUC. The only exceptions are the Eskom metering equipment, remote terminal units and communications infrastructure. These will be Eskom owned, operated and maintained. Specifics regarding the ownership of other plant, including the instrument transformers, must be agreed between the participants. Nevertheless, the following ownership regimes are preferred:

1. The EG owns, operates and maintains the PUC circuit-breaker. Specifically, the EG shall own the circuit-breaker and associated instrument transformers and protection and the isolator to be installed between the PUC circuit-breaker and the Distributor's network. The specific point of demarcation between the utility and the EG shall be the Distributor-side terminals of the isolator. The clamps or cable terminations made at this point shall be the responsibility of the Distributor.

OR

2. The Distributor owns, operates and maintains the PUC equipment. Specifically, the Distributor shall own the circuit-breaker and associated instrument transformers and protection and the isolator to be installed between the PUC circuit-breaker and the EG's facility. The specific point of demarcation between the utility and the EG shall be the EG-side terminals of the isolator. The clamps or cable terminations made at this point shall be the responsibility of the EG.

Each party shall be responsible for the commissioning, operation and maintenance of plant installed on their side of the PUC. The Eskom-owned metering equipment, remote terminal units and communications infrastructure will be commissioned, operated and maintained by Eskom irrespective of its specific location.

All equipment at the PGC, except the Eskom metering, telecontrol and communications equipment, shall be owned, operated and maintained by the EG.

Where the PUC and the PGC are the same point, Eskom shall install a second "back-up" circuit-breaker in line with the PUC/PGC circuit-breaker. The PUC/PGC shall fully comply with the PUC and PGC requirements of Section 4.6. The Eskom-owned circuit breaker shall provide the necessary back-up protection functions as indicated in Section 4.6.2.1.

4.1.4 Autonomy

Each party is to design, protect and maintain their own assets to industry best practice. The PUC represents the point of demarcation, and is a point of common interest. The standard provides minimum technical requirements for the equipment and functionality to be provided at the PUC. The PGC provides back-up to the protection functions of the PUC, and is also subject to minimum technical requirements imposed by the Distributor.

All of the required PUC functionality shall be provided at the PUC or in exceptional circumstances at an alternate location agreeable to both parties. All of the required functionality shall be provided at the same location. Any changes to the PUC or PGC will be agreed between the parties prior to implementation.

4.1.5 Audits

Owing to the strong interdependence between the EG and the Distributor, and so as to avoid duplication of equipment as far as possible, either party is entitled to perform technical audits of the other's equipment relevant to the interconnection. This specifically includes the PUC and PGC equipment and the metering equipment. Audits shall be performed with a minimum of 24 hours notice.

4.2 Legal requirements

The Electricity Regulation Act 6 of 2006 details the legislative requirements with regard to the generation, transmission, distribution and trading of electricity. In this regard, the operator of a grid-connected generator is required to hold a licence from the Regulator (Section 8). Operators of non-grid connected generators are not required to hold a license provided that the plant is designated only for own-use, and is not used commercially (Schedule II).

Section 47 (1) of the Act makes provision for the Regulator to, following consultation with licensees and other participants, set guidelines and publish codes of conduct and practice. The South African Grid Code and Distribution Code are examples of such codes of practice.

The South African Distribution Code includes a section of specific requirements for the connection of EG's. The Distribution Code (Section 8.4.1.1 (1)) requires that all EG's of nominal capacity greater than 10MVA shall in addition to the requirements of the Distribution Code, also comply with Section 3.1 of the South African Grid Code: Network Code.

Under Section 8.2 (4) of the South African Distribution Code: Network Code, each South African Distributor is required to develop a protection requirement guide for the connection of EG's. This standard serves to fulfil Eskom Distribution's obligation in this regard.

Each EG installation must be designed to comply with the Grid Code, Distribution Code and Eskom requirements detailed in this standard.

4.3 Operational safety

4.3.1 Operational and safety aspects

The EG must obtain from the relevant Distributor a written agreement to operate generating equipment in parallel with the Distributor's network. A plant diagram and schedule giving details of ownership, operation, maintenance and control of substation and generation plant shall be prepared, as agreed between the parties. The schedule shall include:

a) Names and contact details of responsible persons from both parties.

b) A description of any operating limitations with regard to the plant and/or the interconnection.

The EG shall ensure that all operating personnel are competent in that they have adequate knowledge and sound judgment to take the correct action when dealing with an emergency. Failure to take correct action may jeopardize the EG's and/or Eskom's systems.

EG shall ensure:

a) Except in the case of agreed unmanned facilities, that a responsible person is available at all times to receive communications from Eskom's system controller so that emergencies requiring urgent action by the EG can be dealt with adequately. Where required by Eskom, it will also be a duty of the EG's staff to advise the Eskom system controller immediately of any abnormalities that occur on the Embedded Generating plant which have caused, or might cause, disturbance to the Eskom system;

b) In the case of unmanned facilities that Eskom will have remote control facilities to trip and isolate the generator.

c) That where it is necessary for his employees to operate Eskom equipment (where provided), they have been designated in writing by Eskom as an "authorized person" for this purpose. All operations on the Eskom equipment must be carried out to the specific instructions of the Eskom system controller. In an emergency, a switch can be opened by anybody, without prior agreement in order to avoid danger. The operation must be reported to the Eskom system controller immediately afterwards.

4.3.2 Means of isolation

Every installation or network which includes an Embedded Generating plant must include a means of isolation, suitably labelled, capable of disconnecting the whole of the Embedded Generating plant infeed from the Distributor's network.

The means of visible-break isolation must be lockable, in the open position only, by a padlock. Rackable indoor metal clad switchgear is deemed acceptable for this function, provided that it is lockable.

The EG must grant Eskom rights of access to the means of isolation without undue delay. Eskom shall have the right to reasonably isolate the EG's network connection at any time as network conditions dictate. The means of isolation will normally be installed at the PUC, but may be positioned elsewhere with Eskom's agreement.

4.4 Generator capabilities and operation

4.4.1 Excitation control and governor requirements

The Distribution Code: Network Code requires all EG's of nominal capacity greater than 10MVA to comply with Section 3.1 of the South African Grid Code: Network Code. The requirements of the Grid Code apply specifically to synchronous generators/machines and not asynchronous generators. Section 3.1.3 of the same document stipulates the excitation system requirements for synchronous generators.

Synchronous generators shall be equipped with excitation controllers capable of connecting and operating on a network that may be subjected to voltages in a range between 95% and 105% of the nominal voltage.

Induction or asynchronous generators, which are not capable of voltage or reactive power control, are consumers of reactive power. The EG must thus supply reactive power compensation to correct the power factor to within ±0.90 at the PGC, unless otherwise negotiated with Eskom.

Inverter-type generating equipment can control its power factor over a wide operating range, typically ±0.75. Thus an EG connecting to the Distributor's network via an inverter shall be capable of adjusting the power factor to within a range of ±0.90, unless otherwise negotiated with Eskom.

The EG shall consult the Distributor's standards and shall familiarise themselves with the local operating conditions. The EG's normal operation shall not cause conditions on the network which are outside the accepted power quality standard limits. The generator's excitation control mode must best suit the local environmental conditions.

All EG units of nominal capacity larger than 50MVA shall conform to the continuous and short-duration frequency operating limits outlined in the Section 3.1.6 (Governing) of the South African Grid Code: Network Code. The Code states that the continuous operational range for the generation unit is between 48.5 Hz - 51.5 Hz. The same section of the code also stipulates the frequency vs. guaranteed operating time capability, as well as the requirements for governor control using a 4% droop characteristic, required by turbo-alternators.

EG units of nominal capacity ranging from 10MVA to 50MVA may or may not be required to comply with the requirements of Section 3.1.6 of the Grid Code: Network Code. Clarity on this issue shall be resolved in consultation with the Eskom System Operator/Regional Control Centre.

EG units of nominal capacity less than 10MVA are not required to comply with the governing and continuous frequency operational requirements as stipulated above.

4.4.2 Synchronization

All Embedded Generating plant other than mains excited asynchronous machines must be synchronized with the Eskom supply prior to making the parallel connection.

The voltage between the unit and the system prior to synchronizing shall not differ by more than the values specified in Table 1. Where the mode of operation of generating equipment is such that synchronizing of a machine or machines will occur at intervals of less than two hours, the voltage fluctuation at the PGC resulting from the generation capacity being connected shall not exceed 1 %.

Automatic synchronizing equipment shall be the preferred method of synchronizing. However, manual synchronization of the EG units is permissible on condition that synchronizing check relays (three phase comparators) are used by the EG in conjunction with the manual synchronizing, and that the EG's responsible person is authorised in writing to do so.

It is the responsibility of the EG to provide synchronizing facilities. Typical limits for synchronising parameters are given in Table 1 below:

Table 1. Typical synchronising parameter limits (IEEE 1547 p.12)

Aggregate rating of EG (kVA)	**Maximum Frequency Difference** Δf (Hz)	**Maximum Voltage Difference** ΔV (%)	**Maximum Phase Angle Difference** $\Delta\phi$ (Degrees)
S < 500	0.3	10	20
500 ≤ S < 1500	0.2	5	15
S ≥ 1500	0.1	3	10

4.4.3 Islanded operation

Intentional islanding of a generator with part of the Eskom network is not permitted unless specifically agreed to with Eskom.

For unintentional islanding, where a generator is synchronised with the Eskom network at the time that an upstream Eskom circuit-breaker opens, severing the connection between the generator supply and the grid supply, the generator shall cease to energise the local Eskom network within 2 seconds.

4.4.4 Fault ride through capabilities

This section is under consideration for a future revision of the standard.

4.5 Requirements for the Utility Network interface

4.5.1 Fault Infeed

When it is proposed to install Embedded Generating plant, consideration must be given to the contribution that the plant will make to the fault levels on the Distributor's network. The design and safe operation of the EG's and Distributor's installations depend upon accurate assessment of the fault contributions made by all plant operating in parallel at the instant of the fault. The EG shall discuss this with the relevant Distributor at the earliest possible stage. The EG shall provide all relevant information for the Distributor to be able to model the generator and its contribution to fault current.

Should the EG result in the increase of fault levels to such an extent that the Distributor's or customer's plant at the PCC is placed at risk, the EG shall apply fault current limiting measures to ensure that the fault levels are maintained at acceptable levels. The fault limiting solution applied shall be presented to the Distributor for acceptance prior to implementation.

4.5.2 Quality of Supply

Voltage quality parameters, i.e. voltage regulation, unbalance, flicker and harmonic distortion, at the PCC and other customer points of supply, may not exceed the compatibility levels or limits as prescribed in NRS 048-2 and Distribution Standard 34-542 due to operation of the EG. The rapid rate of voltage change limits, as set out in NRS 048-4, shall also not be exceeded by the EG. The actual polluting voltages and/or currents generated by the customer/EG will be apportioned as per standard Eskom apportioning methods (described Eskom document ESKPVAAN6 and NRS 048-4).

4.5.3 Neutral Earthing

This standard stipulates the neutral earthing philosophy to be applied on EG networks that are galvanically connected to the Eskom supply network. Adequate earthing of networks at other voltage levels within the EG plant is the responsibility of the EG, and is not stipulated herein.

The Distributor's networks may use effective, resistive or reactive earthing methods depending on the voltage level and local requirements. The magnitude of the possible earth fault current will depend on which of these methods is used. The EG's earthing arrangement must therefore be designed as follows:

a) In consultation with the Distributor such that the EG's system is compatible with the Distributor's system.

b) Such that the EG's plant safety is not compromised due to the above requirement.

The actual earthing arrangements will also be dependent on the number of machines in use and the EG's system configuration and method of operation.

Earthing may be achieved by the use of a busbar earthing transformer (e.g. NEC/R), the use of the star point of the generator, or by earthing the star point of the generator transformer.

Care should be taken with multiple generator installations to avoid excessive circulating third harmonic currents. It may therefore be necessary to restrict the earthing to the star point of a single machine and provide automatic transfer facilities of the generator star point earth to another machine in the event of the selected machine being tripped. The use of suitable generator transformers with delta windings may provide a means of avoiding excessive circulating harmonic currents.

Where used, the winding configuration of the generator transformer (e.g. Delta-Star, Star-Delta etc.) shall be such that zero sequence currents on the Distributor's network and EG systems are decoupled from one another.

Where transportable or mobile generating plant is used, it is essential that all earthing connections to the generator are effectively made prior to making off any phase connections or running the generator.

Under conditions of separation between the Distributor's network and the EG system, care must be taken to not run any part of any of the systems unearthed.

HV networks

HV networks are required to be effectively earthed. The HV generator transformer winding shall therefore cater for solid earthing of the neutral using a Star-connected winding at the side of the transformer connecting to the Distributor's network.

MV networks

Eskom's MV networks are resistively earthed at the source substation so as to limit earth fault currents to the typical ranges: less than 720A (Rural networks) and less than 1600A (urban networks). Refer to Distribution Standard SCSASACB6: *Medium Voltage Earthing Practice* for further information.

The preferred neutral earthing philosophy for MV-connected generators or generator transformers is that the MV neutral point be left un-earthed. This will serve to avoid issues of earth fault relay de-sensitization, as well as avoiding "circulating" zero sequence or triplen (i.e. 3rd, 6th, 9th etc.) harmonic currents between the distant earth connections.

With the EG not earthing the MV network, and in the case of the source tripping as a result of a line earth fault, the healthy line voltages will be raised to full phase-to-phase values. In addition, there is a possibility of resonant over-voltages arising from the generator transformer reactance and the line capacitance. Possible damage to surge arresters may be avoided by specifying arrester Maximum Continuous Over Voltage (MCOV) values at the full phase-to-phase voltage.

In the case of an agreed upon intentional island, the conditions of which are stipulated in Section 4.4.3, the MV star-point shall be earthed. The EG shall ensure that the star-point is resistively earthed the instant prior to intentional islanded operation, as per Eskom standard. The earth shall be disconnected prior to the reconnection to the grid for resumption of parallel operation.

In the absence of a MV neutral earthing point at the point of connection, line earth faults will be detected by phase-to-earth under-voltage and/or residual over-voltage protection (i.e. a neutral to earth VT), and also over-frequency protection as a result of the generator supplying a lightly loaded or unloaded island. Under-voltage protection located on the generator-side of the generator transformer may not be adequate on account of the voltage balancing effect of the transformer (depending on the winding configurations).

4.5.4 Prevention of out of synchronism closure

The Distributor shall provide synchronism check and/or live-line close blocking functionality on all circuit-breakers and/or pole-mounted switchgear between the Embedded Generator's PUC and the SSP. This shall serve as additional security against possible out-of-phase closure onto an islanded EG. Synchronising (auto or manual) shall remain the sole responsibility of the EG and this shall be done at the PUC, PGC, and/or elsewhere within the EG's plant.

4.5.5 Requirements for directional protection

In many cases, the fault current infeed from the EG to network faults will be a small fraction of the grid-supplied fault current. The fault current infeed from the generator may also decay rapidly with time. As a result, it is unlikely that the traditional non-directional overcurrent, earth fault and SEF protection applied to radial MV and HV Distribution networks will be rendered unsuitable by the presence of an EG. This must, however, be confirmed during the design phase of each project.

4.5.6 Auto-reclose dead-time settings on networks with Embedded Generation

Auto-reclose dead-time settings on all circuit-breakers between the PUC and the SSP shall be increased from the standard 3 seconds to at least 5 seconds so as to provide additional margin for the detection and isolation of possible power islands.

4.6 Requirements at the PUC and PGC

This section details the requirements for the primary- and control plant equipment to be installed at the PUC and PGC.

4.6.1 Primary equipment

4.6.1.1 Current Transformers

Current transformers shall be specified in accordance with NRS 029. Protection CTs shall be in compliance with the protection relay manufacturer's requirements with regard to accuracy class. Metering circuits shall use Class 0.2 CTs. Refer to Section 4.6.4 for further requirements with respect to metering CT cores for Eskom use. Measurement circuits shall use Class 0.2 CTs or protection class CTs. Protection class CTs will typically be used for measurements where the measurement data is derived from a protection relay instead of a stand-alone transducer.

4.6.1.2 Voltage Transformers

Voltage transformers shall be specified in accordance with NRS 030. Metering and measurement circuits shall use VTs of accuracy class 0.2. Protection VTs shall be of Class 3P accuracy. The VTs shall be burdened so as to ensure accuracy within class definitions.

4.6.1.3 Isolator/Disconnector

The isolator fulfilling the requirements of Section 4.3.2 shall be specified in accordance with NRS 031.

The isolator shall include at least one normally-open and one normally-closed auxiliary status contact for use by Eskom for remote indication purposes. The contacts shall operate in the fully-open and fully-closed positions of the primary contacts respectively. These contacts may not be provided by a separate relay or device not forming an integral part of the isolator.

The isolator shall be lockable using a standard Eskom padlock:

a) Case: 35mm – 38mm high, 28mm – 40mm wide, 18 – 20mm thick; and

b) Shackle: 6mm diameter, 30mm-34mm length (in the locked position), 20mm width (minimum).

(Dimensions from Distribution Specification DISSCAAM8 Rev.1 *Specification for Master Locks and Master Keys for Electrical and Related Equipment*)

4.6.1.4 Circuit-Breakers

The circuit-breakers shall comply with the requirements of IEC 62271-100 and shall be suitably rated to interrupt the maximum prospective fault current at the PUC or PGC as appropriate.

To allow for network growth the fault interruption capability of circuit-breakers shall be chosen to be at least 30% higher than the maximum fault levels calculated in the initial integration study for the EG plant.

The maximum circuit-breaker operating times shall be as follows:

a) HV network: < 60ms

b) MV network: < 100ms

The circuit-breakers shall have a “maximum over-voltage” factor for switching conditions of IEC 62271-100 of 2.5pu or higher.

The circuit-breakers shall include at least one normally-open and one normally-closed auxiliary status contact for use by Eskom for remote indication purposes. These contacts may not be provided by a separate relay or device not forming an integral part of the circuit-breaker

4.6.2 Protection

4.6.2.1 Protection Overview

This section details the protection functionality that shall be installed at the PUC, irrespective of whether the same functionality is installed elsewhere within the EG’s plant. Protection requirements are also stipulated for the PGC, providing back-up to the PUC protection. The protection systems shall provide adequate protection of the parts of the Distributor’s network that could be supplied by the EG, either in parallel operation or under conditions of the EG supplying an intentionally islanded portion of the Distributor’s network.

Further, the protection systems shall:

a) inhibit connection of the generating equipment to the Eskom supply unless all phases of the Eskom supply are energized and operating within the agreed limits;

b) disconnect the generator from the system when a system abnormality occurs that results in an unacceptable deviation of the voltage or frequency at the point of connection; and

c) prevent un-intentional islanding of the EG with a portion of the Distributor’s network.

Table 2 includes a summary of specific protection functions that shall be provided at the PUC.

Note: The requirements of this section indicate Eskom’s minimum requirements at the PUC and PGC so as to safeguard the Distributor’s network in the event of faults within the EG’s facility, or faults on the Distributor’s network with a fault current contribution from the EG. In keeping with the requirements of the South African Distribution Code: Network Code, the EG may require additional protection (e.g. biased differential, Restricted Earth Fault, pole slipping protection, negative phase sequence overcurrent etc.) to safeguard his assets against damage due to abnormal events or faults on the power system.

Table 2. PUC protection requirements per voltage level

Protection Type	**Section**	**HV**	**MV**
Overcurrent, Earth Fault	4.6.2.3	Yes	Yes
Sensitive Earth Fault (SEF)	4.6.2.3	No	Note 1
Phase Under/Over Voltage	4.6.2.4	Yes	Yes
Residual over-voltage	4.6.2.5	No	Note 1
Under/Over Frequency	4.6.2.6	Yes	Yes
Loss-of-Grid	4.6.2.7	Yes	Yes
Check Synchronising / interlocking (Block dead line charge)	4.6.2.8	Yes	Yes
Reverse Power	4.6.2.9	Note 2	Note 2
DC Failure Monitoring	4.6.2.10	Yes	Yes
Note 1: Depends on neutral earthing philosophy adopted. Neutral voltage displacement protection will be applied on networks where the EG or generator transformer does not provide an earth connection to the Eskom network. Earth Fault and Sensitive Earth Fault protection will be required in the event that an earth connection is provided Note 2: Reverse power protection shall be applied in the event that the EG does not plan to, or is not permitted to export power to the grid, but which will be synchronised with the grid.			

Notwithstanding the requirements of Table 2 for the PUC, Table 3 lists the minimum protection functionality to be installed at the PGC.

Table 3 PGC Protection requirements

Protection Type	**Section**
Phase Under/Over Voltage	4.6.2.4
Under/Over Frequency	4.6.2.6
Auto synchronising	4.4.2
Reverse Power	4.6.2.9
DC Failure Monitoring	4.6.2.10
Negative Phase Sequence overcurrent	4.6.2.11

The Distribution Code: Network Code requires generators of nominal capacity greater than 10MVA to comply with Section 3.1 of the South African Grid Code: Network Code. The latter requires generators to be provided with back-up impedance and circuit-breaker fail protection in addition to the requirements of Tables 2 and 3 above. In addition, generators of capacity larger than 20MVA may require loss of field and pole slipping protection.

In the event that the PUC and the PGC are the same point (e.g. for MV directly-connected generators) the protection system at the combined PUC/PGC shall comply with the requirements of both Tables 2 and 3. In addition, the Distributor shall install a back-up circuit-breaker on the Distributor-side of the PUC. The back-up circuit-breaker (typically an auto-recloser) shall include protection functionality as indicated in Table 4.

Table 4. Back-up circuit-breaker protection requirements (combined PUC/PGC)

Protection Type	**Section**
Overcurrent, Earth Fault	4.6.2.3
Sensitive Earth Fault (SEF)*	4.6.2.3
Phase Under/Over Voltage	4.6.2.4
Under/Over Frequency	4.6.2.6
Check Synchronising / interlocking (Block dead line charge)	4.6.2.8
DC Failure Monitoring	4.6.2.10

* where applied at the PUC/PGC

4.6.2.2 General Protection Requirements

a) All protection relays used at the PUC and PGC shall comply with the type test requirements of Annex C.

b) Protection relay accuracy requirements of the following sections shall be defined as per IEC60255-3 and -6.

c) Except where the PUC and PGC are the same point, the PUC and PGC protection shall be totally independent of each other.

d) Protection clearance times and coordination shall comply with the requirements specified as a result of the EG integration fault studies.

e) If automatic resetting of the protective equipment is used (e.g. for an unmanned EG facility), the time delays must applied in consultation with the regional auto-reclose philosophy. The automatic reset must be inhibited for faults within the EG installation.

f) Each protection relay system shall include a sequence of event recording function that logs any settings change; settings group change, protection pick-up or trip operation, or change in circuit-breaker and/or input and output status.

g) The relay system installed at the PUC shall incorporate an oscillographic waveform recording function capable of storing at least five 15-cycle recordings at a sampling rate of 16 samples per cycle or higher. The waveform recording shall contain the three phase voltage, three phase current and neutral current signals from the PUC as well as all significant digital signals (i.e. protection tripping elements, circuit-breaker status, input and output contact status etc.). A recording shall be triggered upon any protection operation.

h) The event and waveform recordings shall be stored in non-volatile memory and shall be time stamped with a resolution of 1 millisecond real time. It shall be possible for the recordings to be made available in COMTRADE format.

i) Protection settings for all functions identified in Tables 2 and 3 to be applied at the PUC and PGC will be to Eskom's written approval. No changes to the settings shall be made without written consent from Eskom. The EG shall keep written record of all protection settings, and provide a signed electronic copy of the same to Eskom.

4.6.2.3 Overcurrent, Earth Fault and Sensitive Earth Fault protection

Overcurrent and earth fault protection shall provide Inverse Definite Minimum Time (IDMT) time-current characteristics. IDMT curves shall be in accordance with the requirements of IEC-60255-3: Type A, B and C curves (i.e. IEC Normal Inverse, Very Inverse and Extremely Inverse).

Overcurrent protection will be provided in all cases. Voltage-controlled overcurrent protection shall be considered in applications where the fault current contribution of EG decays with time.

Appropriate Earth Fault protection will be applied in all cases. Current-based detection is not appropriate in MV networks where the generator or generator transformer does not include a point of neutral earthing.

Sensitive Earth Fault protection will be applied on MV networks where the generator or generator transformer provides a point of neutral earthing to the Eskom network. SEF protection will be set in compliance with *Distribution Standard 34-540*.

Sensitive Earth Fault protection will use a Definite Time characteristic.

The overcurrent, earth fault and SEF protection shall be set to coordinate with the Eskom network protection as dictated by the integration fault studies.

4.6.2.4 Under and Over Voltage protection

Under- and over-voltage protection shall be provided. The voltage protection functions shall detect the effective (i.e. root mean square) or the fundamental component of each phase-to-phase voltage. Maximum operating times for the voltage protection are indicated in Table 3 below [IEEE 1547].

Table 3. Maximum operating times for voltage protection

Voltage range (% of nominal)	**Maximum Operate Time** (s)
V < 50%	0.2s
50% ≤ V < 90%	2s
110% < V < 120%	1s
V ≥ 120%	0.2s

In cases where the EG facility may import or export power from the Eskom network, the voltage protection may be supervised so as only to operate in the event of real and/or reactive power export by the facility to the network.

4.6.2.5 Residual over-voltage / neutral voltage displacement protection

Residual over-voltage (also known as neutral voltage displacement) protection shall be applied on MV networks where the generator or generator transformer MV neutral is unearthed. The voltage signal must be derived from a VT configuration that is capable of transforming zero-sequence voltage: three single phase VTs or three phase 5-limb VTs, with primary neutral earth connection. The residual voltage may be derived from a broken-delta configuration of the VTs, or may be calculated by the relay based on the measured phase-to-neutral voltages.

The pick-up and time delay of the residual over-voltage protection shall be chosen so as to grade with the current-based earth fault protection that is applied to the Distributor's network. It is preferred that the residual over-voltage protection uses an inverse voltage-time characteristic rather than a definite time characteristic. The residual over-voltage protection will be less sensitive and slower than the Distribution network protection. Refer to Annex D for a worked grading example.

4.6.2.6 Under and Over Frequency protection

Under- and over frequency protection shall be provided. The under- and over frequency protection relay shall be accurate to within 10 millliHertz of setting. Where an averaging "window" is used for the frequency measurement, this shall be limited to a maximum length of 6 cycles.

The frequency protection shall be set so as to allow generator operation within the frequency ranges stipulated in Section 4.4.1. Operation outside these ranges shall cause the EG to sever the connection with the Eskom network within 300ms.

In cases where the EG facility may import or export power from the Eskom network, the frequency protection may be supervised so as only to operate in the event of real power export by the facility to the grid.

4.6.2.7 Loss-of-Grid protection

Operation of an EG in an unintentional islanded mode with part of the distribution network constitutes a serious safety hazard to both equipment and personnel, and is to be avoided as far as is practicable.

The philosophy to be applied is that the detection of an islanding condition shall take precedence over the continuity of the generator's grid connection (via the PUC). The generator must be disconnected from the Distribution network upon reasonable suspicion of islanded operation. Generators of capacity greater than 50MVA will typically include more definitive islanding detection methods (e.g. communication-assisted intertripping schemes); so as to further avoid nuisance tripping for non-islanding events.

Dedicated loss-of-grid protection will be applied at the PUC in all applications. An EG may be exempted from this requirement in the event that it is prohibited from exporting real power to the Distribution network by a suitable reverse power relay (see Section 4.6.2.9).

Loss-of-grid protection may take the form of Rate-of-Change of Frequency (ROCOF) or Voltage Vector Shift protection.

Table 4. Typical settings for loss-of-grid protection

ROCOF	Δf	0.2 – 1.0Hz/s (0.4Hz/s typical)
	Δt	40ms – 2s
	Time delay	200ms – 500ms
Voltage Vector Shift	ΔV	6° – 12° (6° typical. 12° on weak networks).

Where ROCOF or Voltage Vector Shift protection is not deemed suitable, a communication-based direct transfer trip scheme may be applied such as to disconnect the EG in the event of an island developing.

4.6.2.8 Check Synchronising / Block dead line charge

The circuit-breaker at the PUC shall be blocked from closing onto a de-energised Distribution network (block dead line charge). Charging of the EG network shall be permitted subject to synchronism check having been performed.

Synchronising shall be done at the PGC, in accordance with the requirements of Section 4.4.2. Where synchronising occurs at the PUC, for situations where the EG would island onto his own internal network, the PUC shall also adhere to the requirements Section 4.4.2.

4.6.2.9 Reverse Power protection

There are two principal applications of reverse power protection:

1) Prevention of generator motoring.

This shall be applied as standard at the PGC on all rotating generators.

The recommended setting for a reverse power relay is 10 – 20% of the maximum allowable motoring power. The operating time is typically 10 – 30s. The time delay is required to prevent maloperation during power swings or when synchronising the generator to the network [Jenkins p.177].

2) Prevention of power export to the grid

A reverse power protection relay may be installed at the PUC of an EG whose entire output will be consumed by the plant in which it is embedded. The reverse power protection relay will prevent unintended export of power to the Distributor's network, and may obviate the need for dedicated loss-of-grid protection (see Section 4.6.2.7). When serving as loss-of-grid protection, the reverse power protection relay shall be graded with time overcurrent protection in order to ensure ride-through during fault conditions. The clearance times shall comply with the requirements determined by the EG integration fault studies.

4.6.2.10 DC Failure Monitoring

DC failure within the EG facility is deemed a serious safety risk. The DC supplies provided for the PUC and PGC circuit-breakers and associated protection systems shall be subject to continual monitoring. Two separate DC alarms shall be provided per DC system:

a) Non-urgent DC alarm: an alarm activated when the battery voltage is lower than normal, or for any fault appearing on the AC supply to the battery charger.

b) Urgent low DC voltage alarm: an alarm activated when the battery voltage is such that the available capacity is less than 20% of the rated Ampere-hour capacity.

The EG shall initiate disconnection from the Distribution network immediately upon receipt of an urgent low DC voltage alarm.

4.6.2.11 Negative Phase Sequence Overcurrent

Negative phase sequence overcurrent protection shall be applied as a generator protection function, and shall serve to protect the generator against damage due to unbalanced loading, broken conductors or other asymmetrical operating conditions.

Negative sequence current components can be extremely harmful to the EG. Distribution network faults, by their nature, are a large contributor to negative sequence currents. The EG should be aware that negative phase sequence overcurrent protection must be effectively applied.

4.6.3 DC Systems

The circuit-breakers and associated protection systems at the PUC and PGC shall operate from independent DC supplies.

The DC supplies to the PUC and PGC shall be subject to continual monitoring as per Section 4.6.2.10. The EG shall cease to energise the Distributor's network upon critical failure of either the DC system at the PUC or that at the PGC or both.

The DC systems at the PUC and PGC shall be maintained in accordance with the applicable Eskom standard or an alternative written policy acceptable to Eskom. Eskom reserves the right to perform audits on the DC systems.

4.6.4 Metering

The metering arrangement adopted per EG application will depend on the specific conditions of the power purchase agreement. The following metering philosophy shall, however, apply to all EG interconnections:

a) Tariff metering and billing shall be done by the party selling the energy, using meters that are owned, commissioned and maintained by the selling party.

Note: In certain cases, Eskom will be both a buyer and a seller of the EG's electrical power output (from the same location) in which case, one Eskom and one EG meter will be installed at the same electrical node.

b) Where Eskom includes a tariff meter at the point of energy purchasing from the EG, this meter shall be used as the check meter for power purchased from the EG. Eskom will install a dedicated check meter at all other points of energy purchasing from the EG. The EG tariff meter shall constitute the main meter in these cases.

c) Tariff meters for the sale of electrical energy to Eskom will be located such that they measure the net energy exported by the EG, excluding the power consumed by its auxiliaries.

d) All Eskom-owned meters shall include facilities for automated remote downloading by Eskom. The meters shall be available for communication at any time. This requires that the VT supply to the meter is energized at all times or that the meter is provided with a separate 230V ac auxiliary supply (typically from the EG facility).

e) In cases where the Eskom metering system is installed within a customer- or EG-owned substation or industrial plant:

   i) Eskom may install its own instrument transformers for metering, or shall make use of suitable instrument transformers provided by the EG. In the latter case, this shall include:

      - A dedicated CT core per phase: accuracy as per NRS 057. The measurement cores shall preferably be of fixed ratio. Where multi-ratio cores are provided, the lowest ratio shall be capable of carrying the generator's full output current continuously. Eskom will use the lowest available ratio for metering purposes.

      - A three phase VT secondary input as per NRS 030, accurate to Class 0.2 and burdened within accuracy class requirements with the Eskom metering system and EG equipment connected. In the case of MV networks this shall be a 5-limb three phase VT or three single phase VTs. In the case of HV networks three single phase VTs will be suitable. The VT primary and secondary neutrals will both be earthed in all cases.

ii) EGs of nominal capacity less than or equal to 10MVA may use a combined CT/VT unit incorporating one CT per phase, and a three phase 5-limb VT in a single tank. In this case, it shall acceptable for the EG's and Eskom's meters to share the available CT cores. Other requirements for the CT and VT cores shall be as in (i) above.

iii) The EG must provide the civil works for the metering equipment to be installed by Eskom. Where Eskom-owned instrument transformers are to be used, these will be provided by Eskom together with the relevant standard steelwork and foundations.

f) All Eskom metering shall be done in secondary quantities with the necessary instrument transformer and/or pulsing factors applied by the remote data warehousing/billing system.

g) The EG shall not have direct access to data on any Eskom meter. The EG may request a copy of historical metering information from the Eskom data warehouse via their Eskom Customer Services representative.

h) All tariff and check meter(s) shall be time synchronized with South African Standard Time in order to ensure synchronised billing information.

4.6.5 Supervisory Control and Data Acquisition (for the Eskom Control Centre/s)

4.6.5.1 General requirements

There shall be an RTU at the PUC and at the PGC. Where these are the same location a single RTU may be provided.

The RTU(s) shall be in accordance with the relevant Eskom standard and shall be supplied, installed, commissioned and maintained by Eskom. The EG must provide the civil works in which the equipment will be installed by Eskom. RTUs at EG facilities with a total capacity of less than or equal to 20 MVA shall interface with the appropriate Eskom Distribution control centre. RTUs at EG's larger than 20 MVA shall consult with Eskom to determine whether its RTU(s) shall interface with only the regional Distribution control centre, or both the regional Distribution control centre and the National control centre.

4.6.5.2 Indications and Alarms

The preferred method of communication from the protection system to the RTU is an EIA-232 serial connection via the DNP3 protocol. If the preceding is not possible, hard-wired (i.e. mechanical, potential free contact) indications are permitted.

The following indications and alarms shall be provided to the RTUs by the EG:

1) PUC and PGC Circuit-Breaker open and closed indications (Double Bit)

2) Isolator open and closed indications (Double Bit) – only required from the PUC.

3) Non-urgent DC alarm (refer to Section 4.6.2.10)

4) Urgent low DC voltage alarm (refer to Section 4.6.2.10)

5) Protection trip indication

6) Manual trip indication

7) Auto synchronising failed

A hard-wired (i.e. mechanical, potential free) contact shall be provided to the RTU for the "Protection

Not Healthy" alarm. The "Protection Not Healthy" alarm shall be raised by any condition indicating that the protection system is unable to function according to its specification. This typically includes protection relay watchdog contacts, VT fuse fail indication, circuit-breaker SF_6 gas blocking alarm etc.

4.6.5.3 Controls

Remote circuit-breaker controls will typically only be required for Eskom-owned switchgear or in cases where the EG's facility will be unmanned. Switching of the EG's equipment by Eskom shall only be conducted under emergency conditions, or as arranged between the parties. Provision for the execution of these controls shall be made at the PUC by the PUC equipment owner.

4.6.5.4 Measurements

The following measurement requirements are in keeping with the requirements of ESKASACL3.

The following power system measurements shall be provided to supervisory via an EIA-232 serial interface to the RTU via the DNP3 protocol. Many modern protection relays include suitable measurement functions for this purpose.

Alternatively, should DNP3 serial communication not be possible, one or more 0 – 5mA transducers complying with the requirements of Distribution Specification 34-392 may be used as an alternative, although this is not preferred.

The quantities that shall be measured at the PUC and PGC and the required accuracies are as follows:

1) the true r.m.s. red-to-white phase voltage (kV): ± 0.5 %

2) the true r.m.s. white phase current (A), range 0 to 1.1 x full load: ± 0.5 %

3) the three-phase active power in kW/MW: ± 0.5 % (Import and Export)

4) the three-phase reactive power in kVar/MVar: ± 0.5 % (Import and Export)

5) the frequency (Hz): ± 0.1 %

Reference conditions for the accuracy measurements shall be as indicated in Distribution Specification 34-392.

The polarity of the measurements shall be such as to indicate positive readings for power export away from the busbar at which the measurements are made (as per Eskom Standard ESKASACL2).

The RTU and protection relay/transducer shall sample the analogue inputs once every second, or more frequently.

5 Tests

Full tests on the equipment needed to meet the requirements of this document must be carried out to the satisfaction of Eskom. These tests are the responsibility of the equipment owner. Tests carried out on equipment installed at the PUC and PGC, as well as loss-of-grid and synchronising tests must be witnessed by a representative of Eskom.

The test on primary equipment must be carried out on site with the equipment installed in its final position. Results from tests performed before delivery and installation are not acceptable.

The EG must keep a written record of all protection settings and of test results. A copy of this record should be available for inspection at the PUC or as required by Eskom.

Measurement and injection test equipment used in testing shall have a traceable calibration record, and shall be of suitable accuracy for the tests to be undertaken.

5.1 Pre-commissioning and Commissioning Tests

Tests to be conducted at the PUC and PGC are divided into two categories:

a) Pre-commissioning tests include all tests to be performed prior to the EG synchronising with the Distributor's network for the first time.

b) Commissioning tests: those tests that can only be completed during the first synchronisation of the EG with the Distributor's network, or thereafter. Commissioning tests shall be conducted upon written agreement of the Distributor after acceptance of the pre-commissioning test results.

Pre-commissioning and commissioning tests for equipment installed at the PUC and PGC shall be as per the requirements of Tables 5 and 6 below. Tables 5 and 6 also indicate the applicable synchronising tests to be conducted at every point at which auto-synchronising functionality is provided.

The applicable pre-commissioning and commissioning tests shall be repeated in the event of any firmware or software change on the control plant equipment, or any hardware component has been replaced, repaired or modified.

Table 5. Pre-commissioning Tests at the PUC and PGC

Equipment	Applicable Eskom Test Procedure	Test requirements
Primary Plant Equipment		
Current Transformers	DISPVAEC6	Insulation Resistance test. Ratio test. Magnetising test. Secondary resistance and burden test. Polarity test. Primary injection test. Visual inspection and application checks.
Voltage Transformers	DISPVAEB6	Insulation Resistance test. Ratio test. Lead and burden resistance test. Polarity test. Visual inspection and application checks.
Isolators	DPC 34-1034	Insulation Resistance test. Contact Resistance test. Contact Timing test. Visual inspection and application checks.
Circuit-breakers	DISPVAEQ6	Insulation Resistance test. Contact Resistance test. Timing Test. SF6 Gas/Oil tests. Miscellaneous and General Checks.
Control Plant Equipment		
Over Current, Earth Fault & SEF Protection	DISPVAED1	Insulation resistance test of CT, VT and DC circuits. Pick-up/Drop Off tests. Timing Characteristic Test. Directional limit tests (where applicable). Visual Inspection.
Voltage Protection	-	As per IEEE 1547.1 Section 5.2.
Frequency Protection	-	As per IEEE 1547.1 Section 5.3. See Note 1.
Loss-of-grid protection	-	As per IEEE 1547.2 Section 5.3 using appropriate frequency ramps.
Synchronisation	-	As per IEEE 1547.1 Section 5.4.1.
Reverse Power	-	As per IEEE 1547.1 Section 5.8.
DC Failure	-	Non-urgent and urgent DC failure alarms to be issued as per the requirements of Section 4.6.2.10.
Note 1. For Frequency relays employing an averaging technique, timing tests may be more appropriately done using ramp frequency changes in the range from ±50mHz/s to ±1Hz/s rather than a step frequency change as per IEEE 1547.1.		

Table 6. Commissioning Tests

Equipment	Applicable Eskom Test Procedure	Test requirements
Control Plant Equipment		
Unintentional islanding (PUC only)	-	As per IEEE 1547.2 Section 5.7.
Synchronisation (all points of synchronisation)	-	As per IEEE 1547.1 Sections 5.4.2, 5.4.3 or 5.4.4 as appropriate.

5.2 Maintenance Tests

Maintenance of the primary and control plant equipment shall be conducted according to the recommendations of NRS-089.

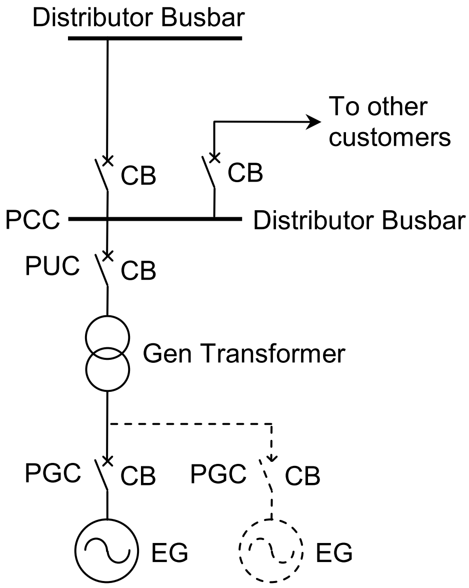
The control plant equipment at the point of connection shall be subject to routine inspection on a three year cycle, witnessed by a representative of Eskom. Major maintenance including secondary injection of all protection relays and testing of primary equipment (e.g. CTs, VTs, circuit-breakers etc) shall be conducted at intervals of 6 years. Major maintenance shall include repeating the unintentional islanding test conducted during commissioning.

Annex A – Summary of generator connection types

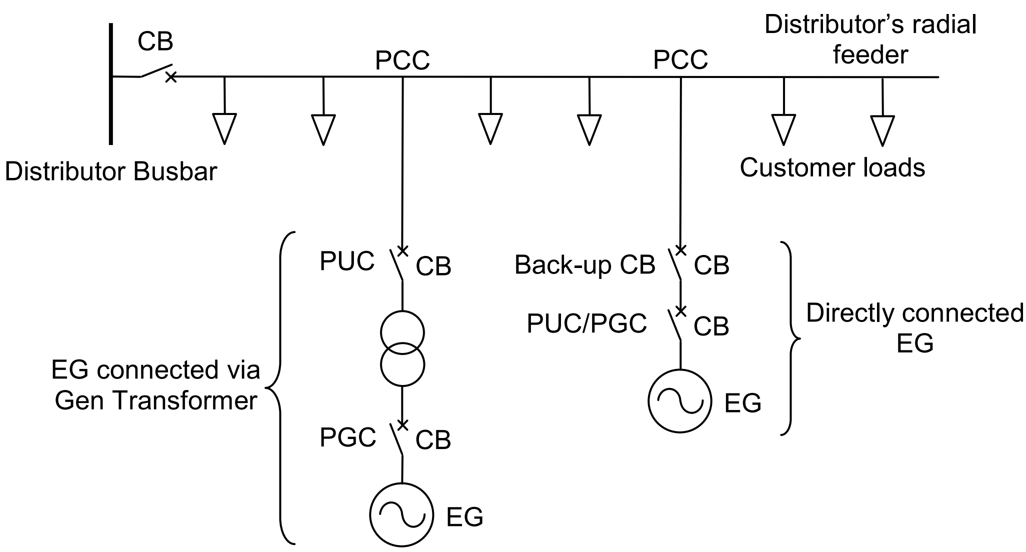
(Informative)

This section provides typical examples of generator connection types to which this standard shall apply, indicating the likely locations of the PUC, PGC and PCC in each case. The application of the standard shall not be limited to only these plant connection types.

Generator connection to Distributor busbar: The EG (or multiple EGs) in this case is connected directly to a Distributor busbar, usually via a generator transformer.



Radial line tee-in generator connection: The EG is connected via a tee-in on a radial distribution line, either via a transformer or directly. In the case of direct connection, the utility will install a back-up circuit-breaker after the PUC/PGC, since no EG is permitted to connect to the Distributor's network via a single circuit-breaker.



Annex B – Summary of plant types

(Informative)

This section provides a summary of the typical plant types to which this standard shall apply. The application of the standard shall not be limited to only these plant types.

Synchronous generator: A type of rotating electrical generator which operates at a speed that is directly related to system frequency. The machine is designed to be capable of operation in isolation from other generating plants. The output voltage, frequency and power factor are determined by control equipment associated with the generator. Under certain conditions, the synchronous generator may be paralleled with a network containing other generation. On disconnection of the paralleled connection, the synchronous generator will continue to generate at a voltage and frequency determined by its control equipment.

Mains-excited asynchronous generator: A type of rotating electrical generator which operates at a speed not directly related to system frequency. The machine is designed to be operated in parallel with a network containing other generation. The machine is excited by reactive power drawn only from the network to which it is connected.

The output voltage and frequency are determined by those of the system to which it is connected. On disconnection of the parallel connection, the mains-excited asynchronous generator will cease generation.

Power factor corrected asynchronous generator: A derivative of the mains-excited asynchronous generator where the machine is excited partly by the network to which it is connected and partly by a device of fixed capacitance connected locally to the machine. On disconnection of the parallel connection, the power factor corrected asynchronous generator may continue to generate electrical power at a voltage and frequency determined by the machine and system characteristics.

Self-excited asynchronous generator: A derivative of the mains-excited asynchronous generator where the machine is excited purely by a device of variable capacitance connected locally to the machine. The machine is capable of operation in isolation from a network containing other generation and in this respect is similar to the synchronous generator. Under certain conditions, the self-excited asynchronous generator may be operated in parallel with other generation, and on failure of that connection, the machine will continue to generate at a voltage and frequency determined by its control equipment.

Self-commutated static inverter: An electronic device to convert direct current (d.c.) to alternating current (a.c.) in which the output value of a.c. frequency and voltage is determined by control equipment associated with the device. It is similar to the rotating synchronous generator in that, under certain conditions, it may be connected in parallel with a network containing other generators. On failure of that connection, the device will continue to provide power at a voltage and frequency determined by its control equipment.

Line-commutated static inverter: A derivative of the self commutated static inverter where the output a.c. frequency and voltage are determined by the network containing other generation to which it must be connected. On disconnection of the parallel connection, the line-commutated static inverter will normally cease operation.

Annex C – Protective Relay Type Test requirements

(Normative)

Protective relays installed at the Point of Connection shall comply with the following international type test requirements.

Table B1. International standard type test requirements for protective relays

Item	Test	Standard	Test Level	Compliance Criteria
Auxiliary power supply				
1	Operating range		-	V_{Nom} – 20% to V_{Nom} + 10%.
2	Interruption	IEC 60255-11	-	For supply interruptions lasting less than 10ms, the device shall function as if no interruption had occurred.
3	A.C. ripple	IEC60255-11	-	Device shall function correctly with 12% 100Hz a.c. signal superimposed on the d.c. supply.
Power frequency magnetic field				
4	Steady State	SANS 61000-4-8	Class 4	30A/m continuous, 300A/m short duration, 50Hz
Insulation resistance				
5	Dielectric withstand	IEC 60255-5	-	2kV rms 50Hz for 1 minute between all terminals to case earth. Transverse tests between contacts shall also be performed to the above specification.
6	Insulation resistance	IEC 60255-5	-	Insulation resistance greater than 20MΩ when measured at 500Vdc
Environmental tests				
7	Cold	IEC 60068-2-1	-10°C or less	Operates within tolerance at -10°C (LCD screen operative)
8	Dry Heat	IEC 60068-2-2	+55°C or more	Operates within tolerance at +55°C
9	Cyclic Temperature and Humidity	IEC 60068-2-30	Test Db	25°C and 95% relative humidity/ 55°C and 95% relative humidity, 12 + 12 hour cycle
10	Enclosure protection	SANS 60529	IP53	Protected against ingress of dust particles, spraying water
Mechanical tests				
11	Vibration	IEC 60255-21-1	Class 2 (response and endurance)	Response: 1g, 10 - 150Hz, 1 sweep energised. Contacts should not close for longer than 2ms. Endurance: 2g 10 – 150Hz, 20 sweeps, unenergised contacts should not close for longer than 2ms.
12	Shock	IEC 60255-21-2	Class 1 (response and withstand)	Response: 5g, 11ms, 3 pulses in each direction, energised Withstand: 15g, 11ms, 3 pulses in each direction, unenergised
13	Bump	IEC 60255-21-2	Class 1	10g, 16ms, 1000 pulses unenergised.
14	Seismic	IEC 60255-21-3	Class 1	Test method A (single axis sine sweep test) 1 – 35Hz, 1 sweep.

Table B1. International standard type test requirements for protective relays (continued)

Item	Test	Standard	Test Level	Compliance Criteria
Impulse tests				
15	Electrical impulse (1.2/50 µs)	IEC 60255-5	-	5kV 1.2/50µs waveform, 0.5J
Electromagnetic compatibility				
16	1MHz Disturbance Burst	IEC60255-22-1 or SANS 61000-4-12	Class 3	2.5kV common mode, 1kV differential mode, 2s total test duration, 6 – 10 bursts
17	Fast Transient	IEC 60255-22-4 or	Class A (IV)	4kV, 2.5kHz 2kV, 5kHz on Comms ports
		SANS 61000-4-4	Class 4	4kV, 5kHz (power port) 2kV, 5kHz (I/O signal, data and control ports)
18	Electrostatic Discharge	IEC 60255-22-2 or SANS 61000-4-2	Class 3	6kV Contact Discharge, 8kV Air Discharge
19	Surge immunity	IEC 60255-22-5 or SANS 61000-4-5	- Class 3	2kV
20	Radiated Radio Frequency EM field immunity	IEC 60255-22-3 or SANS 61000-4-3	- Class 3	10V/m, 80MHz – 1GHz
21	Conducted Radio Frequency EM field immunity	IEC 60255-22-6 or SANS 61000-4-6	- Class 3	10Vrms, 150kHz – 80MHz

Annex D – Residual over-voltage protection grading example

(Informative)

Reference: Network Protection & Automation Guide, p309.

This section provides an example of the method to be used to grade the residual over-voltage protection at an MV point of connection with the current-based earth fault protection on the Distribution network.

The voltage pick-up must be set at a value corresponding to the current pick-up of the least sensitive earth fault relay on the network. The least sensitive current pick-up will typically occur on the source substation feeder circuit-breakers. For a relay that operates using the residual voltage, $3V_0$, the effective setting is given by Equation D.1.

$$V_S = \frac{I_S \times (3 \times Z_N)}{\text{VT Ratio}} \quad \text{(D.1)}$$

Where:

V_S = Voltage setting of the residual over-voltage protection

I_S = Highest current setting of the Distribution network earth fault protection

Z_N = Earthing impedance

The time delay of the residual over-voltage protection, either definite time or using an inverse-time characteristic, must be chosen such that it operates after the slowest earth fault protection relay on the feeder.

Application example:

Consider a 22kV network that is supplied by two power transformers, each earthed via a 35.8Ω resistor to limit the earth fault current to 710A. The highest earth fault current pick-up applied on the network is 40A. The earth fault protection uses a normal inverse characteristic with a time multiplier of 0.2.

The voltage setting is calculated as follows:

$$V_S = \frac{I_S \times (3 \times Z_N)}{\text{VT Ratio}} = \frac{40A \times (3 \times \frac{35.8\Omega}{2})}{200} = 10.8V$$

The earth fault protection will operate in 470ms for a 710A fault. Assuming that the residual overvoltage protection uses a time-current curve given by the equation:

$$\text{Trip Time, } t = \frac{K}{\frac{V_M}{V_S} - 1}$$

Where:

K = Time multiplier

V_M = Measured voltage during the fault

V_S = Voltage setting.

For the residual over-voltage protection to operate in 870ms at 190V requires a setting of K = 14.5.

Annex E – Impact assessment

Impact assessment form to be completed for all documents.

1 Guidelines

- All comments must be completed.
- Motivate why items are N/A (not applicable)
- Indicate actions to be taken, persons or organisations responsible for actions and deadline for action.
- Change control committees to discuss the impact assessment, and if necessary give feedback to the compiler of any omissions or errors.

2 Critical points

2.1 Importance of this document. e.g. is implementation required due to safety deficiencies, statutory requirements, technology changes, document revisions, improved service quality, improved service performance, optimised costs.

The document serves to establish the technical standard for the interconnection of Embedded Generation to Eskom Distribution's networks. The standard sets out some key safety aspects relating to the interconnection of Embedded Generation and is central to the National Co-generation project.

2.2 If the document to be released impacts on statutory or legal compliance - this need to be very clearly stated and so highlighted.

The standard serves to fulfil the requirements of the South African Distribution Code: Network Code in so far as a protection interconnection standard for Embedded Generation is required of each Distributor.

2.3 Impact on stock holding and depletion of existing stock prior to switch over.

Not applicable

2.4 When will new stock be available?

Not applicable

2.5 Has the interchangeability of the product or item been verified - i.e. when it fails is a straight swop possible with a competitor's product?

Not applicable

2.6 Identify and provide details of other critical (items required for the successful implementation of this document) points to be considered in the implementation of this document.

A generic Power Purchase Agreement (PPA) and Connection Agreement for EG's has been developed separately to this document. A planning guideline for the integration of Embedded Generation is presently being developed, and will describe in detail the types of impact assessment studies required.

2.7 Provide details of any comments made by the Regions regarding the implementation of this document - None.

Annex E

(continued)

3 Implementation timeframe

3.1 Time period for implementation of requirements.

Not applicable.

3.2 Deadline for changeover to new item and personnel to be informed of DX wide change-over.

Not applicable.

4 Buyers Guide and Power Office

4.1 Does the Buyers Guide or Buyers List need updating?

No.

4.2 What Buyer's Guides or items have been created?

Not applicable.

4.3 List all assembly drawing changes that have been revised in conjunction with this document.

Not applicable.

4.4 If the implementation of this document requires assessment by CAP, provide details under 5

4.5 Which Power Office packages have been created, modified or removed?

Not applicable.

5 CAP / LAP Pre-Qualification Process related impacts

5.1 Is an ad-hoc re-evaluation of all currently accepted suppliers required as a result of implementation of this document?

No.

5.2 If NO, provide motivation for issuing this specification before Acceptance Cycle Expiry date.

Not applicable.

5.3 Are ALL suppliers (currently accepted per LAP), aware of the nature of changes contained in this document?

Not applicable.

Annex E

(continued)

5.4 Is implementation of the provisions of this document required during the current supplier qualification period?

Not applicable.

5.5 If Yes to 5.4, what date has been set for all currently accepted suppliers to comply fully?

Not applicable.

5.6 If Yes to 5.4, have all currently accepted suppliers been sent a prior formal notification informing them of Eskom's expectations, including the implementation date deadline?

Not applicable.

5.7 Can the changes made, potentially impact upon the purchase price of the material/equipment?

Not applicable.

5.8 Material group(s) affected by specification: (Refer to Pre-Qualification invitation schedule for list of material groups)

Not applicable.

6 Training or communication

6.1 State the level of training or communication required to implement this document. (e.g. none, communiqués, awareness training, practical / on job, module, etc.)

Workshops are presently being arranged with Distribution technical personnel to share the requirements of this standard.

6.2 State designations of personnel that will require training.

Project Engineers, EDFS staff, Field Services staff, Network Operators.

6.3 Is the training material available? Identify person responsible for the development of training material.

No training material is available at this stage.

6.4 If applicable, provide details of training that will take place. (E.G. sponsor, costs, trainer, schedule of training, course material availability, training in erection / use of new equipment, maintenance training, etc).

To be announced.

6.5 Was Training & Development Section consulted w.r.t training requirements?

No.

Annex E

(continued)

7 Special tools, equipment, software

7.1 What special tools, equipment, software, etc will need to be purchased by the Region to effectively implement?

None.

7.2 Are there stock numbers available for the new equipment?

Not applicable.

7.3 What will be the costs of these special tools, equipment, software?

Not applicable.

8 Finances

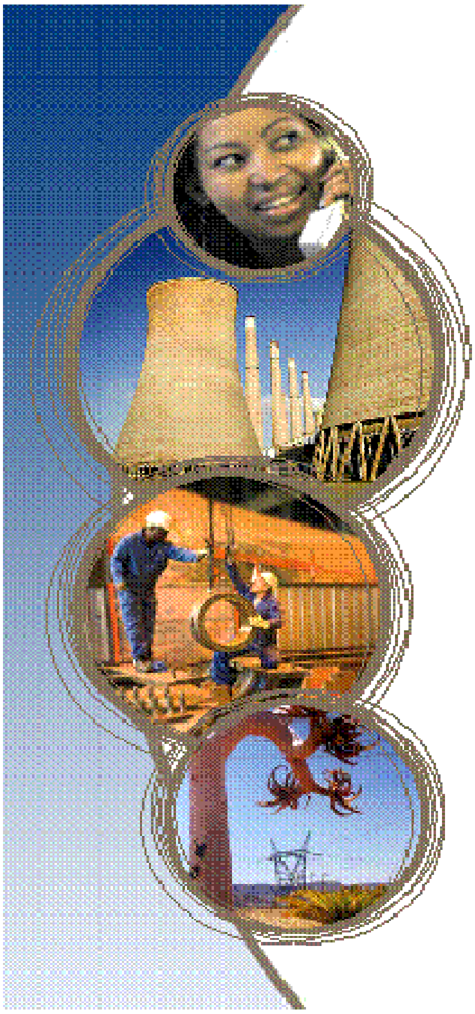
8.1 What total costs would the Regions be required to incur in implementing this document? Identify all cost activities associated with implementation, e.g. labour, training, tooling, stock, obsolescence

Project costing will be evaluated on a per-project basis via the normal Investment Committees, guided by the pricing policies for Embedded Generation presently under development.

Impact assessment completed by:

Name: Stuart van Zyl

Designation: Chief Engineer, Protection Discipline Specialist



Guide for IPP grid application process

(15 February 2011)

15 Feb 2011

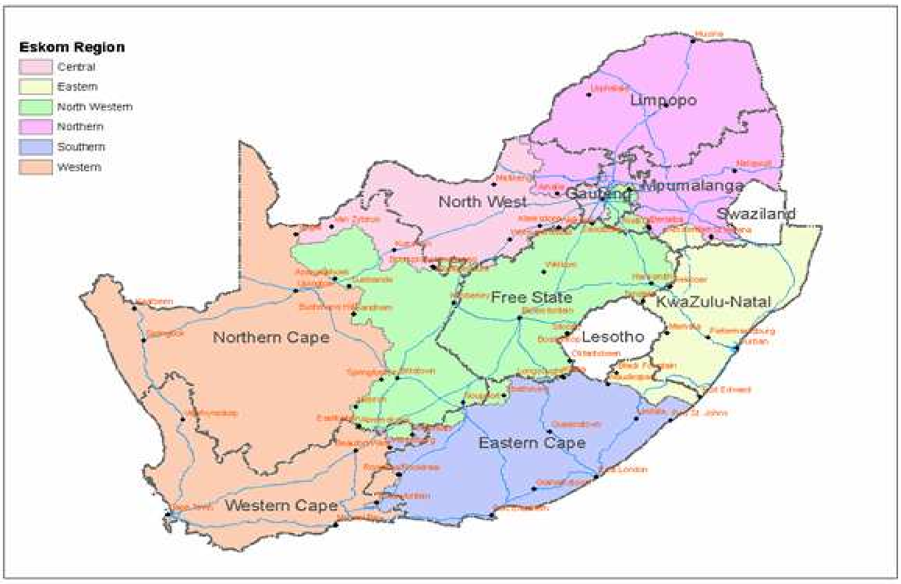
Page No

Follow this guide to connect a generator to the Eskom Network

Read further information below about the commercial and technical requirements to connect a generator to Eskom's network.

General	
1 Licenses for the generation or supply of electricity	Eskom does not issue generation licences/approvals. NERSA is responsible for the issuing of licenses for the generation and supply of electricity. The connection to the Eskom network is subject to the issuing of a License by NERSA. For further information, please contact NERSA at www.nersa.org.za Note that Eskom cannot provide a connection to a generator that does not receive its required approvals from NERSA
2 Generator connected to municipal network	This process only deals with applications to Eskom, i.e. where the generator is located in the Eskom's licensed area of supply. You will need to contact your local municipality if your generator is located in a Municipality licensed area of supply. Eskom can assist with contact details; alternatively contact NERSA to facilitate the process.
3 Important documentation	Please refer to the following sources: 1. Application form 2. Eskom's interconnection standard 3. NERSA website www.nersa.org.za • Generator licence requirements • The SA Grid code and Distribution Code 4. Department of Energy (DOE) website www.energy.gov.za
	Application for connection
4 Completion of part 1 of the application form	Fill in part 1 of the application form. Please note that this form will shortly be able to be completed electronically. Please indicate clearly if you will be submitting bids in terms of regulated IPP procurement programmes e.g REFIT or generating for private use.

5 Submission of application form



Send completed application to one of the following email addresses

Contact details	Eskom Region
are.vanzyl@eskom.co.za	Western Region
billy.madike@eskom.co.za	Central Region
FerreiPJ@eskom.co.za	North West Region
eddie.leach@eskom.co.za	Southern Region
wolfgang.bohmer@eskom.co.za	Northern Region
Ravi.moonsamy@eskom.co.za	Eastern Region
annaline.hambly@eskom.co.za	General enquiries

See map below for the Eskom Regions

You will receive a reference number as confirmation of the receipt of the application (within 3 days) and this will be your reference in all correspondence.

Cost estimate letter

6 Cost estimate letter

Eskom will provide an indicative cost estimate based on part 1 of the application. This cost estimate is based on the assumption that your generation facility will be the only one connected in the area and the following further technical assumptions:

The criteria to be met before a ***non-binding cost estimate*** will be provided are:

- Completion of Part 1 of the application form. (Application for the Connection of a Generator to the Eskom Network)
- Reasonable assurance of the right to develop on the proposed site.
- Environment Impact Assessment (EIA) activities initiated;
  - Proof that the application has been submitted to the

	Department of Environmental Affairs (DEA) in the form of an acknowledgement of receipt letter. o Proof of the appointment of an EIA consultant. o If available, information regarding the public participation process. ➢ The cost estimate letter will contain: o The assumptions used, the estimated scope including the proposed line route, and the indicative estimated costs and connection charge based on assumptions and scope. o A quote for the non-refundable quotation fee to cover costs. o The quotation fee payable by the generator covers, amongst other items, Eskom's cost of design, survey and detailed studies for the grid connection, that are necessary in order to prepare a budget quotation should the generator decide to proceed with the project by requesting a budget quotation. o The terms and conditions contained in the indicative cost estimate letter regarding the non-refundable quotation fee are valid for one (1) year from the date of the letter to allow time for the necessary conditions to be met. o The cost-estimate letter does not place any obligation on Eskom to provide a connection or either party to enter into any other agreements as the provision of a connection is subject to, amongst other conditions, NERSA providing approvals or licences. o The cost estimate is currently provided to the generator at no charge.
	Budget quote
7 Budget quote conditions	If you want a binding quotation, there are a number of conditions that have to be complied with before Eskom is able to proceed to provide the budget quote: ➢ For applications in terms of a regulated IPP purchase programme, e.g. Renewable Energy Feed-In Tariff (REFIT) programme: o The entity responsible for procurement shall pre-qualify applications to receive a budget quotation based on the published pre-qualification criteria. o Completion of Part 2 of the application form. o The quotation fee is payable only once the applicant has been pre-qualified and only after this payment has been received will a budget quotation be initiated and provided. ➢ For applications that do not intend to be part of a regulated IPP purchase programme. o A letter from NERSA confirming receipt of an application for a licence. o Acceptance of the cost estimate conditions and the payment of the quotation fee.

- Proof of land ownership or permission to use the land obtained.
- EIA progress, i.e. a letter of confirmation from DEA giving approval of the scoping report and appointment of an EIA consultant.
- Proof of reasonable viability of the proposed technology regarding the primary energy source.
- Approval of the investment and quote in terms of the relevant Eskom Delegation Of Authority (DOA).
- Completion of Part 2 of the application form.

Note: Please take care to note the estimated connection date provided in the budget quote and the conditions attached to the connection date. No agreements with Eskom or any other party regarding the commercial operation date should be submitted before this date.

8 The budget quote

The budget quote will contain:

- The estimated capital costs and the cost confidence level.
- The technical assumptions, the scope including the proposed line route and the cost based on the assumptions and scope.
- The calculated connection charges, the early termination guarantee, Use-of-System charges security based on the costs.
- The validity period of the budget quotation. The terms and conditions to be valid for one hundred and twenty (120) days from the date of the quotation to allow time for decisions such as approvals of bids.

The budget quotation will contain the following conditions which have to be fulfilled before supply can be made available, either in time or at all:

- That Eskom obtains suitable way-leaves or servitudes, at no cost to itself, for its power lines and cables across the desired route.
- That the various authorities grant approval, with no further cost implications, for the erection of the power lines / cable along the desired routes.
- That the customer must provide and maintain at the customer's site accommodation for Eskom's equipment, where this is required.
- That any required environmental impact studies are completed on time.
- That long lead-time materials can be delivered on time.
- That no force majeure event occurs.
- That where there is upstream work required that Eskom has the necessary capital required for the upstream costs

9	**Acceptance of budget quote and signing of the connection and use of system agreement**	The following will be required before Eskom will proceed with the connection works (construction): ➢ For any regulated IPP procurement programme, e.g. the Renewable Feed-in Tariff programme, a letter from the entity responsible for the procurement programme indicating a successful bid. ➢ A letter from NERSA giving the required approvals regarding licensing. ➢ A copy of the final environmental authorisation. ➢ The connection charge must be paid and the budget quotation must be accepted in writing. ➢ The connection work will be initiated on receipt of the necessary approvals and compliance with the conditions. The project schedule will be negotiated and agreed upon once the budget quotation has been accepted. ➢ A Connection, Use of System agreement and Operating Agreement must be signed between the generator and Eskom before Eskom will allow a connection and/or synchronisation of the generator to the Transmission or Distribution networks. The terms and conditions of the budget quotation will form part of the connection agreement. ➢ An expenditure reconciliation will be done upon completion of the Connection Works. ➢ If the generator is not part of, or is not successful under a regulated IPP procurement programme, but wants the connection, the necessary approvals from NERSA in line with the relevant regulations and the Electricity Regulation Act will be required before Eskom proceeds with the connection works. ➢ If the project is cancelled by the generator a refund of the connection charge amount already paid will be given less all Eskom costs incurred as of the date of cancellation.
		Connection and use of system agreement
10	**Connection and use of system agreement**	A connection, use-of-system agreement and operating agreement must be signed between the generator and Eskom, before Eskom will allow a connection and/or synchronisation of the generator to the Transmission or Distribution networks.

	Connection works
11 Connection works	➢ The connection works will be initiated after acceptance of the budget quote, the payment of the connection charge and the signing of the connection and use-of-system agreement. ➢ Note that the date of connection will be subject to the EIA ROD approval. ➢ The project schedule will be negotiated and agreed upon.

Connection charges

	Connection charges
12 What are connection charges	Connection charges are a contribution towards the costs of connection and are payable upfront before connection works commence.
13 Reliability of supply	Where the customer requests a supply above what Eskom determines as a standard supply, a premium connection charge will be raised.

Technical standards

	Technical standards
14 Grid Code	The generator and Eskom are required to comply with the SA Grid Code and the Distribution Code and any Code that may be approved from time-to-time
15 Interconnection standard	Refer to Eskom's interconnection standard for an embedded generator on the IPP website.

CITY OF TSHWANE METROPOLITAN MUNICIPALITY
PUBLIC WORKS AND INFRASTRUCTURE DEVELOPMENT
ENERGY AND ELECTRICITY
PRIMARY DEVELOPMENT

CITY OF TSHWANE
"we are the same"

STANDARD SPECIFICATIONS FOR MUNICIPAL ELECTRICAL ENGINEERING WORKS

ISSUED BY:

City of Tshwane
Energy & Electricity
PO Box 6338
PRETORIA
0001

First Edition 2010

TABLE OF CONTENTS

PART 1.1 : GENERAL REQUIREMENTS

SPECIFICATION No : GR.01/0-97 – Rev 4

CONTENTS

1. SCOPE

Part 1 is the general specifications and must be read with the specific specifications of the various equipment.

2. STANDARDS AND COMPLIANCE WITH SPECIFICATION

All work shall be in accordance with this Specification and Standard Specifications herein, and the General Conditions of Contract Governing Tenders and Special Conditions of Contract Governing tenders: Electricity Department : Electrical Tenders of the City Council of Pretoria.

Where no particular specification clause is referred to with respect to any item of equipment to be supplied, the latest issue/amendment of the relevant SABS specification or NRS, IEC or BS Specification shall be adhered to (in the same order).

In order to help control costs, the Tenderer shall where possible offer his available standard commercial equipment.

Tenderers shall highlight any deviations from the specification on a clause by clause basis explaining the reasons for any deviations in detail. Reference to attached pamphlets, brochures etc., which may contain details of such deviations, are not acceptable. Tenderers main offer must comply fully with this specification. Any alternative offer shall supply the same functionality as called for in this specification. Tenders not complying with these functional requirements will be summarily rejected.

All civil work shall be in accordance with the Standard Specifications for Municipal Civil Engineering Works.

3. ENVIRONMENT

Altitude above sea-level	1 530 m
Maximum ambient temperature	40 °C
Average daily maximum ambient temperature	30 °C
Minimum ambient temperature	-5 °C
Average daily minimum ambient temperature	2 °C
Maximum ground temperature	25 °C
Minimum ground temperature	10 °C
Relative humidity	94%
Lightning conditions	Severe
Degree of pollution	Medium
Earth resistivity	Varying between 50 and 1000 ohm per metre at a depth of 1,5m
Maximum wind speeds :	
a) Steady conditions;	25 m/s
b) Gusty conditions.	45 m/s

4. SYSTEM PARTICULARS

4.1 132 kV System

Nominal system voltage (r.m.s. line to line)	132 kV
Highest system voltage (r.m.s. line to line)	145 kV
System frequency	50 Hz
Maximum symmetrical fault current capacity (3 second rating)	31.5 kA
System BIL at sea-level	650 kV
System insulation level at Pretoria altitude	550 kV
Number of phases	3
Phase rotation	R-Y-B anti-clockwise
System earthing	Neutral points on 132kV transformer windings solidly earthed

4.2 33 kV System

Nominal system voltage (r.m.s. line to line)	33 kV
Highest system voltage (r.m.s. line to line)	36 kV
System frequency	50 Hz
Maximum symmetrical fault current capacity (3 second rating)	13.10 kA
System BIL at sea-level	170 kV
Number of phases	3
Earthing	Through NEC and NER

4.3 11 kV System

Nominal system voltage (r.m.s. line to line)	11 kV
Highest system voltage (r.m.s. line to line)	12 kV
System frequency	50 Hz
Maximum symmetrical fault current capacity (3 second rating)	20 kA
System BIL at sea-level	95 kV
Number of phases	3
Earthing	NER on star/star transformer NEC on star/delta transformer

5. RECONSTRUCTION AND DEVELOPMENT PROGRAMME

The contractor shall approach this contract and execute the Works with due consideration of the Reconstruction and Development Programme (RDP) of the

Government of National Unity. It is expected that existing local Planning and Development Forum of RDP Committees or forums or committees still to be established, will monitor the extent to which government policy in this regard is supported.

It may be expected that these forums or committees or a committee established specifically for this contract, will also be involved in the requirements of labour, assessment of training needs and development requirements of entrepreneurs as contractors/sub-contractors as well as utilisation of sub-contractors from the relevant local communities.

The contractor shall give his full co-operation to these forums and committees.

All labour and sub-contractors utilised on this contract shall be drawn from the communities of the CITY OF TSHWANE METROPOLITAN MUNICIPALITY where large unemployment prevails and the need for a better quality of life exists, all in accordance with the goals of the RDP.

If the contractor intends to utilise certain categories of employees (generally considered as being key-personnel of the contractor), or certain sub-contractors (generally specialist sub-contractors) in the Works, full details in this regard must be provided with the Tender. This clause shall apply mutatis mutandis to such a sub-contractor if accepted in terms of the General Conditions of Contract.

Should the contractor fail to comply with the conditions of this clause, the Engineer may suspend the progress of the Works in terms of clause 48 of the Special Conditions of Contract and the contractor shall not be entitled to make a claim for a delay or additional Cost.

Compliance with this clause does not relieve the contractor of any of his contractual obligations or liabilities

6. SITE SECURITY

The Contractors will be responsible for all security until hand over to the Council. This shall include all temporary security site lighting.

7. SITE OFFICE

The Engineer will allocate to the Contractor an area for the purpose of stacking or storing materials and the erection of site offices. On completion of the Contract Work, the Contractor will remove all buildings, equipment, rubble and materials at the construction site and leave it in a tidy condition.

8. FOOD, ACCOMMODATION AND TRANSPORT

Suitable provision shall be made for the supply of drinking water and food under sanitary conditions acceptable to the health inspectors of the Council.

The safe transport of plant, tools, materials and labour to and from the working sites is the responsibility Contractor.

9. CONTRACT MANAGEMENT

9.1 Project Team

The Tenderer shall submit a list of his proposed project team, with a brief CV of each candidate. The Engineer shall have the right to instruct the Contractor to change the team after negotiation with the Contractor.

9.2 Subcontractors

The Contractor shall submit a list of proposed subcontractors for approval to the Engineer. Any changes to the list of subcontractors shall be approved by the Engineer. Subcontractors may not subcontract work further without permission of the Engineer. The Engineer may at any time ask for a subcontractor to be changed.

9.3 Work Scheduling

Within 3 weeks of order date the Contractor shall submit a detailed plan covering all important activities. The Engineer, together with the Contractor, shall agree the final schedule. This schedule will be saved as the base case and may not be changed. The milestones so generated will become the contractual dates for payments.

9.4 Site Office

The Contractor shall establish a permanent on-site organisation for the proper control, management and execution of the works.

9.5 Progress Meetings

Fortnightly meetings shall be held at which reports shall be submitted to the Engineer indicating progress and adherence to the work program.

Minutes of meetings shall be kept by the contractor and shall be made available to all participants, and others to be decided by the Engineer, within 3 working days.

Agenda to be circulated to all participants by fax or by hand 1 week before each meeting.

9.6 Progress Reports

Monthly progress reports reflecting the status at the end of each calendar month shall be made available to the Engineer before the 5th working day of the following month and shall include, but not be limited to, updated versions of the following:

a) Cover sheet for monthly report;

b) minutes of the previous meeting;

c) cash flow statements showing actual expended amounts and forecast amounts to the end of the project on a monthly basis;

d) gantt charts generated on the approved project management software showing sequence and duration of work, as well as actual progress achieved and expected completion time. The base information as quoted for shall be shown and shall remain unchanged for the duration of the project;

e) attendance list;

f) list of site instructions to date;

g) list of variation orders to date;

h) list of drawings on the project;

i) list of rainfall days;

j) schedule of plant and personnel on site; and

k) list of subcontractors on site.

Furthermore, all variations to the contract, extras, omissions, etc., shall be processed and presented in the form to be directed by the Engineer.

10. SITE INSTRUCTION BOOK

The Contractor shall supply and keep in safe custody on site, a site instruction book of standard A4 size, with numbered pages and provision for two carbon copies per page.

The first page of every instruction will be removed and retained by the Engineer for record purposes.

11. DELIVERY AND STORAGE

The Contractor shall make his own arrangements regarding transport and off-loading of labour and materials and shall provide his own plant. The Contractor will be responsible for the safe storage of all equipment, materials and plant after delivery and will be held responsible for loss by theft or damage in any way, whether installed on the contract or not, until take-over of the works by the Council.

The Contractor will assume full responsibility for all materials which are supplied to him on site. He must provide adequate security measures to minimise the risk of theft. Materials on site shall be insured by the Contractor against all risks to their full value. Proof of such insurance and pre-payment of premiums to cover the duration of the Contract must be provided before the issue of any payment certificates will be considered.

12. SAFETY OF PERSONNEL

The Contract may involve work within close proximity of and work upon possible live high voltage equipment. Correct safety procedures must be adhered to at all times and work must be carried out under control and supervision of an experienced responsible person as detailed in the Occupational Health and Safety Act of 1993 as amended.

13. COMMENCEMENT AND COMPLETION DATES, PROJECT SCHEDULING

Within 1 week of written notification of acceptance of his tender, the Contractor shall arrange a kick-off meeting with the Engineer at which open points will be discussed and design freeze dates established.

The Contractor shall put the work in hand and shall submit a detailed programme to the Engineer for approval within two weeks after award of the contract, detailing the commencement date, duration and completion date and detail cash flow of each activity concerning the works. A suitable number of milestones shall be defined in order to ensure that the project is kept on schedule and that sufficient resources are employed.

The Contractor shall use a project planning programme approved by the Engineer.

Manufacture of equipment off-site is to run concurrently with the execution of the civil and building works. The various phases shall be properly co-ordinated to ensure that accommodation for equipment is ready when the equipment is ready for delivery.

A detailed manufacturing schedule for all equipment shall be supplied to the Engineer for his approval within 1 month of award of the contract. The Engineer will then insert hold points and inspection points at his discretion. The Engineer reserves the right to visit any works of the Contractor or any Sub-contractor at any reasonable time without prior announcement.

14. INFORMATION TO BE SUBMITTED WITH TENDER

Tenders shall be submitted complete with comprehensive literature, drawings, etc., describing the equipment offered. This information shall include the following as a minimum requirement:

a) Dimensioned drawings, to metric scale of each item of equipment;

b) Typical circuit diagrams of control and protection system;

c) Description of units and its operation, including vital design parameters (max. system voltage, fault capacity, current rating, impulse withstand level etc.).

All tenders must be fully priced. Items not specifically called for, but required for the successful completion of the works, shall be added by the tenderer.

Tenderers are further required to indicate in their tender their past experience in the execution of works of similar nature and scope.

Detail cash flow for each activity concerning the works.

15. INFORMATION TO BE SUBMITTED BY SUCCESFUL TENDERER

15.1 As-Built Drawings

The successful Tenderer shall during the course of this service update all drawings to reflect the as-built status of the works. Full sets of "AS-BUILT" drawings shall be supplied by the Contractor before final take over. These drawings must be to the satisfaction of the Engineer. One set of drawings shall be left on site, and the other used by the Contractor to correct the originals.

16. STATEMENT OF COMPLIANCE

Tenders are to be accompanied by the Statement of Compliance, stating whether the tender complies with the Conditions of Contract and the Specification.

17. STANDARD REGULATIONS

Wherever applicable the equipment, work and installation shall conform with:

a) The Standard Regulations for the Wiring of Premises issued by the South African Bureau of Standards.

b) Any special requirements of the Supply Authorities of the area or district concerned.

Please note the requirements of Electrical Machinery Regulation R4 and R5. These state that no person employed by the Contractor or any Sub-contractor may enter any existing substation or switch-house without the uninterrupted presence of a "competent person" as defined in the Occupational Health and Safety Act acting on behalf of the client, unless a "permit to work" as referred to hereinafter has been obtained. When the electrical apparatus in any new substation or switch-house is made alive for the first time, and at all times thereafter, such substation shall be treated as an existing substation and the requirements of the above paragraph shall apply for high voltage work.

18. PERMIT-TO-WORK

As the work may be done in stages, sections of the area can be energised. We draw your attention to the Electrical Machinery Regulation R4 & R5. The Contractor shall not work on any part(s) of the high voltage distribution system until such part(s) of the system have been isolated and earthed and the appropriate measures have been taken to prevent accidental re-energising of the part(s) and a "permit to work" authorisation in writing has been obtained from the Engineer or his duly authorised representative.

Before the responsible person of the Contractor signs for and accepts the permit he must satisfy himself that the part of the system on which he requires to work has been effectively isolated and earthed, that all circuits have been clearly identified, and that the Engineer has made it safe to work at the point of working.

The "permit-to-work" shall be made in duplicate and shall contain the following:

a) Written description of location of points of isolation and of earthing.

b) Name and signature of person to whom the permit is issued.

c) Time and date of issue of permit.

d) Statement handing-over section(s) of system clearly defining the part(s) handed-over as being safe to work upon.

e) Signature of the Supply Authority or his duly authorised representative.

The responsible person of the Contractor shall retain the original "permit-to-work" shall be handed to the Contractor and shall retain it while his work is being completed on that part of the system covered by the permit.

After ensuring that no person employed by the Contractor or any Sub-contractor is still working on the system, that work is completed and that the installation has been made safe, the Contractor shall sign the "permit-to-work" and return it to the Engineer. Then the electrical installation may be re-energised. The same person that took out and signed the permit must return it.

Notwithstanding the foregoing, the Contractor shall at all times take all necessary precautions and make all necessary tests to ensure the safety of all persons employed by him or by any Sub-contractor.

No extras to the contract or extension of time will be allowed due to any of the above factors.

19. PROTECTION OF EQUIPMENT AGAINST DAMAGE

Equipment shall be adequately protected against possible damage during transportation, off-loading and handling on site. Relays, instruments and other delicate equipment shall be adequately protected against transport and other damage to the satisfaction of the Engineer.

20. LV DISTRIBUTION VOLTAGE

The low voltage distribution will be at a nominal voltage of 400/230 volt 50 Hz 3 phase AC.

The voltage on miniature substations or transformers shall be set at a No Load voltage of 400/230 volts.

Distribution will be by 4 wire, 3 phases and a neutral. The neutral shall be solidly earthed at the substation.

21. TEST BY SUPPLY AUTHORITY

On completion of the work, the whole of the installation will be inspected and tested by the Engineer.

The Contractor will be required to attend on the Supply Authority's inspector(s) requests and give all assistance required and provide such tools, materials, implements and instruments as are necessary for the tests.

22. ARTICLES OF VALUE

Any article of value, archaeological finding, etc., found on the site during the execution of the Contract shall be handed to the Engineer who shall be the sole referee as to what constitutes articles of value and to report to who ever may be concerned.

23. WITNESSING OF TESTS

The Council reserves the right to have the Engineer inspect and witness factory and onsite commissioning tests of all equipment to the satisfaction of the Engineer.

The Contractor shall make due allowance for these inspection points in his manufacturing programme and to avoid delays occurring, shall notify the date for inspection or witnessed tests at least 14 days in advance of the actual date.

The Council does not accept responsibility for the late delivery on the basis of inspection delays.

All tests shall be documented to the satisfaction of the Engineer.

24. EXISTING SERVICES

The Contractor shall be responsible for obtaining drawings from other Municipal Departments and authorities showing the positions of underground services.

25. HANDOVER

The last payment on takeover (i.e prior to retention payments) will only be done on completion of a Handover Certificate and receipt of all manuals and test certificates

PART 1.2: SITE SAFETY, SEQURETY, STORAGE AND SUPERVISION REQUIREMENTS

SPECIFICATION No: SR.01/0-2003 (Previous No: SR.01/0-97)

CONTENTS

1. WORKING IN LIVE YARDS

In order that the Council may make the necessary arrangements, each application for a Work Permit shall be submitted to the Engineer, together with all the required particulars, **at least three full working days** before access to the site yard is required.

With regard to the switching out of equipment to facilitate the carrying out of Contract Work, it shall be distinctly understood that switch-out dates, times and periods are subject to load and operational requirements. Operational and/or load requirements may dictate that Contract Work on the existing network be carried out over weekends or outside normal working hours.

The Contractor shall obtain, complete and return the following documentation one week before access to the site is require :

a) Issuing of substation keys to Contractors (where applicable)

b) Temporary Permit to enter a security area

c) Appointment of a competent person to supervise workers near electrical equipment

d) Duties and responsibilities for the competent person supervising construction work near live electrical work.

2. SECURITY MEASURES

Work inside electrical yards is subject to the Council's security measures and the contractor shall contact the Council's Chief Security Officer prior to the commencement of any work under the Contract, in order to make the required security arrangements. The costs of security measures shall be included in the rates for site work.

If so required by the Council, all Employees of the Contractor and his Subcontractors employed with regard to the execution of the Contract shall be security cleared on such conditions as laid down by the Council.

Should any Employee of the Contractor or his Subcontractor be declared unfit for whatever security reasons, the Contractor or the Subcontractor shall have the right to appoint any person in lieu of the disqualified Employee, subject to the Council's security clearance.

The Contractor undertakes -

a) to treat all information regarding the Contract and the execution thereof as strictly confidential;

b) that he himself, his Subcontractors and all Employees concerned will sign the Council's Declaration of Secrecy;

c) in the execution of the Contract, to report to the Council's Chief Security Officer, without delay and confidentially, any information regarding:

d) Any suspected espionage in respect of the lay-out of the site where the work is being executed, or in respect of sites where protective measures are applied.

e) Actions which may be interpreted as sabotage, or any planning in this regard.

f) Any suspected subversive activities among his Employees.

g) The loss of any classified documents which came into his possession as a result of the Contract.

h) The contravening of any security measure by an Employee.

i) Housebreaking, theft, arson, vandalism, loss of identity documents, security keys or lock combinations.

j) Corruption, blackmail, intimidation, striking or inciting or unauthorized access to an office or premises.

k) Any Employee who is involved with the Contract and who is suspected of bringing drugs, intoxicating liquor, a weapon, ammunition or explosives on the site of the Council.

The Council shall have the right to inspect, at all reasonable times, and through its Security Department, the Contractor's and Subcontractor's premises and offices where work in connection with the Contract is executed or where documents in that connection are kept, in order to prescribe suitably security measures, and to determine whether the prescribed security measures are bing implemented satisfactorily.

3. STORAGE OF MATERIALS

The Contractor shall be solely responsible for all security arrangements for the safe storage of materials on site. The Council will not be liable for any loss or damage of any materials or equipment whatsoever.

Prices for supply and delivery of materials shall allow for all transport, handling, loading and off-loading on site.

The receiving and handling thereafter on site of all materials is the responsibility of the Contractor.

4. WORKING HOURS

Site work carried out for the execution of this Contract shall be confined, as far as possible, to normal working hours on normal working days (i.e. 07h00 - 17h00 on Mondays to Fridays) excluding Public Holidays.

Work to be done outside normal working hours shall be approved by the Engineer who shall be notified of the reasons in writing at least three working days in advance of any work to be done outside normal working hours.

5. CLEARING SITE

On completion of the Contract the contractor shall clear the Site of all temporary offices, sheds, temporary structures and waste material and rubbish. Nothing shall be buried on site.

PART 1.3 : QUALITY ASSURANCE REQUIREMENTS

SPECIFICATION No : QR.01/0-2003 – Rev 4 (Previous No: QR.01/0-97)

CONTENTS

1. QUALITY SYSTEM

The Contractor shall provide and operate throughout the Contract, to the satisfaction of the Engineer, a Quality System in accordance with the requirements specified hereinafter.

The Contractor's quality assurance activities shall include, but not be limited to, those functions defined in the Schedule and such additional activities as the Engineer may direct to prove conformity to the Specification. They shall provide for the detection and removal of all non-conforming material either prior to or at the latest state of process or manufacture where the required characteristics can be measured or observed.

A valid ISO 9000 listing will be acceptable to the Engineer.

2. INFORMATION REQUIRED IN THE TENDER

The Contractor shall complete and submit in his Tender the Quality System Questionnaire.

In support of this information and when called upon to do so, the Contractor shall submit a description of his Quality System or a Quality Manual.

3. QUALITY SYSTEM DOCUMENTATION

3.1 Contractor's Quality Control Plan (QCP)

Within one month of instructions to proceed, the Contractor shall submit for approval of the Engineer two copies of a draft Quality Plan for the contract Works, defining the inspections, tests and other quality activities, which he proposes to carry out at each stage of his work under the Contract. The Engineer shall add his witness and hold points to the quality plan. Quality activities, which are to be performed at sub-contractor's premises, shall be clearly defined.

The Quality Plan shall be in two parts, covering:

a) Quality activities during design (if applicable), and manufacture.

b) Quality activities at Site.

Following approval of the Quality Plan and within 1 month of approval by the Engineer, the Contractor shall submit to the Engineer four copies of the approved documents.

3.2 Witnessing by Engineer

Following his approval of the Contractor's Quality Plan the Engineer will notify to the Contractor the inspections, tests and other quality activities, which he intends to witness. He may at any time call for the witness of such additional inspection and tests as he may require proving conformity with the Specification. When the Engineer has confirmed his intentions to witness any inspections or tests the Contractor shall be given due notice of his readiness. Work or dispatch may not proceed if the Engineer has not witnessed or attended tests required by the Quality Control plan.

The Engineer shall indicate on the QCP whether he wishes to attend factory witness tests, and site commissioning tests. The documentation of these tests shall be incorporated into the Contract Documentation system.

4. INSPECTION AND TESTING

4.1 Scope

Inspection and testing shall include all items in Schedule A and all relevant tests listed in the appropriate Standards. The quality plan shall be to the approval of the Engineer.

4.2 Statutory Testing

The Contractor shall be responsible for ensuring that all tests and approvals required by Statutory Authorities are duly performed and the relevant approval documents issued, free of charge, to the Employer.

Where classification of equipment is required, an approved Classification Society shall carry it out at the Contractor's expense. On completion, the Contractor shall issue the relevant documents to the Engineer.

4.3 Testing

Cognisance should be taken of the specific requirements detailed in other parts of Section 3 regarding testing. Tenderers are to ensure that all uncertainties regarding separate requirements are clarified with the Engineer in advance.

All test reports shall be incorporated into the Instruction, Operating and Maintenance Manuals.

4.3.1 Type tests

The electrical equipment, relays and control equipment shall be certified by means of test certificates to have been tested successfully and in accordance with the specified requirements and Standards. It shall also be certified that they have passed the following tests successfully:

a) Temperature rise test;
b) ability to withstand overload test;
c) durability test;
d) contact test;
e) insulation test;
f) high-frequency disturbance test; and
g) any other type tests normally carried out by the manufacturer and those laid down by the appropriate Standard Specifications.

If type testing is to be done specifically for the purpose of this contract, testing shall be carried out in accordance with the specified requirements by an independent recognised testing institute approved by the City Council.

Existing type test certificates will be considered on their merits and Tenderers are requested to submit copies of existing type test certificates with their tenders. Should reasonable doubt arise as to the validity of the test certificates submitted and accepted by the City Council, in respect of the relays to be supplied, the City Council may direct that further certificate(s) be obtained on a sample unit/sample units, provided by the successful Tenderer at his expense. An independent recognised testing institute shall carry out such further testing.

4.3.2 Routine tests

These are part of the manufacturing process and the test results shall be included in the operation and maintenance manuals.

A high-voltage test of insulation shall be carried out.

Any other factory routine tests normally carried out by the manufacturer and those laid down by the appropriate Standard Specification.

The general philosophy shall be to deliver a system to site only once it has been thoroughly tested and its specified performance has been verified, in so far as site conditions can be simulated in a test laboratory.

4.3.3 Instruments

All measurements shall be calibrated in accordance with SABS-ISO 9000.

4.3.4 Detailed testing requirements

The Contractor shall give the City Council or its appointed representative not less than fourteen (14) days notice of such equipment being ready for inspection or witnessing of tests, as necessary (90 days in respect of overseas tests).

In order to assist the City Council in making provision for inspection and witnessing of tests, the name of the manufacturer, the place of manufacture, the place where equipment can be inspected and where equipment will be tested, shall be provided. Should the Contractor wish to change to another manufacturer, he shall in due time advise the City Council in writing of the details called for above.

The Contractor shall at the time of placing orders or sub-orders advise all Sub-contractors that all equipment may be subject to inspection and witnessing of tests by the City Council or its appointed representatives.

Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying.

Site and commissioning tests shall be regarded as an integral part of the installation of the various items and shall be allowed for in the unit prices quoted for installation.

The Engineer shall be furnished with two copies of the Contractor's records of all factory tests immediately after such tests and before any material is shipped. No material shall be installed before the Engineer has officially approved these tests.

The Engineer shall be furnished with two copies of the Contractor's records of all site and commissioning tests immediately after completion of such tests.

4.3.5 Site tests

Site tests shall be carried out in detail to confirm the integrated operation of the control and protection scheme.

Testing shall at the least include the following:

a) Secondary injection tests, to prove panel circuits and the operation, speed and operating curves of relays;
b) functional testing of all elements, to prove the operation of the different circuits. This includes the interfacing with yard equipment and the various other substation functions, like busbar protection, breaker fail/busbar strip protection, inter-tripping, aided tripping, interlocking, indications, alarms, control functions, communication networks, operator stations and master station control operations;

c) tests to prove the key features of instrument transformers;
d) primary injection, carried out from the yard equipment, to prove instrument transformer circuits; and

On-load testing, as a final proof of instrument transformer circuits and the phase relation of current and voltage inputs to the protection relays.

4.4 Procedures Subject to Approval

The Contractor shall submit his proposal to the Engineer when it is a condition of this Specification that a manufacturing, inspection or testing process be subject to the approval of the Engineer or when any matters require to be agreed between the contracting parties, as when specified Standards leave acceptance criteria to be so agreed.

Wherever practicable the Contractor's proposals shall be submitted early enough to allow ample time for agreement to be reached.

The approval of equipment, etc (issue for Manufacture/Construction) shall not relieve the Contractor of his responsibility regarding the correctness thereof or any subsequent failures as a result of faults or omissions by the Contractor.

5. WELDER QUALIFICATION

Welders who hold valid certificates of competence in accordance with the relevant National or International Standard shall carry out all welding.

6. CONTRACTOR'S RECORDS AND REPORTS

The Contractor shall maintain adequate records for inspection by the Engineer and shall submit for the Engineer's approval all test data, results and certificates as required. Following final tests on completion, test sheets recording the results of the tests shall be submitted in triplicate.

The Contractor shall obtain and submit to the Engineer copies of the relevant data and certificates when others carry out inspections and tests.

7. AUDITS BY THE ENGINEER

The Contractor's procedures and implementation thereof shall be subject to audit by the Engineer after Contract award. The frequency of audits shall be dependent upon the complexity and duration of the work. The Engineer shall give Two weeks notice to the Contractor of an intended audit.

8. QUALITY ASSURANCE REQUIREMENTS

Tenders shall present a Quality Plan to the satisfaction of the Engineer in the format suggested by ISO 9000.

9. PROVISION OF STANDARD SPECIFICATIONS

The Tenderer shall supply the latest issues and amendments of the list of specifications to be issued on the tender designation to the successful tenderer. The standard specifications are:

a) SABS Catalogue;

b) IEC Catalogue;

c) BSI Catalogue;

d) IEC 129 - Disconnectors;

e) IEC 51 - Switchgear;

f) IEC 255 - Protection relays;

g) IEC 694 - Common clauses;

h) IEC 298 - Metal encapsulated, type tested, works manufactured switchgear assemblies for voltages up to 72.5kV;

i) IEC 298 - Testing the response of Type tested, works manufactured, metal encapsulated switchgear, for voltages up to 72.5kV, to an internal arc fault;

j) NRS 001 - Technical specifications guidelines for drafting;

k) SABS 0200 - Earthing;

l) IEC 185 - Current transformers;

m) IEC 186 - Voltage transformers;

n) IEC 529 - Degrees of protection afforded by enclosures (IP code);

o) SABS-1195 - Busbars and busbar connections; and

p) SABS-1222 - Enclosures for electrical equipment.

PART 1.4 : TECHNICAL REQUIREMENTS

SPECIFICATION No : TR.01/0-97 – Rev 5 (previous No: TR.01/0-97)

CONTENTS

1. STANDARDS

The design, manufacturing and testing of the equipment offered shall be strictly in accordance with this specification and the current editions of the following Standard Specifications and Codes of Practice, except where amended herein.

The hierarchy of the specifications shall be as follows:

a) This specification;

b) SABS;

c) NRS;

d) IEC; and then

e) BS

The following documents shall be read in conjunction with this specification or the latest specification:

1.1 South African Sources

Occupational Health and Safety Act No 85 of 1993.	
Bolts and Nuts	SABS 135
Busbars	SABS 1195
Galvanising	SABS 763
Insulating Oil	SABS 555, IEC 296
Insulators	SABS 177
Marking of small wiring	NRS 003-1:1994
Mineral Lubricating Oil	SABS 053
Moulded case circuit breakers.	SABS 156: 1977 Amendment No 1: March1987
National colour standards for paint.	SABS 109: 1975 Amendment No 2: 1989.
PVC Insulated Electric Cables	SABS 150, SABS 1507

1.2 IEC Sources

Alternating current and disconnectors and earthing switches.	IEC 129 (1984)
Auxiliary switches	IEC 129
Bushings for alternating voltages above 1000 V.	IEC 137 (1984)
Common clauses for high-voltage switchgear and control-gear standards.	IEC 694 (1980) Amendment No1 (1985) Amendment No 2 (1993)
Contactors	IEC 158-1
Current transformers	IEC 185

Degrees of protection afforded by enclosures (IP code).	IEC 529 (1989)
Dimensional standardisation of terminals for high-voltage switchgear and control-gear .	IEC 518 (1975)
Dimensions of low-voltage switchgear and control-gear. Standardised mounting on rails for mechanical support of electrical devices in switchgear and control-gear installations.	IEC 715 (1981)
Disconnectors	IEC 129
Electric Power Switchgear and Accessories	IEC 51
Electrical and magnetic devices.	IEC 50-151 (1978)
Electrical Protection Relays	IEC 255
General definitions and test requirements.	IEC 60-1 (1989)
Graphical symbols for use on equipment.	IEC 417 (1973)
Guide for the checking of SF_6 taken from electrical equipment	IEC 480 (1974).
Guide to the testing of circuit breakers with respect to out-of phase switching	IEC 267 (1968)
High voltage alternating current circuit breakers - guide for maintenance.	IEC 1208 (1992)
High voltage metal-enclosed switchgear for rated voltages of 72,5 kV and above	IEC 517.
High voltage test techniques.	IEC 60 (1989)
High-voltage alternating current circuit breakers	IEC 56 (1987) Amendment 1 (1992)
IEC Standard voltages	IEC 38 (1993)
Insulation Co-ordination	IEC 71
International Electrotechnical Vocabulary	IEC 50
Low voltage control gear. Part 1 : Connectors	IEC 158-1 (1970)
Low voltage motor starters	IEC 292-1
Oil immersed Power Transformer	IEC 354
On-load tap changer	IEC 214
Partial discharge measurement	IEC 529, IEC 270 (1981)
Post Insulators	IEC 273
Power Transformers	IEC 76
Radio interference measurement	IEC 270
Rotating electrical machines	IEC 34 (1994), BS 2613 and BS 3979
Specification and acceptance of new sulphur hexafluoride.	IEC 376 (1971)
Sulphur Hexafluoride (SF6) Gas	IEC 376

Surge Diverters	IEC 99.1
Switchgear, control gear and fuses.	IEC 50-441 (1984)
Synthetic testing of high voltage alternating current circuit breakers.	IEC 427 (1989) Amendment No 1 (1986)
Tests on hollow insulators for use in electrical equipment.	IEC 233 (1990)
Voltage transformers	IEC 186

1.3 British Sources

Cartridges fuse for voltages up to and including 1 000V ac and 1500 V dc.	BS 88 (1988)
Direct Acting Indicating Analogue Indicating Instruments	BS 3693
Electrical Measuring Instruments and Associated Apparatus.	BS 162
Electrical power switch-gear and associated apparatus	BS-162
Electrical protection relays.	BS 142 (1982) Appendix G.
Electroplated coatings of tin	BS-1872
Lead Based Primary Paints	BS 2523
Phosphate Treatment of Iron and Steel	BS 3189
Specification for current transformers	BS 3838: 1973 (1982)
Structural Steel	BS 5950, BS 449
Weldable Structural Steel	BS 4360

The equipment shall be designed to include all possible provisions for the safety of those concerned in operation and maintenance.

All outdoor equipment shall be designed to prevent accumulation of moisture. The terminal boxes shall be to IP55 as a minimum requirement.

Where it is not possible to protect metal parts by painting or galvanising, these parts shall be constructed of stainless steel or brass.

Control panels and kiosks shall be designed to be rodent proof and outdoor 'live' structures shall be designed and positioned to eliminate possible short circuits, which could be caused, by birds or animals.

2. REQUIREMENTS FOR DESIGN AND LAYOUTS OF EQUIPMENT

The contractor shall ensure that the design and layout of the equipment to be supplied on this contract is such that in the operating condition it shall comply fully with the regulations promulgated in terms of the Occupational Health and Safety Act of 1993 and the latest amendments.

Where equipment supplied on this Contract is to be positioned in the proximity of existing equipment, structures or plant, the Contractor shall establish beyond any doubt that the said Regulations shall not be contravened by virtue of this proximity during the erection and testing periods and in the final operating conditions. Any queries in this regard must be submitted in writing to the Engineer.

Where special inspection and testing are required the cost shall be included in the contract price for the equipment and the contractor shall be responsible for the arrangement of such inspections and testing.

3. GALVANISING

The pre-galvanising treatment, the hot process galvanising and the testing shall be carried out in accordance with SABS 763.

A minimum thickness of 0.063mm of zinc is to be achieved during the galvanising process.

The preparation and the galvanising shall not adversely affect the function or the properties of the galvanised equipment.

The material shall be completely shaped, cut, drilled, countersunk, welded, etc., before galvanising.

Surfaces, which are in contact with oil while in service, shall not be galvanised.

Alternative processes shall not be used unless approved in writing by the Engineer.

The galvanising of bolts shall be carried out after all mechanical operations have been completed, but the associated nuts may be threaded after galvanising. The galvanised threads of bolts shall be cleaned of spatter by spinning or brushing.

4. PAINTING

4.1 General

The material shall be completely shaped, cut, drilled, countersunk, welded, etc. before any paintwork commences.

4.2 Painting of Non-Galvanised Steelwork

Cubicles, which contain wiring and other apparatus and are assembled in the works, shall receive the external finishing coat of paint in the works.

Before painting the parts shall be thoroughly cleaned by sand or shot-blasting or metal brushes and acid bathed to remove all traces of rust, scale or grease.

Immediately after cleaning all rough surfaces shall be filled.

Paint finish for indoor conditions shall be powder coating in excess of 80 microns. White chassis plates shall be supplied.

Unless otherwise specified, all indoor Panels should be painted Cloud Grey F48 to SABS 1091 of 1975.

5. BOLTS AND NUTS

Bolts and nuts shall comply in all respects with the current edition of SABS 135.
The bolts, nuts and washers used on outdoor galvanised steel work shall be hot dip galvanised in accordance with Clause 1.4.

For electrical connections, no brass bolt or stud shall be less than M6 size.

6. ALUMINIUM AND ALUMINIUM ALLOYS

Aluminium shall be of the highest purity commercially obtainable, and be suitable for the electrical and mechanical applications for which it is intended.

Aluminium and aluminium alloy castings shall be free from porosity.

7. LABELS

All equipment to be supplied on this contract shall be provided with clear and concise descriptive labelling describing the function and the circuit number of the apparatus concerned. These shall be to the approval of the Engineer. All labels shall be in English.

In the case of open busbar, phase identification discs shall be fitted where practical, i.e. for strung busbar on the gantry beam below every string insulator set and for solid busbar on post insulator support pedestals. These shall be 150mm diameter discs and shall be coloured red, yellow or blue according to phase and shall be fitted to be visible from ground level. They shall be properly affixed by each fuse holder, link, protection relay, switch, control handle, control relays and indicator lamps shall be labelled to indicate its function and current rating for fuses.

Complete particulars of instrument transformers and surge diverters must be engraved or stamped on permanent weatherproof labels.

The manufacturer's details of switchgear such as rating, type, serial number etc. shall be engraved or stamped on a permanent weatherproof label.

8. OIL

New oil shall be supplied on this contract for all equipment required to be oil filled. Re-refined oil will not be accepted.

Insulating oil shall comply with the current editions of SABS 555 and shall be passed through a filter before use.

Lubricating oil shall comply with the current edition of SABS 053.

9. SF6 GAS

New sulphur hexafluoride (SF6) gas shall be supplied on this contract for all equipment required to be gas filled.

SF6 gas shall comply with the recommendations of IEC Publication No. 376.

10. DENSITY METERS

Unless specified elsewhere each gas compartment of equipment supplied with SF6 gas shall be supplied with density gauges equipped with at least one change-over contact for low gas density alarm condition and density alarm condition trip and one for lockout if applicable.

These gauges shall be easily visible from ground level by the operator. Arrangement of the gauges shall be to the approval of the Engineer.

11. SPARES

All spare parts or materials containing electrical insulation shall be delivered in approved cases suitable for storing such parts over a considerable period of time without deterioration due to climatic conditions or other causes.

Cases of spares shall be clearly marked with the contract number and as to what their contents are and a packing list shall be easily accessible from outside.

Individual spares shall be packed in plastic sheet or plastic bags, and tags listing the part number and description tied to the parts.

12. SPECIAL TOOLS

Where special tools are required for effecting adjustments, for dismantling purposes or for maintenance, a full kit of such tools shall be provided.

The cost of the special tools shall be deemed to have been included in the price of the device for which they are required, unless specially listed.

These tools are not to be used during erection.

A special lockable cupboard shall be supplied at each substation to house the special tools.

13. STRUCTURES

Structures with foundations shall be provided and erected to support the busbars, isolating switches, earthing switches, instrument transformers, surge diverters, etc.

A drawing (or drawings) shall be issued with this specification detailing the envisaged layout of the substation equipment. The design and layout of the equipment to be supplied on this contract shall be based on this envisaged layout.

The structures complete with busbars and droppers shall be designed such that under all conditions of loading, temperature variations and maximum swing under fault conditions the electrical clearances shall be equal to or greater than those specified. The temperature variation of busbars shall be considered to be 75° C to -5° C.

Safety clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work shall be strictly in accordance with BS 162.

This contract covers the supply and fitting of droppers and connecting clamps to all items of equipment shown on the drawings of an envisaged layout of yard equipment whether these are to be supplied on this contract. The name/s of the supplier/s of associated yard equipment will be available from the Engineer. Where these connections are to be made onto existing commissioned equipment this work shall be carried out only after staff of the Engineer have certified that the existing equipment has been made safe and the necessary dead orders have been obtained.

Where the supply to the substation is by overhead line, the yard structures covered by this contract shall be provided with all the fittings or anchor bolts necessary for the anchorage of the tension insulators to be provided and fitted by the overhead line contractor. The structures shall be designed to allow for the loading of these incoming conductors (and earth wires) with the factors of safety specified in Clause 14 below. The final connection from the yard equipment to the terminal landing span conductors shall be the responsibility of the supplier of the yard structures specified herein.

Provision shall be made on each leg of all structures to accommodate an M16 bolt for the earth strap.

14. LOADING CALCULATIONS AND FACTORS OF SAFETY

The assumed maximum working loads shall be the combined simultaneous loading of "dead weight", windage and tension loadings.

The "dead weight" shall be the vertical loading of the conductors, insulators and equipment supported by the structures and the structures themselves.

The windage loading shall be the product of an assumed wind pressure of 700 Pa and the "effective projected area" of the structures, equipment, insulators and conductors supported. The "effective projected area" is as follows: -

a) The true projected surface area of flat objects x 1.

b) The true projected surface area of round, elliptical or hexagonal objects x 0.6.

c) The true projected area of all the members of the side of lattice supporting structures X1.5.

For equipment and structures of less than 10 metres total height the wind pressure shall be assumed to be 900 Pa. For structures of total height above 10 metres the assumed wind pressure shall be that determined from the curve of pressure against height as shown in Table 3 (section 4.5) of SABS 0160 - 1980 "Code of Practice for the general procedures and loadings to be adopted for the design of buildings", adjusted by multiplying the figure by a gushing factor of 1,37 (i.e. for a 140km/hour wind).

The tension loading shall be the combination of the tensions applied to the supported yard conductors and the tension due to the incoming lines and earth wires.

For calculation purposes working tension of each line conductor (or earth wire) shall be considered to be 4500 Newtons (i.e. 9000 Newtons per phase for twin conductors per phase) and allowance must be made for variation in landing direction (from that shown on the drawings issued with this specification) of up to 30° laterally and 20° vertically. The yard conductors shall be assumed to be at -5 C for the calculation of the assumed maximum working load.

The ratio of unsupported length of compression members to their least radius of gyration shall not exceed 120 for main members or 200 for bracing members.

The calculated tension/compression stress of any member of the completed structure resulting from the assumed maximum working load shall not exceed 40% of the elastic limit/crippling strength of that member (i.e. a safety factor of 2.5).

The tension of each single conductor shall not exceed 4500 Newtons at -5 C and a maximum safety factor of 2.5, based on the elastic limit or the 0.1% proof stress, shall apply.

The strength of the insulator strings shall be such that a factor of safety of 3 exists at maximum assumed working load condition.

The clamps and connectors shall be such that no slipping shall occur at any load less than 3 times the maximum nominal working tension of 4500 Newtons.

The design of the structures shall be such that under the assumed maximum working loads the deflection in the structures will not exceed the limits as specified by BS 5950 and SABS 0160, nor shall this deflection disturb the alignment of the apparatus supported.

15. MANUFACTURE AND ERECTION OF STRUCTURES

The design of the structures should preferably allow for the use of readily available standard steel sections. All structural steel shall be of mild steel to the requirements of BS 4360.

All members of the structure shall be manufactured with the utmost care. Jigs shall be used for cutting and drilling of the material such that when erected on site all members shall fit neatly together and all holes shall be truly aligned. No cutting, drilling, punching etc. of steel already galvanised will be permitted.

Bolthole clearances shall not exceed 2mm for bolts of up to M15 and shall not exceed 3mm for larger bolts unless otherwise approved. Holes shall not be elongated unless otherwise approved.

Each fabricated member shall be stamped (before galvanising) with an erection mark corresponding to the markings shown on the final approved structural arrangement drawings.

All structural steelwork shall be hot-dip galvanised.

Care shall be taken that the galvanised surfaces are not damaged during storage, transport or erection.

The design of the structure and the procedure for erection shall ensure that no members are strained or damaged during erection of the structures or the erection and tensioning of conductors.

Bolts shall be galvanised, and shall project at least 1 thread past the fastening nut, but not more than 3 threads or 3 mm, whichever is the lesser.

A hole to accommodate an M16 bolt for the earth strap shall be provided on each leg.

Foundation bolts shall be cast into the foundation on site using templates made of steel angle or U-section.

16. DRAWINGS, DOCUMENTATION AND DETAILED DESIGN

16.1 General Requirements for Drawings

Cognisance should be taken of the specific requirements detailed in other parts of Section III regarding the drawings and documentation. Tenderers are to ensure that all uncertainties regarding separate requirements are clarified with the Engineer in advance.

All manufacturing, layout, construction and detail drawings shall be to scale and fully detailed.

Schematic and other electrical drawings shall preferably be A3 in size and suitable for reduction to A4 for inclusion in instruction books, etc. All drawings and graphical symbols shall be to IEC specifications. Graphical symbols shall be in accordance with NRS-002.

Drawings for approval shall bear approved contract references and shall be submitted in duplicate as prints. After having been approved, the contractor shall supply CAD drawings on CD (Compact Disk) in DXF format suitable for use with Autocad version 12 and with Microstation version 5.0.

All drawings to be supplied shall be approved and signed before manufacturing of the equipment is started.

All drawings, diagrams, sketches and plans shall be clear, well laid out, of a high standard and in all respects subject to the approval of the Engineer. Legends, notes and descriptions shall be incorporated in each drawing, diagram or plan. Separate loose legend sheets or descriptions or other leaflets will not be acceptable.

The wording of drawing titles shall be to approval. The name of the Manufacturer, Supplier and/or Contractor as well as the Contract Number shall appear prominently on all drawings, plans and diagrams. All final drawings shall display a drawing number issued by the City of Tshwane.

Drawing sheet sizes shall comply with the ISO A series, sizes A4 to A0, and preferably be in size A3.

All drawings, diagrams or plans shall use S.I. metric units and be in English.

The cost of all drawings, diagrams and plans to be supplied on this Contract shall be included in the Tender Price of the equipment to be supplied. The equipment will not be considered to be "delivered complete" if the drawings and manuals called for have not been supplied, which will result in payment being withheld.

16.2 Documentation to be submitted with the Tender

This list is a minimum requirement only. The Engineer reserves the right to request additional drawings and information during adjudication. Such additional drawings shall be submitted within 7 days of request.

Tenderer's Drawing Number	Description
	a) General arrangement of equipment. This drawing shall give the principal dimensions and approximate position of all equipment. b) General arrangement and Block diagram of all control and protection schemes. c) Configuration of the offered substation automation system; d) technical specification and description of systems; e) outline and general arrangement drawing(s) of all panels, showing the proposed lay-out of equipment on the panels, relay dimensions and method of mounting of relays and other equipment; f) catalogues, brochures, technical specification sheets, schematic diagrams and logic block diagrams of the control gear , relays and other equipment offered; g) scope of supply; h) reference list; i) such other drawings, illustrations, brochures, schedules, diagrams, sketches and descriptions of information as the City Council may require to determine whether the equipment offered complies with the Specification; and j) estimates of cable types and quantities.

Where main and alternative offers are being submitted, a set of drawings for each alternative shall be submitted. In such cases the drawing title shall clearly indicate to which offer the drawing is applicable.

In amplification of his tender, a Tenderer may submit with his tender such descriptive literature, leaflets, brochures or illustrations, as he deems necessary. No information contained in such literature will exonerate the Contractor from his obligations with respect to the particulars and guarantees stated in the Schedule of Particulars and Guarantees or the requirements of the contract.

16.3 Documents and Drawings to be submitted after Award of Tender

A project schedule, which indicates the general approval procedure required for the detailed design stage of this project, has been included with this document.

16.3.1 Electrical Manufacture/Construction Design (M/CD)

The Contractor shall, on or before the date indicated on the provided project schedule, submit a complete detailed Manufacture/Construction Design (for input from the CoT) to the CoT. The first submission of the design shall include at least the following information (in duplicate):

a) Complete index and summary of all documentation submitted for detail design;

b) overall single line diagram of substation;

c) substation yard equipment layout and sectional drawings;

d) substation building equipment layout;

e) 132 kV circuit-breaker mechanism manual & schematic diagrams;

f) 132 kV isolator and earth switch mechanism manual and schematic diagrams;

g) 33 kV switchgear manuals and schematic diagrams;

h) 11 kV switchgear manuals and schematic diagrams;

i) 132/33 & 132/11 kV transformer auxiliary equipment schematic diagrams;

j) battery charger manual and schematic diagrams;

k) DC distribution board schematic diagrams;

l) AC distribution board schematic diagrams;

m) LVAC board layout and schematic diagrams;

n) sample multi-core cable schedules;

o) communication equipment user's guides;

p) communication panel layout diagram;

q) communication panel schematic diagrams;

r) pilot board layout;

s) control system software user's guides;

t) control system programmer's manuals;

u) SMMI operating system manual;

v) operator's training manuals;

w) control system detailed physical implementation;

x) control system detailed screen layouts and implementation-specific information;

y) control panel(s) detailed physical layout and construction;

z) GPS manual;

aa) inverter manual;

bb) detailed battery and battery charger capacity calculations;

cc) type tests for all equipment;

dd) user's guides for all protection relays and auxiliary devices;

ee) protection implementation block diagrams;

ff) relay and controller configuration diagrams;

gg) complete schematic diagrams for all protection & control schemes and panels with proper integration of switchgear and other equipment schematic diagrams; and

hh) any other equipment details considered necessary to constitute a complete design.

The second revision of the Design shall include all the revised items from the first revision, as well as:

a) Detailed cable schedules;

b) detailed factory and site inspection and testing program; and

c) label schedules drawn to scale.

Three iterations have been allowed for the satisfactory completion of the Design. The properly integrated Design submission is considered to be an extremely important part of the Contract, and Tenderers' attention is drawn to the special payment conditions applicable to this Design.

The approval of drawings (issue for Manufacture/Construction) shall not relieve the Contractor of his responsibility regarding the correctness thereof or any subsequent failures as a result of faults or omissions by the Contractor.

16.3.2 Civil and general Manufacture/Construction Design (M/CD)

The following is a list of the documents and drawings to be submitted by the Contractor for approval within the time indicated on the provided project schedule or stated in the specification:

a) Contracts Work Progress Chart in the form of a detailed Gantt chart, which is also to be submitted monthly;

b) detailed sub-order chart;

c) list of drawings to be submitted;

d) arrangement drawings and details of circuit-breakers, disconnectors, earth switches, lighting arrestors, kiosks and auxiliary plant;

e) foundation plans of equipment showing the static and dynamic loading at each support point, together with dimensioned plans of foundations required for all parts of the apparatus including particulars of holding-down bolts, chases for cables, etc. to enable the Civil Contractor to design the various foundations in detail for subsequent approval by the main Contractor;

f) detail drawings of all foundations and associated civil works requirements;

g) detail drawings of structures, showing dimensions of principal members and fixing for equipment and foundations;

h) sectional elevation drawings of each type of switch unit or bay, showing the positions of apparatus forming an integral part of each unit or bay;

i) operating and maintenance instructions. See clause 17 below; and

j) a quality control plan for and with witness and hold part points during the manufacture of the various items in the contract.

17. OPERATING AND MAINTENANCE MANUALS (O&MM'S)

NO WORKS TESTING WILL BE PERMITTED UNLESS THESE MANUALS HAVE BEEN IN THE ENGINEER'S POSSESSION FOR AT LEAST 20 WORKING DAYS.

The O&MM's shall include the following, where applicable:

a) Table of contents;

b) Descriptions. General and detailed descriptions, including pamphlets, mode of operation;

c) maintenance instructions and handbooks of all component equipment for the overall system;

d) drawings, including layouts, mechanical drawings, single line diagrams, schematics, cable block diagrams and schedules;

e) parts lists, drawings and schedules for spares ordering purposes;

f) commissioning reports, including all settings;

g) test reports;

h) program listings; and

i) equipment settings.

One month after final take-over the Contractor shall submit two (2) further IOMM's in a form approved by the Engineer.

Note:

Both approval copies shall be marked up by the Contractor's commissioning engineer before leaving site. One copy shall be left at the CoT site, and the other copy shall be used by the Contractor to compile the final O&MM's, including as-built drawings and commissioning reports.

Approval copies are considered an integral and essential component of the system to be supplied. Payment on delivery will only be made if the O&MM's for approval have been delivered to the Engineer and the required operator training has been completed (if required by Protection, Power system Control and/or Scada). Similarly, retention's will only be released when the final O&MM's have been received by the Engineer.

The Contractor shall also provide O&MM's for any spare apparatus and materials which he may be called on to supply.

18. WIRING

Wiring shall be carried out strictly in accordance with the requirements of the appropriate NRS, SABS, IEC or BS Standards and the following supplementary rules.

18.1 Small Wiring

The marking and colouring of small wiring shall be carried out strictly in accordance with NRS003-1: 1994 and the following set of supplementary rules:

All cables and wiring shall be of approved types and sizes. Unless otherwise approved. The minimum size of wire to be used internally in the control cubicles shall be multi-strand, 2,5 mm² copper wire. The size of the wiring for current transformer secondary circuits shall be 2,5 mm². Should the total circuit burden become excessive the size of the wiring for current transformer secondary circuits shall be increased to 4,0 mm².

All multi-core cable cores shall be of at least seven strands of copper. All panel wires shall have at least 40 strands of copper.

Small wiring shall be properly insulated and of CMA grade manufactured in accordance with the appropriate SABS Standard Specification. PVC insulated wire shall be of the fire retardant type, insulated to withstand 2kV to earth for one minute.

All wires shall be terminated with suitable crimped lugs, fitted with a compression tool designed for this purpose.

If stud type terminals are employed, stranded conductors shall be terminated with tinned (not soldered) approved claw washer or lock nuts, or with approved crimping lug. Separate washers or lugs shall be used for each conductor.

All wiring shall be taken to terminals and wires shall not be jointed or teed between terminal points.

All wiring, external as well as internal, shall be ferrule marked to approval with suitable ferrules. Both ends of the same wire shall be identically marked and shall be consistent with the associated drawings. Spare cores shall be marked with their respective cable number in addition to the requirements of NRS003-1, Annexure A.

Ferrule markers shall be of a durable insulating material having a reasonable glossy finish to prevent adhesion of dirt. Ferrule markers shall be marked clearly and permanently and shall not be affected by moisture or oil. Unless otherwise approved, ferrules shall be white with black marking. The type of ferrule marker to be used shall be to approval.

All communication cables like optic fibre, twisted pair, ribbon and coaxial cables shall be uniquely marked and labelled to the approval of the Engineer.

All optic fibre cables, twisted pair, ribbon type and coaxial type communication cables shall be routed separately or individually. They shall be mechanically protected and supported, and shall not rely on control wiring looms for support. Requirements in terms of minimum bending radii shall be observed.

18.2 Interpretation of and additions to NRS003-1

Numbering shall always be in ascending order from the defined starting point.

Where a starting point is defined as an odd or even number, the ascending numbers shall be odd or even only.

Connections made directly to the secondary terminals of current transformers and to star points in current transformer circuits shall take the lowest number in the group allocated for the purpose. The lowest even number shall be used for S1 terminal connections and the lowest odd number for S2 and/or S3 terminal connections. Preference shall be given to commencing the ascending numbering from the S1 terminal side. Where phase and neutral current transformers are in circuit together, phase current transformers shall take precedence.

The polarity of current transformers shall be determined as follows:

a) Terminal P1 shall always be nearest the circuit breaker.

b) Terminal P2 shall always be nearest the star point of a transformer.

Numbers shall be skipped where necessary for the possible future addition of items of equipment in series.

The addition of 500 to numbers, where associated equipment on the same panel would otherwise have caused a duplication of numbers, shall be extended to provide for more than two associated sets of equipment by adding 600, 700, 800 or 900 to the numbering of the third, fourth, fifth and sixth similar set of associated equipment respectively.

Numbering of a circuit shall continue in ascending order from the branch point but shall have 100, 200, 300 or 400 added to prevent duplication of numbers already appearing in the main succession numbering. For example, a branch connection from H13 through a coil shall be numbered H114 beyond the coil and shall progress to H116 etc.

18.3 MCCB's, Isolators, Fuses and Links

MCCB's, isolators, fuses and links shall be provided as required for the protection and isolating of circuits. The arrangement, type and kA rating of MCCB's and fuses shall be to approval.

The MCCB's, isolators, fuses and links shall be mounted vertically in horizontal rows in such a way as to allow easy access and replacement from the front. MCCB's shall be mounted at or near the top of control panels to prevent inadvertent operation by substation maintenance and cleaning staff.

All MCCB's, isolators, fuses and links of the same circuit shall be mounted adjacent to each other.

MCCB's and isolators shall be of the DIN rail mounting type to allow for easy replacement.

Fuses and links shall be mounted on insulated draw-out carriers that hold the fuses or links positively after withdrawal. In all cases the top terminal of the fuse or link shall be the live terminal.

Fuse link holders shall be black and solid link holders shall be white.

All MCCB's, isolators, fuses and links shall be suitably and permanently labelled, displaying the designation and identification number and using the prefix "MCB" for circuit breakers, "ISOL" for isolators, "FS" for fuses and "LK" for links. Current ratings shall also be displayed.

The labels shall not be fixed to removable parts of MCCB's, isolators, fuses or links.

18.4 Multi-Core Cable and Wire Terminals and Trunking

Terminal blocks shall be provided inside the control cubicles in an easily accessible position(s) for terminating multi-core cable tails and for connecting up with the internal wiring in the cubicles. Unless otherwise approved, terminal blocks shall be mounted horizontally in vertical rows in order that ferrule numbers may be read without difficulty.

All terminals and connections for secondary wiring shall be sufficiently large to accommodate at least <u>two</u> 2,5 mm² PVC insulated wires.

Terminal blocks shall either be of the double-ended insertion type with suitable provision made for mounting the terminal blocks on terminal boards or rails in rows.

Terminal blocks of the insertion type shall incorporate serrated clamping yokes of plated steel which clamp the wire ends onto a silver or nickel plated serrated current bar by means of plated steel clamping screws. The complete assembly shall be encased in a non-hygroscopic moulding of insulating material with high electrical and mechanical strength. Entrelec M10/10.RS or Klippon type RSF 1 spring loaded terminals are preferred. Klippon type SAKR terminals are required for pilot cable termination board application. Terminals of the type where clamping screws are in direct contact with the wire are not acceptable. The Engineer shall approve the precise type of terminal used.

Terminal blocks shall be mounted such as to allow sufficient space for cable tails and working on cable glands without impeding access to any other equipment.

Terminal blocks shall be wired such that all internal or incoming wiring enters from one side and all outgoing or external connections (multi-core cable tails) enter from the other side.

Terminal blocks shall not be covered by compound.

No more than two wires shall be connected to any one terminal

At least 10% spare terminals shall be provided on all sets of terminal blocks, with a minimum of two (2) terminals.

Covers of transparent insulating material shall be fitted where necessary on terminal rows to prevent accidental contact with live equipment.

Each terminal shall be marked clearly, permanently and conspicuously and all sets or groups of terminal blocks shall be suitably identified with durable labels fixed in an approved manner.

Suitable slotted trunking with clip on covers shall be installed to channel interior wiring in a neat and orderly way. The space between the rows of terminal blocks and slotted trunking shall preferably not be less than 75 mm.

PART 1.5 : YARD LABELLING

SPECIFICATION No. : YL2009/01

1. EXTENT OF WORK

Comprehensive yard labelling has to be implemented for the indication of circuits, bays and primary equipment items, in addition to the normal requirements for labelling for new equipment. The labels must be ready for installation during individual bay outages where a bay outage is required to install a label.

Tenderers are referred to:

a) Part 1.4: Item 7 "Labels" for normal requirements for labelling of new equipment.

b) Tender document - Part C2.2: Schedule of Prices for individual price items.

c) Tender document - Part C4: Drawing number PS09-150Z for the different label details.

PART 1.6 : SUBSTATION TESTING & RE-COMMISSIONING

SPECIFICATION No : Rev Z/9

CONTENTS

1. SCOPE

This specification covers the complete testing and commissioning of all new control and protection (ICAP) equipment and all new non-ICAP equipment as well as the testing and re-commissioning of all existing primary and secondary equipment in order to re-commission the total substation.

2. STATION TESTING AND RE-COMMISSIONING OF ALL EQUIPMENT

The new control and protection (ICAP) equipment shall be tested and commissioned by the contractor, but he will also be responsible to test and re-commission "other" or non-ICAP equipment in order to re-commission the total substation. All existing and new secondary (non-ICAP) equipment such as battery chargers and auxiliary supply equipment, as well as primary equipment such as circuit breakers, isolators, current transformers, voltage transformers, current carrying connectors, surge diverters and power transformers shall be tested and re-commissioned as specified. Earthing and bonding of equipment must also be confirmed. The work shall encompass the following aspects with respect to the substation as an entity as well as to each individual bay.

2.1 First stage:

Available drawings, substation and equipment are available at the clients drawing office.

All marshalling kiosks and other panels and cubicles that are to remain after the refurbishment shall be dusted out and cleaned (apart from any cubicle refurbishment work described elsewhere).

The schematic diagrams shall be correlated with the physical bay wiring and cabling by means of visual inspection, ringing out and tracing of the circuits. Any alterations that may be found shall then be marked up on the schematic diagrams to represent 'as found' drawings. Again, this can primarily be restricted to the equipment and circuits, or parts of circuits, which will be retained after the station refurbishment.

Proposals as to the improvement of equipment characteristics or sub-standard parameters, correction of errors and replacement of defective parts or functions must be submitted as part of the first stage of the testing.

Generation of a new set of drawings, as if for a new substation, combining the new control and protection schemes with the existing drawings and the existing equipment, for each bay of the substation, the substation itself and scheme common drawings (i.e. bus zone scheme). It has to be ensured that all details of non-ICAP equipment are included in the drawings listed in Part 1.3: Drawings and Documentation. Schematic diagrams of motor drives, mechanisms and interface equipment of transformers, circuit breakers, isolators, earth switches and transformer cooling equipment must be included.

These proposals and drawings shall be handed to the Engineer and where applicable, approval will be given by the Engineer to incorporate the proposed changes. All the information gathered shall be incorporated in the ICAP-designs and be included in the DDS in a suitable format.

2.2 Second stage:

All approved modifications shall be carried out and commissioned as part of the control and protection installation and commissioning process.

Apart from the tests prescribed for the ICAP system the following tests shall be conducted on each bay for a given substation:

a) All the circuit breakers associated with the panels shall have their opening and closing motion measured depicting the position of the breaker related to time as the breaker opens or closes. The total opening and closing times shall also be indicated. These results shall be graphically represented and the breakers shall then be certified if it complies with the manufacturers specifications.

b) In conjunction with the Control Centre, functional test of inter-trip circuits:

   i. For inter-trip receive relay: - determine the operating range and operating time over the relay's range of operating voltage at 10 V intervals.

ii. For inter-trip system: - From the furthermost point on the line, send an inter-trip signal and measure the receiving voltage at the substation being tested with the relay in service.

iii. For all inter-trip systems: - In conjunction with the Engineer or his representative, determine the time elapsed for a substation on a particular line to send an inter-trip and for the system voltage at the substation to fall below 30% of the nominal system voltage.

c) Measure and record the earthing bonding resistance as well visually inspect the earthing from a centrally defined point within the substation that has been proved to have a low earthing resistance:

i. Control panels

ii. Protection panels

iii. Tap change control panel (TCCP)

iv. Transformer/line marshalling kiosk (TMK), (LMK)

v. Transformer

vi. Cooling fins (where applicable)

vii. Closing rectifier

viii. Battery chargers

ix. HV apparatus (neutral CT's etc)

x. Neutral isolators

xi. Switchgear

xii. Fences

Where there are two bonding straps to a piece of equipment, the resistance of each bond shall be determined separately.

d) Do core and sheath insulation tests on all multi-core cables for the complete bay/scheme

e) Current transformers, determine:

i. Polarity from the furthermost possible point.

ii. Magnetising curves. One ratio per core. Specify the ratio. The magnetising curves shall be represented graphically in the format as described in the requirements for documents.

iii. Star point connections

f) Functional tests, as part of the commissioning of the ICAP system, of:

i. Main tripping circuits

ii. Back-up circuits

iii. Control circuits

iv. Tap change control circuits (where applicable)

v. Alarms circuits

vi. No volt relay (secondary injection)

vii. Back-up Auxiliary supply failure circuits

viii. Battery charger chop over relay

ix. Stability of the bus zone tripping circuits

x. Coupler interlocking

g) Functional testing of all VT circuits and testing of VT's (phasing).

h) Check all fuse ratings and MCB ratings (mainly restricted to remaining battery charger, transformer marshalling kiosks and HV yard JB's.

i) Check lugs for correct application and type (crimping).

j) Do primary injections on all CT's and VT's and record readings on the secondary side at the furthermost accessible points.

k) All redundant wiring inside the remaining panels shall be removed and all redundant cores shall be strapped into the harness inside the panel (mainly restricted to remaining battery charger, transformer marshalling kiosks and 275 kV yard marshalling kiosks).

l) Commission with primary voltage and current. Prove phasing with phasing gear where possible. Do synchronising checks. Voltage and current measurement on all accessible points and record results. Prove stability of the bus-zone.

Any changes made during the testing and commissioning shall be included in the "as commissioned" documentation.

PART 1.7 : IMPLEMENTATION PLAN

SPECIFICATION No. : Rev Z/8

1. IMPLEMENTATION PLAN

The purpose of this section is to highlight the aspects involved and points for consideration in preparation of the detail implementation planning that is required of the Contractor in order that due allowance is made in terms of budget and manpower to perform this element of the project work at a sufficient level of refinement. Preparing the Detail Implementation Program will be the second major project activity running concurrently with and following the Functional Design Specification activity as an important step towards preparation for site work.

Here a distinction is drawn between the Detail Project Schedule in the sense of the overall scheduling of all the project elements and activities including detailed equipment specification and procurement scheduling, schemes design, laying down the sequence and duration of activities in the factory and on site including testing and commissioning to ensure optimal (cost/time/quality) project scheduling on the one hand and;

A Detail Implementation Plan in terms of which the project work on site is interfaced with physical and operational system constraints to ensure that the intervention at the Sub-station in order to refurbish the control and protection equipment is done at the absolute minimum risk to the safety of workmen, system stability and disruptions of supply on the other hand.

The Detail Implementation Plan shall be drawn up taking into account the following considerations plus any further factors that come to the fore in the process. The Contractor shall submit the Plan to the Engineer for approval and endorsement by all parties that could be affected by it.

1. Seasonal loading of the Infeed Station;
2. Operational constraints;
3. Minimum / maximum loading;
4. Energy unit (opportunity) cost for different system switching configurations and the duration of these conditions;
5. System stability and outage risk associated with specific temporary switching configurations;
6. Minimising loss of protection functionality in terms of bus zone or back-up protection schemes including the justification of specific interim protection schemes;
7. Considerations such as sequence of work dictated by the re-use requirement on certain of the existing protection equipment in the same or similar equipment bays and;
8. Basic constraints such as the accessibility of existing multi-core cables in cable ducts for purposes of re-routing.

PART 1.8 : DAYWORKS

SPECIFICATIO No : Rev Z/8

SCOPE

Extra work which is not covered in any Contract Item and which is ordered by the Engineer in writing as such shall be undertaken by the Contractor on a day work basis.

Day labour as may be required for such day works shall be provided by the Contractor at the rates of wages of the particular category as inserted in the schedules provided for this purpose.

When the Contractor is required to supply materials in connection with such day works as may be ordered, the percentage over actual cost price at the Works on which the Contractor agrees to supply such material as may be required shall be as inserted in the schedules provided for this purpose.

The Contractor shall, when required by the Engineer, produce all time sheets, correspondence, invoices and receipts and any other particulars necessary to enable the Engineer to certify the correctness of claims for payment in terms of this provision.

PART 1.9 : HEALTH AND SAFETY

SPECIFICATION No. : HS09/01

CONTENTS

1. DOCUMENT PURPOSE AND INTENT

The specifications contained in this document relate to the health and safety requirements pertaining to the associated works, so as to ensure the health and safety of the persons carrying out the associated works.

Compliance to the Occupational Health and Safety Act (Act 85 of 1993) and the Regulations shall not be limited to the specifications and definitions contained in this document.

A comprehensive, documented Health and Safety Plan is to be drawn up by the Main Contractor, based on the results of Health and Safety Risk Assessments conducted by him, and the specifications provided, and presented to the engineer for approval prior to commencement of work.

Monitoring of compliance on site shall be to the requirements of the OHS Act and Regulations as well as the contents of the H&S Plan(s) of the Main-Contractor and Sub-Contractors.

2. APPLICATIONS AND INTERPRETATION

This document is to be read and understood in conjunction with the following:

- Occupational Health and Safety Act (Act 85 of 1993).
- All regulations published in terms of the Occupational Health and Safety Act.
- Construction Regulations, 2003.
- SABS codes referred to by the Occupational Health and Safety Act.
- Contract Documents
- Basic Conditions of Employment Act (Act 75 of 1997)
- South African Rail Commuter Corporation Ltd: General conditions and specifications for work on, over, under or adjacent to Railway lines and near High Voltage Equipment. (SPK7/2)

ABBREVIATIONS

- OHS: Occupational Health and Safety
- CEO: Chief Executive Officer
- CR: Construction Regulations
- HCS: Hazardous Chemical Substances
- MSDS: Material Safety Data Sheet
- AIA: Approved Inspection Authority
- HBA: Hazardous Biological Agents
- OEL: Occupational Exposure Limit

3.1 DEFENITIONS

The following definitions from the Occupational Health and Safety Act are listed as follows:

Chief Executive Officer
In relation to a body corporate or an enterprise conducted by the State, means the person who is responsible for the overall management and control of the business of such body corporate or enterprise.

Danger
Means anything that may cause injury or damage to persons or property.

Employee (Contractor)
Means, subject to the provisions of Subsection (2), any person who is employed by or works for any employer and who receives or is entitled to receive any remuneration or who works under the direction or supervision of an employer or any other person.

Employer (Client / Engineer**)**
Means, subject to the provisions of Subsection (2), any person who employs or provides work for any person or remunerates that person or expressly or tacitly undertakes to remunerate him, but excludes a labour broker as defined in Section 1(1) of the Labour Relations Act, 1953 (Act No. 28 of 1956).

Healthy
Means free from illness or injury attributable to occupational causes.

Machinery
Means any article or combination of articles assembled, arranged or connected and which is used or intended to be used for converting any form of energy to performing work, or which is used or intended to be used, whether incidental thereto or not, for developing, receiving, storing, containing, confining, transforming, transmitting, transferring or controlling any form of energy.

Medical Surveillance
Means a planned programme of periodic examination (which may include clinical examinations, biological monitoring or medical tests) of employees by an occupational health practitioner or, in prescribed cases, by an occupational medicine practitioner.

Plant
Includes fixtures, fittings, implements, equipment, tools and appliances, and anything which is used for any purpose in connection with such plant.

Properly Used
Means used with reasonable care, and with due regard to any information, instruction or advice supplied by the designer, manufacturer, importer, seller or supplier.

User
In relation to plant or machinery, means the person who uses plant or machinery for his own benefit or who has the right of control over the use of plant or machinery, but does not include a lessor of, or any person employed in connection with, the plant or machinery.

Reasonably Practicable
Means practicable having regards to:

(a) the severity and scope of the hazard or risk concerned,
(b) the state of knowledge reasonably available concerning that hazard or risk and of any means to remove or mitigate that hazard or risk.
(c) the availability and suitability of means to remove of mitigate that hazard or risk; and
(d) the cost of removing or mitigating that hazard or risk in relation to the benefits deriving there from.

Risk
Means the probability that injury or damage will occur.

Safe
Means free from any hazard.

Standard
Means any provision occurring:
(a) in a specification, compulsory specification, code of practice or standard method as defined in Section 1 of the Standards Act, 1993 (Act No. 29 of 1993); OR
(b) in any specification, code or any other directive having standardization as its aim and issued by an institution or organization inside or outside the Republic which, whether generally or with respect to any particular article or matter and whether internationally or in any particular country or territory, seeks to promote standardization.

The following definitions from the Construction Regulations are listed as follows:

Agent
Means any person who acts as a representative for a client.

Competent Person
Means any person having the knowledge, training, experience and qualifications specific to the work or task being performed:
Provided that where appropriate qualifications and training are registered in terms of the provisions of the South African Qualifications Authority Act, 1995 (Act No. 58 of 1995), these qualifications and training shall be deemed to be the required qualifications and training.

Construction
Means any work in connection with:

(a) the erection, maintenance, alteration, renovation, repair, demolition or dismantling of or addition to a building or any similar structure;
(b) the installation, erection, dismantling, or maintenance of a fixed plant where such work includes the risk of a person falling;
(c) the construction, maintenance, demolition or dismantling of any bridge, dam, canal, road, railway, runway, sewer or water reticulation system or any similar civil engineering structure; OR
(d) the moving of earth, clearing of land, the making of an excavation, piling or any similar type of work.

Contractor
Means an employer, as defined in Section 1 of the Act, who performs construction work and includes principal contractors.

Hazard Identification
Means the identification and documenting of existing or expected hazards to the health and safety of persons, which are normally associated with the type of construction work being executed or to be executed.

Health and Safety File
Means a file, or other record in permanent form, containing the information required as contemplated in these regulations.

Health and Safety Plan
Means a documented plan, which addresses hazards, identified and includes safe work procedures to mitigate, reduce or control the hazards identified.

Health and Safety Specification
Means a documented specification of all health and safety requirements pertaining to the associated works on a construction site, so as to ensure the health and safety of persons.

Method Statement
Means a document detailing the key activities to be performed in order to reduce as reasonably as practicable the hazards identified in any risk assessment.

Principal Contractor (Main Contractor)
Means an employer, as defined in Section 1 of the Act who performs construction work and is appointed by the client to be in overall control and management of a part of or the whole of a construction site.

Risk Assessment
Means a program to determine any risk associated with any hazard at a construction site, in order to identify the steps to be taken to remove, reduce or control such hazard.

4. NOTIFICATION OF CONSTRUCTION WORK

- The Principal/Main Contractor shall notify by registered mail, the local relevant Provincial Director of the Department of Labour, before commencing with construction work, of the intended work in the form of Annexure A of the Construction Regulations.
- A copy of the completed Annexure A of the Construction Regulations, as well as proof of notification shall be included in the Health and Safety Plan. (Proof of fax or proof of hand delivery)
- A copy of the completed Annexure A is to be kept on site by the principal Contractor.

5. LEGAL DOCUMENTATION/APPOINTMENTS

The following documents must be provided in the Health and Safety Plan:

- Health and Safety Policy signed by CEO.
- Letter of good standing with the Compensation Commissioner, Federated Employers or similar insurer.
- Health and Safety Organogram (or table), outlining the Health and Safety Team, as well as the appointment(s) they have under the Act and Regulations (reference to specific section/regulation applicable to appointment)

Example:

Tom Smith
Section 16(2)
Construction supervisor CR 6(1)

Dick Smith
Construction vehicle competent person CR 21(1)(j)
Excavation competent person CR 11(1)

Harry Smith
H&S Rep - Section 17(1)

- The competency of each member of the Health and Safety Team must be provided and should` include knowledge, training, experience & qualifications specific to the work or task being performed.

Signed copies of the following legal appointments must be provided in the Health and Safety Plan:

APPOINTMENT	OHS-ACT / REGULATION REFERENCE
Section 16.2 appointment	Section 16.2
Health and Safety Representative (if necessary)	Section 17
Health and Safety Committee Members (if necessary)	Section 19
Incident Investigator	GAR 8(2)
First Aiders (Include training certificates)	GSR 3
Fire Fighters	ER 9 & CR 27(h)
Risk Assessor	HC (Incl. Asbestos & Lead); CR 7

The following information must be provided in the Health and Safety Plan:

- Indicate the estimated number of employees to be working on site.
- Indicate the expected number of contractors to be appointed by the Principal/Main Contractor.

The following Competent Persons, **where applicable**, shall be appointed in writing by the Principal/Main Contractor, prior to any work being carried out, and shall adhere to the requirements of the specific sub-regulations.

The competency of each of these appointed competent persons must be provided and should include knowledge, training, experience & qualifications specific to the appointment.

The table below indicates the applicability of the appointments but contractors should by no means be limited to these indications.

APPOINTMENT	OHS-ACT / REGULATION REFERENCE
Construction Supervisor	CR 6 (1)
Assistant Construction Supervisor	CR 6 (2)
Fall Protection Competent Person	CR 8 (1)
Formwork/ Support Work Competent Person	CR 10 (a)
Excavation Work Competent Person	CR 11 (1)
Demolition Work Competent Person	CR 12 (1)
Scaffolding Competent Person	CR 14 (2)
Batch Plant Competent Person	CR 18 (1)
Explosive Powered Tools Competent Person	CR (b) 19
Construction Vehicle and Mobile Plant Competent Person	CR 21 (1)(j)
Electrical Installation Competent Person	CR 22 (d)
Stacking Competent Person	CR 26 (a)
Fire equipment Competent Person	CR 27 (h)
Confined Spaces Competent Person	GSR (5)
Blasting Competent Person	
Safety Officer Full time or part time	CR 6(6)
Traffic Safety Officer	CR 6(6)
General Machinery Competent Person	GMR (2)
Lifting Machines Operators	DMR 18(11)
Pipe Jacking Competent Person	
Competent Person referred to in South African Rail Commuter Corporation Ltd: General conditions and specifications for work on, over, under or adjacent to Railway lines and near High Voltage Equipment. (SPK7/2)	(SPK7/2)

- **Indicate in the H&S Plan, which of these listed appointments are applicable to the construction work in question.**
- no work involving any of the listed appointments may be performed without the knowledge and approval of an appointed competent person.
- The competent person shall be responsible to determine the level of supervision required for each activity.
- The agent/engineer must be informed of any changes made to the above appointments.
- The agent/engineer reserves the right to require from any contractor at any stage to appoint a full or part time construction health and safety officer.

6. GENERAL DUTIES OF PRINCIPAL CONTRACTOR

- The principal contractor will be responsible for co-operation between all contractors to ensure compliance to the OHS–Act and Regulations on site.

- To ensure the above, the Principal/Main Contractor must carry out the following and provide proof of such in his H&S plan:

    - Provide health and safety specifications to Contractors.
    - Appoint Contractors in writing.
    - Proof than Contractors H&S Plan has been approved, implemented and maintained.
    - Proof that Contractors are registered with the Compensation Commissioner or similar insurer.
    - Proof that Contractors made provision for the cost of Health and Safety measures during the construction process.
    - A comprehensive & updated list of all contractors on site, also indicating the type of work being done.
    - Copies of Section 37(2) agreements with the relevant contractors.

7. SUPERVISION OF CONSTRUCTION WORK

- The agent/engineer must be informed if the Construction Work Supervisor is also appointed as a Construction Supervisor for another site.

8. RISK ASSESSMENT

- Risk assessments of all required activities/hazards shall form an integral part of the Health and Safety plan.

- All risk assessments shall be conducted in terms of an acceptable methodology, prior to commencement of work, according to the provisions of CR 7 and should cover at least the following:

    - Excavations
        - including excavating in proximity of Petronet pipe line
    - Backfilling in trenches
    - Pipe laying
    - Blasting
        - blasting in proximity of Petronet pipe line
        - open trench blasting
        - pipe jack blasting
    - Identification of existing Services
    - Pipe jacking underneath Railway line (SPK7/2)

- Pipe Jacking
    - Ventilation
    - Lighting
    - Flooding
- Clearing of vegetation
- Work in the vicinity of houses/buildings
- Movement of Construction Vehicles
- Working in confined spaces
- Demolition
- Temporary stockpiling
- Connecting to existing sewer
- Accommodation of traffic
- Accommodation of pedestrians
- Temporary pedestrian bridges
- Temporary vehicle bridges
- Employee movement across railway line
- Control of access of public/pedestrians to excavations
- Work surrounding live sewage connection
- Possibility of flooding of Moreleta Spruit

- All health hazards that can be present during any of the above activities and should include individual dusts, gases, fumes, vapours, noise, extreme temperatures, illumination, vibration and ergonomic hazards due to any of the above activities.

- The above list is by no means exhaustive and should not be limited to these activities but must cover all activities that forms part of the said construction work. Each activity must be split down to individual tasks and all associated hazards identified and listed in the risk assessment. This ensures that critical tasks and subsequent critical hazards are not missed.

- The risk assessment to be included in the H&S Plan must clearly indicate:

    - The methodology used to do the risk assessments.
    - Breakdown of processes and activities covered.
    - High risks anticipated.

- All risk assessments are to be conducted by competent persons as appointed under paragraph 5 of this document. The plan must include a declaration in this regard or the risk assessment must contain the signature(s) of this appointed persons.

- Risk assessments are to be handed to the agent prior to commencement of work.

- The agent reserves the right to stop any work if such work is not conducted in terms of the recommendations of the risk assessment.

- Risk assessments are to **cover safety as well as health and ergonomical hazards.**

9. SAFE WORK PROCEDURES

Safe Work Procedures are to form part of the H&S Plan and **must be compiled for all the above-identified activities.**

The safe work procedures must address the following elements:

- The work method to be followed to conduct work safely

- Mitigation of identified risks
- Reducing and controlling risks and hazards that have been identified
- Responsibilities of competent persons
- Required personal protective equipment
- Correct equipment/tools/machinery to be used
- Reference to relevant registers to be completed
- Reference to applicable risk assessment
- **The following two tables provides information on all factors to be taken into account when the Risk Assessments and Safe Work Procedures are compiled:**

Physical	Chemical	Biological	Mechanical	Psycho-social
Noise	Liquids	Insects	Guards	Stress
Vibration	Dusts	Fungi	Hand tools	Work pressure
Ionising radiation	Fumes	Bacteria	Machinery	Monotony
Non-ionising radiation	Fibers	Viruses		Unsociable hours
Health and cold	Mists			Ergonomical:
Electricity	Gases			• Posture
Pressure	Vapours			• Movement
				• Repetitive tasks

System	Stress/Agency	Illness/Disease
Musculoskeletal	Lifting/loads Repetitive strain Abnormal postures Whole body vibration	Muscular pain syndromes Tenosynovitis Bursitis Osteoarthrosis
Sensory	Noise	Hearing loss
Skin	Cement (chromates), rubber Thinners, epoxies Tar, pitch Solar radiation	Allergic contact dermatitis Irritant contact dermatitis Acne, Skin cancer Keratoses, Cancer
Respiratory	Silica Asbestos Spray paints, woods, epoxies Irritant dusts, welding fumes Organic Solvents	Silicosis, TB Asbestosis, Cancer Asthma Bronchitis Headaches, Dizziness, Cancer
Psychosomatic	Physical stress Psychosocial stress	Head aches Depression Fatigue Substance abuse
Nervous System	Lead Organic solvents	Peripheral and central neuropathy Headaches, Dizziness, Mood disorder, Dementia, Cancer

10. SAFETY OF PUBLIC/PEDESTRIANS

Access to the construction site must be cordoned off as much as possible in all work areas. All excavations are to be fenced/barricaded to prevent access by public / pedestrians. Barriers must be of an impenetrable nature – barrier tape will not be seen as a sufficient barrier mechanism.
Work must be planned in such a manner as to ensure that the minimum amount of trenches are left open after hours or during weekends.
No trenches/excavations are to be left open during any December shutdown period.
Temporary pedestrian crosses over excavations are to be of adequate width and provided with sturdy handrails.

11. FALL PROTECTION

In addition to the requirements of this regulation (CR 8) the following shall apply:

- The fall protection plan is to be prepared by a competent person. This competent person must sign the fall protection plan.
- Contents of the fall protection plan must cover all the requirements as stated in sub-regulation CR 8.
- The fall protection plan is to be handed to the agent before work commences.
- The level of supervision is to be stated in the fall protection plan.
- Medical certificates, work near edges, presence of dew, dangerous walking areas etc. should be addressed in the fall protection plan.

12. REGISTERS

- Examples of the registers listed below must be provided in the Health and Safety Plan.
- All registers must be available at the site offices at all times for inspection by the agent.
- The list of registers to be kept is by no means exhaustive and the H&S Plan should list all the registers that are applicable and at what frequency they are going to be maintained.

ACTIVITY	FREQUENCY	FORMAT
Form work / Support work	Daily, prior to any shift	
Excavation Work	Daily, prior to any shift, after rain or blasting or after unexpected fall of ground	
Scaffolding	Daily, prior to any shift, after rain or blasting.	
Material Hoist	Daily	
Batch Plants	Daily	
Explosive Powered Tools	Daily Before Use	
Crane(s) Logbook	As per DMR 18	
Construction Vehicles and Mobile Plant	Daily	
Temporary Electrical Installation	Weekly	
Stacking	Weekly	
Fire Extinguishers	Bi – Monthly	
Ablution Facilities	Weekly	
Ladders	Weekly	
Incident Register in terms of GAR 9	As Required	Annex 1 of GAR
Fall Protection Equipment	Daily	
Portable electrical tools	Weekly	
Suspended Platforms	Daily	
Accommodation of traffic	Daily	
Fire fighting equipment	Monthly	

13. TRAINING

Each Health and Safety Plan shall indicate the following regarding training:

- Name and contents of the following training courses which have to be conducted:
  - Induction Training
  - Training regarding hazards identified and any corrective measures in place
  - Training regarding all applicable regulations
  - Specific training regarding applicable competencies
- Attendance registers must be kept as proof of training provided
- Method of informing visitors and other persons entering the site of hazards prevalent on site.
- Method of providing personal protective equipment to visitors and non-employees.
- An example of ID training card for each employee (if used).
- Methodology to be used in the issuing and communication of written instructions/safe work procedures.

14. AGENT HEALTH AND SAFETY INSTRUCTION REGISTER

- All Health and Safety instructions will be given via the resident engineer in writing
- The Principal Contractor shall be required to sign the register at the end of each day to acknowledge any instructions issued.

15. GENERAL REQUIREMENTS

- ***Personal Protective Equipment***
  The procedures for issuing and control over PPE shall be indicated in the Health and Safety Plan, as well as the enforcement for the wearing thereof.

- ***Hired Plant***
  The responsibility for the safe condition and use of all hired plant shall be that of the contractor.

- ***Transport of Employees***
  Transport of employees shall be carried out in terms of the National Road Ordinances and the OHS Act - Construction Regulations.
  The Health and Safety Plan shall detail the arrangements and methods of the transportation of workers.

- ***Signs***
  The Principal Contractor shall indicate in his Health and Safety Plan the arrangements regarding the posting of danger signs.

- ***Certificates of fitness***
  The Principal Contractor shall include in his H&S Plan copies of medical fitness certificates for the following:
  - **Crane Operators**
  - **Construction vehicles and Mobile plant operators**
  - **Pipe Jacking employees**

- o **Any other medical certificates that might be applicable in terms of the other regulations governing health & safety of construction personnel such as HCS regulations and Noise induced hearing loss etc.**

- ***Site Visitors Register***
  - o A site visitor's register is to be kept on site and steps are to be taken to ensure that all visitors sign the visitors' register before entering the site.
  - o A sign should also be provided directing all visitors to report to
  - o the site officer.

- ***Safety of excavations***
  - o Provision should be made for the utilisation of geo technical services on a monthly basis to independently evaluate the safety off all excavations
  - o All excavations are to be fenced/barricaded to prevent access by inter alia children and other members of the public
  - o All barricading is to be maintained and protected against theft and vandalism

- ***Blasting***
  - o A separate Health and Safety Plan will be required from the blasting contractor
  - o The Health and Safety Plan must also be approved by the relevant Petronet servitude supervisor
  - o All the requirements of the Petronet Standard Crossing Conditions and Requirements for underground Services document (Ref P2-18 (CE8)) must be complied with. This document is attached to the back this Health and Safety Specification.

16. HAZARDOUS CHEMICAL SUBSTANCES (including Asbestos and Lead)

In addition to the requirements in the HCS Regulations, the principal contractor must provide proof in the H&S Plan that:

- Material Safety Data Sheets (MSDS's) of the relevant materials/hazardous chemical substances are available prior to use by the contractor. Mention should be made how the principal contractor is going to act according to special/unique requirements made in the relevant MSDS's. All MSDS's shall be available for inspection by the agent at all times.
- Risk assessments are done at least once every two years.
- Exposure monitoring is done according to OESSM and by an AIA and that the medical surveillance programme is based on the outcomes of the exposure monitoring.
- How records are going to be kept safe for the stipulated period of 30 years.
- How the relevant HCS's are being/going to be controlled by referring to:
  - o Limiting the amount of HCS
  - o Limiting the number of employees
  - o Limiting the period of exposure
  - o Substituting the HCS
  - o Using engineering controls
  - o Using appropriate written work procedures
- The correct PPE is being used.
- HCS are stored and transported according to SABS 072 and 0228.
- Training with regards to these regulations was given.
- The H&S plan should make reference to the disposal of hazardous waste on classified sites and the location thereof (where applicable).

17. ASBESTOS

Should asbestos be identified as a hazard **whilst work is carried out**, the following must be included in the health and safety plan:

- Notification to the Provincial Director in writing, prior to commencement of asbestos work.
- Proof of a structured medical surveillance programme, drawn up by an occupational medicine practitioner.
- Proof that an occupational health practitioner carried out an initial health evaluation within 14 days after commencement of work.
- Copies of the results of all assessments, exposure monitoring and the written inventory of the location of the asbestos at the workplace.
- Only proof that medical surveillance has been conducted and not the actual records itself since these areas of a confidential nature.
- How records are going to be kept safe for the stipulated period of 40 years.
- Proof that asbestos demolition (if applicable) is going to be done by a registered asbestos contractor and provide proof that a plan of work for such demolition is submitted to an Approved Asbestos Inspection Authority 30 days prior to commencement of the demolition.
- Provide proof that the plan of work was approved by the asbestos AIA and submitted to the provincial director 14 days prior to commencement of demolition work together with the approved standardised procedures for demolition work

18. LEAD

Besides the requirements listed under par. 15 should lead be identified as a hazard at the workplace, the following must be included in the health and safety plan or as soon as its available:

- Proof that an occupational health practitioner carried out an initial health evaluation within 14 days after commencement of work.
- Copies of the results of all assessments, exposure monitoring and the written inventory of the location of the lead at the workplace.
- Only proof that medical surveillance has been conducted and not the actual records since these are of a confidential nature.
- How records are going to be kept safe for the stipulated period of 40 years.

19. NOISE INDUCED HEARING LOSS

Where noise is identified as a hazard the requirements of the NIHL regulations must be complied with and the following must be included/ referred to in the Health and Safety Plan:

- Proof of training with regards to these regulations.
- Risk assessment done within 1 month of commencement of work.
- That monitoring carried out by an AIA and done according to SABS 083.
- Medical surveillance programme established and maintained for the necessary employees.
- Control of noise by referring to:
  - Engineering methods considered
  - Admin control (number of employees exposed) considered
  - Personal protective equipment considered/decided on
- Describe how records are going to be kept for 40 years.

20. LIGHTING

Where poor or lack of illumination is identified as a hazard the lighting regulations must be complied with and the following must be included in the H&S Plan:

- How lighting will be ensured/ provided where daylight is not sufficient and /or after hours are worked.
- Planned maintenance programme for replacing luminares.
- Proof of illumination levels of artificial illumination equipment.

21. HAZARDOUS BIOLOGICAL AGENTS (HBA)

Because of the possible exposure of workers to raw sewage the H&S Plan shall include details of the following:

- The conducting of Risk Assessment specifically aimed at exposure to HBA which shall include the following:
  - Nature and dose of HBA
  - Where HBA may be present and in what physical form
  - The nature of work or process
  - Steps in the event of failure of control measures
  - The effect of the HBA
  - The period of exposure
  - Control measures to be implemented

- Monitoring of exposure of workers shall be conducted to establish whether any worker is infected with an HBA associated with working or being exposed to raw sewage, in terms of the following:
  - By an occupational medical practitioner
  - Before entering the site to establish the workers baseline
  - During the period of the contract the risk assessment indicate possible exposure
  - After completion of the contract

- Medical surveillance should such be required after the above-mentioned by an occupational health practitioner.

- Indication on how all records of assessment, monitoring, etc will be kept, taking into account that records have to be kept for a period of 40 years.

- How exposure to HBA is to be controlled

- The provision of personal protective equipment

- What information and training is to be provided to employees regarding the following:
  - The contents of these regulations
  - Potential risks to health
  - Control measures to be implemented
  - The correct use and maintenance of personal protective equipment
  - The results of the risk assessment.

PART 1.10 : ENVIROMENTAL MANAGEMENT PLAN

SPECIFICATION No. : EPPS0020

1. GENERAL

1.1. This plan is to be adhered to by the Contractors for the life of construction operations; this includes rehabilitation of areas as and when required. The Contractors shall ensure that all construction staff, sub-contractors, suppliers, etc. are familiar with, understand and adhere to the Construction Management Plan. In addition, during construction the Contractors must ensure that all personnel are fully aware of any environmental issues relating to the construction activities that are being undertaken on site and the related environmental precautions that need to be taken. Construction supervisors and crews will be trained to recognize 'chance finds' during construction, and such finds (i) will not be disturbed, damaged or removed and (ii) will be brought to the immediate attention of the relevant authority.

1.2. The Client (Council) shall order the Contractors to suspend part or all of the works if the Contractors and/or any sub-contractors, suppliers, etc. fail to comply with the Environmental Management Plan.

1.3. Prior to construction the Contractors shall provide layout designs of the site indicating the position of all of the following: offices, ablution facilities, storage areas, workshops, batching plant, stockpile areas (i.e. soil/granular chemicals/cement fines, etc.), waste disposal facilities, hazardous substance storage area, access route, etc. This layout plan is to be submitted to the Client (Council) for acceptance prior to site establishment.

1.4. An "Environmental Site Book' should be supplied and kept on site. This book will reflect all issues, and proposed actions as noted during site visits. This site book should be in the form of a file wherein all Environmental Status Reports are kept. In addition, a separate file containing the EMP should also be kept on site. A copy of the Scoping Report, the EMP report and construction layout plan are to be available on site.

1.5. To reduce the effect of habitat loss, construction activities must be planned and implemented in a way that facilitates the restoration of plant communities. Specifications for soil preparation, endemic plant/seed mixes, fertilizer, and mulching should be provided for all areas disturbed by construction activities.

1.6. Restoration activities should be accomplished (established) within a year after construction is completed. The minimum vegetation disturbance must be permitted and the removal of vegetation must be managed and monitored to ensure a minimum exposed period. Monitoring must occur to ensure that revegetation was successful, plantings were maintained, and unsuccessful plant materials replaced.

2. ENVIRONMENTAL MANAGEMENT PLAN (CONSTRUCTION)

2.1. Site establishment and preparation

<u>Management Action</u>:

2.1.1. Limit site to existing road and/or already disturbed areas as far as possible.

2.1.2. Demarcate the boundaries of the total works site clearly for site management purposes. The preferred method of demarcation consists of steel droppers placed at regular intervals with nylon rope between the markers.

2.1.3. Fence off entire works area with 2.4m high temporary fence.

2.1.4. The Contractors shall maintain the demarcation line and ensure that materials used for construction on site do not blow or move outside the site and environs, or pose a threat to animals.

2.1.5. The Contractors shall restrict construction activities to within these boundaries. This extends to ensuring that all construction personnel and equipment remain within the demarcated construction site at all times.

2.1.6. Routes for temporary access and haul roads are to be located within the approved demarcated areas and vehicle movement is to be confined to these roads.

2.1.7. Movement of vehicles outside the designated working areas is not permitted.

2.1.8. Clearly indicated which activities are to take place in which areas within the site e.g. the mixing of cement, stockpiling of materials, etc. Limit these activities to single sites only, preferably on the existing road or otherwise on an already disturbed area.

2.1.9. Remove all markers when the construction phase comes to an end.

2.1.10. Fully rehabilitate (e.g. clear and clean area, rake, pack branches, etc.) the disturbed areas and protect them from erosion.

2.1.11. The Contractor shall only prune or remove vegetation where absolutely necessary. No large trees shall be removed. Topsoil should be stockpiled for later use in revegetation efforts.

2.2. Construction staff

<u>Management Action</u>:

2.2.1. Demarcate the boundaries of the construction staffs' eating and storage areas by means of a 1.5m diamond mesh fence.

2.2.2. Adequate ablutions must be erected on site for construction staff. It is critical that the services (water and sewerage) be properly monitored to ensure that these services are not overused or overloaded. Adequate provision for water shall be made for construction, drinking and washing.

2.2.3. Construction staff (emergency only) may only be accommodated on site once all the necessary services (water, sewerage and waste) are in place.

2.2.4. Dry chemical toilets must be made available on site.

2.2.5. Chemical toilets shall be cleaned and serviced regularly.

2.2.6. A designated place for food preparation and eating must be established.

2.2.7. An adequate number of refuse bins shall be provided.

2.2.8. No pets allowed on site.

2.2.9. All staff to be identifiable through identity badges.

2.2.10. No explosives (with the exception of blasting requirements) or fire-arms to be permitted on site.

2.2.11. No open fires will be allowed.

2.3. **Vegetation clearing**

Management Action:

2.3.1. While bush will have to be undertaken in some areas, the areas needing to be cleared and the degree of clearing required will be determined and demarcated prior to construction. Ancillary activities, such as stockpiles, and storage yards, will be demarcated to areas already disturbed or where they will cause minimal disturbance.

2.3.2. Identify areas to be affected by construction and secure plant species/habitat in these areas. Prevent unnecessary harvesting, destruction and removal of plant material.

2.3.3. No large trees (with trunk diameter exceeding 200mm) are to be removed.

2.3.4. Consider the selective trimming of branches to allow for free vehicle movement before opting to remove any trees.

2.3.5. Remove alien/exotic vegetation, and monitor regularly.

2.3.6. Ensure no exotic vegetation is introduced into the surrounding natural habitat.

2.3.7. All sites disturbed by construction activities shall be monitored for colonization by invasive alien plant species.

2.3.8. The collection of firewood for cooking and other uses is strictly prohibited.

2.3.9. The Contractors may not deface, paint or otherwise mark and/or damage natural feature/vegetation on the site. Any features/vegetation defaced by the Contractors shall be restored.

2.4. **Conservation of topsoil**

Management Action:

2.4.1. The Contractors are required to strip topsoil (as defined in this specification) together with grass/groundcover from all areas where permanent or temporary structures are located, construction related activities occur, and access roads are to be constructed, etc.

2.4.2. Topsoil is to be handled twice only – once to strip and stockpile, and secondly to replace, level, shape and scarify.

2.4.3. Topsoil is to be replaced along the contour.

2.4.4. Topsoil is to be replaced by direct return where feasible (i.e. replaced immediately on the area where construction is complete), rather than stockpiling it for extended periods.

2.4.5. Topsoil stockpiles are not to exceed 1,5m in height and should be protected by a mulch cover. This mulch cover must not contain alien vegetation/seeds.

2.4.6. Topsoil stockpiles are to be maintained in a weed free condition.

2.4.7. Topsoil should not be compacted in any way, nor should any object be placed or stockpiled upon it.

2.4.8. Topsoil, which is to be stockpiled for periods exceeding 4 months, is to be vegetated. A groundcover or grass seeding may be specified.

2.5. Access roads

Management Action:

2.5.1. All disturbed areas along the fringes of the road must be rehabilitated once the road is complete.

2.5.2. Contractors will be required to submit a delivery timetable. Strict control is to be exercised over entering and exiting traffic and delivery procedures.

2.5.3. Special attention will be paid to limit the number of deliveries as far as possible.

2.5.4. Any damage caused by the construction activities to the access roads must be rehabilitated completely upon completion of the works.

2.5.5. Proactively protect steep access roads and cuttings against erosion. Mitre drains, Reno mattresses, extended concrete drifts, drainage pipes, etc. should be considered for this.

2.5.6. Any cement and gravel spillage on the roads is to be cleared up completely.

2.5.7. Construction staff should only use authorised paths and roads.

2.5.8. Construction access roads should not be wider than necessary with a maximum of 3m.

2.5.9. If two-way traffic is to take place, passing bays are to be used to prevent access/detours into the surrounding areas, unless otherwise stated. The drivers delivering construction materials to site are to be made aware of this and are to be forced to utilise the passing bays. They may not drive off the road in order to allow another vehicle to pass.

2.5.10. During the contract period, the Contractors shall ensure that all existing water attenuation and drainage structures are maintained in a state in which they can optimally perform their function.

2.5.11. Vehicles used during construction or to transport material or staff on site, should have the minimum impact on the environment (trees, roads or other) or other road users. The size, height and weight of vehicles must be kept in mind; the access route will determine the type of vehicle that can be used.

2.5.12. Construction vehicles are to be maintained in an acceptable state of repair and cleanliness when leaving the site. Sand, dust and spillages from these vehicles that inevitably fall on the main roads should be cleared on a regular basis.

2.5.13. Drivers of all vehicles on site are to be licensed.

2.5.14. Upon completion of the construction period, the Contractors shall ensure that the access roads are returned to a state no worse the prior to construction commencing.

2.5.15. Continual use of dirt access roads by heavy machinery and increased transport loads means they will have to be carefully monitored and regularly graded as soon as potholes or rutting occurs.

2.5.16. Traffic speeds on the site need to be reduced to a maximum of 25km/hour and regular application of water on gravel road surfaces may be required to prevent high dust disturbance.

2.6. Excavation, backfilling and trenching

Management Action:

2.6.1. Excavation of sand to solid ground to be done carefully and appropriate drainage incorporated i.e. sand and debris need to be removed and solid rock preferably exposed to ensure proper binding with concrete material.

2.6.2. Construction must preferably be extended over rocky substrate to give maximum anchoring opportunity.

2.6.3. Blasting operations, if required, to be planned by competent specialists, with due regard to adjacent land users. Blasting t be programmed in cooperation with adjacent land owners to result in the most impact limiting operation.

2.6.4. Record to be kept of infrastructure and facility conditions prior to and after the blasting operations.

2.6.5. Consider using any excess rocks or boulders that were excavated from the construction site for any erosion protection work which is required on site. Consider removing the rocks for the packing of gabions at other soil erosion sites.

2.6.6. If need be, spread the rocks in as natural a manner as possible in the veld along the access roads. This should be considered as the last option only and only if a few excess rocks remain.

2.6.7. Similarly, excess sand as a result of excavation activities is not to be dumped along the roadsides.

2.6.8. Removed soil is to be used to backfill areas where required and excess is to be landscaped into natural looking banks that fit the surrounding topography.

2.6.9. During excavation, topsoil is to be conserved.

2.6.10. Excavated material is to be stockpiled along a pipeline trench within the working servitude, unless otherwise authorised.

2.6.11. Deficiency of backfill material shall not be made up by excavation in the protected area. Where backfill material is deficient, it should ideally be made up by importation from an approved borrow pit.

2.6.12. The Contractors shall backfill in accordance with the requirements of progressive reinstatement. 'Progressive reinstatement' is defined as: reinstatement of disturbed areas to topsoil profile on an ongoing basis, immediately after selected construction activities (e.g. backfilling of trench) are completed. This allows for passive rehabilitation (i.e. natural re-colonisation by vegetation) to commence.

2.6.13. The following trenching specification shall apply:

2.6.13.1. The trench will be excavated to a depth of 1m where possible. Where shallow bedrock makes this impractical the trench should only then be excavated to the maximum depth possible.

2.6.13.2. Care will be taken to remove the topsoil and then the subsoil and to stockpile these separately.

2.6.13.3. The pipeline/cable should be placed on a 200mm bed of river sand to protect it.

2.6.13.4. The subsoil will then be backfilled.

2.6.13.5. The topsoil will then be replaced and the entire length of the trench compacted.

2.6.13.6. The trench should be compacted to 90-93% AASHTO.

2.6.13.7. Sections of the trench that are excavated in a roadway should be compacted to 98% AASHTO.

2.6.14. Contract personnel at all levels to be made aware of potential archaeological and/or palaeontological artefacts/occurrences.

2.6.15. Any discovery of artefacts to be reported immediately to SAHRA.

2.6.16. Works in areas where artefacts are discovered are to cease immediately until the area has been investigated and a go-ahead has been obtained from SAHRA.

2.7. Levelling

Management Action:

2.7.1. Excess sand and soil resulting from levelling activities of the work area should be stored in low heaps either on the access road or already disturbed area.

2.7.2. Excess topsoil is to be spread evenly over the area in a manner that blends in with the natural topography.

2.7.3. Excess stockpiled building material is to be removed completely and the areas levelled.

2.7.4. Once heavy machinery has cleared the bulk of these material stockpiles, the disturbed areas should be levelled and cleared of any foreign material manually. It is unacceptable to leave foreign material behind with the knowledge that it will become hidden amongst the rejuvenating vegetation with time.

2.7.5. Regular inspections must be undertaken to monitor and audit the effects and impacts of such removals.

2.8. Stockpiling of building materials

Management Action:

2.8.1. Limit to demarcated sites only.

2.8.2. Single sites should be a priority. This may not always be possible for example heaps of topsoil, but should definitely be the case for activities such as the mixing of cement.

2.8.3. Stockpiles of expensive materials such as bags of cement should be such that they can easily be removed from the site over weekends or during rainy weather.

2.8.4. Specific sites should be allocated for waste e.g. empty cement bags, discarded planks, etc. A low temporary fence should possibly be erected around such a site in order to contain the waste and assist the effective removal thereof from the site.

2.8.5. A specific site should be allocated for the storage and handling of diesel, grease, oils, solvents and soap, which create cleaning and disposal issues. This area should be bunded, and thus should take place in the area allocated for permanent storage of such materials.

2.8.6. Fuels required during construction shall be stored in a central depot at the construction camp. This storage area must be bunded.

2.8.7. Rehabilitate the sites as required.

2.9. **Materials handling and storage**

Management Action:

2.9.1. Tanks containing fuel shall have lids, which are to remain firmly shut.

2.9.2. Fuel stores shall be placed on a concrete, or similar, base surrounded by a brick bund.

2.9.3. The bund shall have a volume of 30% of the volume of the largest tank in the storage area plus 10% of the volume of all other tanks.

2.9.4. The slab shall be sloped towards a sump to enable any spilled fuel and water to be removed.

2.9.5. Any wastewater collected at the sump shall be disposed of as hazardous waste.

2.9.6. Gas and liquid fuel shall not be stored in the same storage area.

2.9.7. No smoking shall be allowed inside the stores or within 3m of a bund.

2.9.8. The Contractors shall ensure that there is adequate fire-fighting equipment at the fuel stores.

2.9.9. Do not store fuels and chemicals under trees.

2.9.10. Exercise extreme care with the handling of diesel and other toxic solvents so that spillage is minimised.

2.9.11. Excess concrete from mixing shall be deposited in a designated area awaiting removal to an appropriate landfill site. Liquid wastes to be treated at an approved facility.

2.9.12. The Contractors shall ensure that all operations that involve the use of cement and concrete are carefully controlled.

2.9.13. Concrete mixing shall only take place in the construction camp or in agreed specific areas on site.

2.9.14. Concrete shall not be mixed directly on the ground. No mixed concrete shall be deposited directly onto the ground prior to placing. A board or other suitable platform/surface is to be provided onto which the mixed concrete can be deposited whilst it waits placing.

2.9.15. All visible remains of excess concrete shall be physically removed immediately and disposed of as waste.

2.9.16. Timber products should be treated off-site prior to use in construction.

2.9.17. Periodic on-site application of timber treatment products (for maintenance purposes) should take place with due care for the nature of the product (toxicity) and for potential spillages that may occur. Areas where timber is to be treated should have secondary containment measures instituted, such as the placement of plastic layer (some form of covering) over soils, beneath the timber structures to prevent contamination of the soil surface.

2.10. Servicing and refueling of construction equipment

Management Action:

2.10.1. The Contractors shall ensure that servicing and/or refuelling of vehicles and equipment takes place within the construction camp.

2.10.2. Should construction vehicles have to serviced on site, it must be done in a designated area with a concrete floor and drain system that will prevent oils and fuels from contaminating the environment.

2.10.3. The ground under the servicing and refuelling areas shall be protected against pollution caused by spills and/or tank overfills (bunded/lined).

2.10.4. All water run-off from these areas shall be collected, contained on site and stored in water-tight containers prior to disposal off-site as hazardous waste

2.10.5. All equipment that leaks shall be repaired immediately or shall be removed from site.

2.10.6. The Contractors shall only change oil or lubricant at agreed and designated locations, except if there is a breakdown or emergency repair, and then any accidental spillages must be cleaned up/removed immediately.

2.10.7. In such instances the Contractors shall ensure that he has Drizit pads or similar, and/or drip trays available to collect any oil or fluid.

2.10.8. The only permitted method of refuelling and refilling lubricants is by means of a pump.

2.11. Solid waste management

Management Action:

2.11.1. If construction workers are to eat on site other than at the construction camp, the Contractors shall designate specific areas for eating and shall provide adequate steel refuse bins at al places. The refuse bins shall be cleaned on a daily basis.

2.11.2. The bins shall be provided with lids and an external closing mechanism to prevent their contents blowing out and shall be scavenger-proof.

2.11.3. The Contractors shall supply steel waste bins/skips throughout the site at locations where construction personnel are working

2.11.4. The Contractors shall not dispose of any waste and/or construction debris by burning, or by burying.

2.11.5. The Contractors shall ensure that all personnel immediately deposit of waste in waste bins for removal by the Contractors.

2.11.6. All waste shall be disposed of off-site at an approved landfill site.

2.11.7. Remove loose building materials and waste from the site and dispose of them at an appropriate waste disposal site.

2.11.8. Old cement mixing bags shall be placed in wind and spill proof containers as soon as they are empty. The Contractors shall not allow closed, open or empty bags to lie around the site.

2.11.9. All waste, which includes cigarette butts, cable ties, paper, plastic, tin, glass, organic waste like fruit pips and peels, planks, wire, tins of grease, etc. must be transported in an appropriate manner (e.g. plastic rubbish bags) to an appropriate waste site.

2.12. Liquid waste management

Management Action:

2.12.1. Construction water refers to all water affected by construction activities.

2.12.2. The Contractors may discharge 'clean' silt laden water overland and allow this water to filter into the ground. However, they shall ensure that they do not cause erosion as a result of any overland discharge.

2.12.3. All washing of plant/equipment/concreting equipment etc. shall take place within the construction camp.

2.12.4. Water from washing operations shall be collected in a conservancy tank removed from site and disposed of in the agreed manner.

2.12.5. The Contractors are encouraged to recycle dirty wash water to minimise the amount to be removed off-site.

2.12.6. Trucks delivering concrete shall not be washed on site.

2.12.7. All washing operations shall take place off-site at a location where wastewater can be disposed of in an acceptable manner.

2.12.8. Adequate ablution facilities to be provided on site, conveniently located near to work areas to avoid localised water pollution from camp sewerage.

2.12.9. Neither the river nor any other natural watercourse is to be used for cleaning of tools or any other apparatus. This includes for purposes of bathing, or washing of clothes etc.

2.12.10. A drainage diversion system is to be installed to divert runoff from areas of potential pollution, e.g. batching area, vehicle maintenance area, workshops, chemical and fuel stores, etc.

2.12.11. No spills may be hosed down into a storm water drain or sewer, or into the surrounding natural environment.

2.12.12. Discard construction waste at a registered waste management facility/landfill site, particularly those wastes or products that could impact on surface or groundwater quality by leaching into or coming into contact with water.

2.12.13. Construction vehicles are to be maintained in an acceptable state of repair and cleanliness when leaving site. Sand, dust and spillages from these vehicles that inevitably fall on the main roads should be cleared on a regular basis.

2.12.14. All soil contaminated, for example by leaking machines, refuelling spills, etc., is to be excavated to the depth of contaminant penetration, placed in 200 litre drums and removed to an appropriate landfill site.

2.12.15. The Contractors shall contain wash water from cement mixing operations, by directing the water into a sump for collection. The material contained in the sump shall be removed to an appropriate landfill site.

2.12.16. Water and slurry from concrete mixing operations shall be contained to prevent pollution of the ground surrounding the mixing points.

2.12.17. All visible remains of excess concrete shall be physically removed immediately and disposed as waste. Washing the visible signs into the ground is not acceptable. All excess aggregate shall also be removed.

2.12.18. Where, due to construction requirements, pollution of a water body may potentially occur, the Contractors are to ensure adequate measures (e.g. attenuation/settlement dams/oil absorbent products) are in place to prevent pollution. A method statement is to be provided to this effect.

2.12.19. Exercise extreme care with the handling of diesel and other toxic solvents so that spillage is minimised.

2.12.20. The Contractors shall take reasonable precautions to prevent the pollution of the ground and /or water resources on and adjacent to the site as a result of his activities.

2.12.21. Such pollution could result from the release, accidental or otherwise, of chemicals, oils, fuels, sewage and waste products, etc.

2.12.22. The Contractor shall obtain Drizit pads or similarly designed products or materials to soak up oil, petrol and diesel.

2.12.23. These materials shall be readily available for use wherever construction equipment is working, fuel and lubricants are being offloaded and stored and equipment is filled and serviced.

2.12.24. The Contractors shall ensure that he is familiar with the correct use and disposal of any materials designed to soak op petroleum products.

2.12.25. The Contractors shall ensure that no oil, petrol, diesel, etc. is discharged onto the ground.

2.13. **Hazardous materials**

<u>Management Action</u>:

2.13.1. The Contractors shall comply with all national, regional and local legislation with regard to storage, transport, use and disposal of petroleum, chemical, harmful and hazardous substances and materials.

2.13.2. The Contractors shall obtain the advice of the manufacturer with regard to the safe handling of such substances and materials.

2.13.3. The Contractors shall provide a list of all petroleum, chemical, harmful and hazardous substances and materials on site, together with storage, handling and disposal procedures for these materials.

2.13.4. The Contractors shall furthermore be responsible for the training and education of all personnel on site who will be handling the material about its proper use, handling and disposal.

2.13.5. Storage of all hazardous material is to be safe, tamper proof and under strict control.

2.13.6. Petroleum, chemical, harmful and hazardous waste throughout the site shall be stored in enclosed bunded areas. The bunded areas shall be clearly marked. Such waste shall be disposed of off site at a hazardous waste disposal site.

2.13.7. The bunded area is to be sufficiently large to contain a spillage equivalent to the volume of one container of the substances stored.

2.13.8. Temporary fuel storage tanks and transfer areas also need to be located on an impervious surface adequately bunded to contain accidental spills. Appropriate run-off containment measures must be in place.

2.13.9. All products to be dispensed from 200 litre drums shall be done with appropriate equipment, and not dispensed by tipping of the drum.

2.13.10. Any accidental chemical/fuel spills to be corrected immediately.

2.13.11. Fuels, solvents and other wastes will be stored in vessels equipped with secondary containment structures and will be removed from the concession area and the park being disposed of in compliance with national and local requirements

2.13.12. The containers in which the products are kept should, in compliance with hazardous material management procedures, be removed from the site once empty. Hazardous products should otherwise be stored on adequately bunded surfaces in the designated hazardous material storage areas.

2.14. **Erosion protection work**

Management Action:

2.14.1. Correct any cause of erosion at the onset thereof trough the most appropriate mechanism.

2.14.2. Soils should not be stripped when they are wet. This can lead to compaction and loss of soil structure.

2.14.3. During construction the Contractors shall protect all areas susceptible to erosion by installing all the necessary temporary and permanent drainage works as soon as possible and by taking such other measures as may be necessary to prevent surface water being concentrated in water sources and from scouring the slopes, banks or other areas.

2.14.4. In essence soil erosion protection is about reducing the velocity of water run-off in the disturbed areas. There are many appropriate methods, depending largely upon the size and topography of the area to be protected against erosion.

2.14.5. The stabilisation of disturbed areas, access roads and/or steep cuttings is very site specific and could include:

2.14.5.1. Mitre drains;

2.14.5.2. Drainage pipes;

2.14.5.3. Reno mattresses (biodegradable material, upon which soil and rocks are packed which then keeps it in place to bind the soil);

2.14.5.4. Benches (consisting of sand bags);

2.14.5.5. Gabions;

2.14.5.6. Gabion mattresses;

2.14.5.7. Scarifying (ripping) areas along the natural contours; or

2.14.5.8. Packing branches and rocks in small gullies and disturbed areas.

2.14.6. Drainage of access routes and mitre drains to be maintained and kept open and functional.

2.14.7. Block off access to gravel pits and temporary routes so as to prevent them being used as 'roads' at a later stage.

2.14.8. Surface erosion protection measures shall be required to prevent erosion where slopes are steeper than 1:8 on all soil types.

2.14.9. Erosion protection measures required should include all or some of the below, as specified by the Engineer:

2.14.9.1. Use of groundcover or grass, retention of as much of the indigenous vegetation as possible;

2.14.9.2. Construction of cut off berms (earth and/or rock pack) – these are to be angled across the contour and normally would approximate an angle of 30° from the bisector of the contour;

2.14.9.3. Placing of brush wood on bare surface;

2.14.9.4 Hard landscaping, e.g. gabions etc.

2.14.10. Scour chambers are to be fitted with energy dissipaters, or the jet of water directed onto a protected (i.e. grouted stone pitching/rock pack/Reno mattress) area to dissipate water velocity and to control and prevent erosion.

2.14.11. Storm water drainage measures shall be required on site to control runoff and prevent erosion.

2.15. **Use and rehabilitation of gravel pits**

Management Action:

2.15.1. The extent of the borrow area (envelope area) is to be clearly explained to the contractors prior to the commencement of gravel extraction activities. This gravel area is not to be increased.

2.15.2. Topsoil is to be stockpiled separately and used to recover and rehabilitate the pits after use.

2.15.3. Plan to reuse the soil, as soon as possible; the biological components will deteriorate over long periods of storage.

2.15.4. Do not stockpile in large piles. Store in low heaps no more than one or two metres high to best retain the organic components in good condition.

2.15.5. The stockpiles should be located where they will not be disturbed by activities within the gravel pit. Disturbing the topsoil can further damage the soil structure prior to final reuse.

2.15.6. Soils should not be stripped when wet. This can lead to compaction and loss of structure of the soil.

2.15.7. The stripping of the gravel pit to solid bedrock with no chance for rehabilitation should be avoided. Such areas within the gravel pit should be rehabilitated immediately.

2.15.8. The natural slopes in the area, which have evolved as a result of natural erosion processes, should be studied and used as a guideline to determine the inclination of the reconstructed slopes. Obviously, the size of the area to be rehabilitated is a major consideration.

2.15.9. Slopes should be designed to reduce the velocity of the run-off as the catchment area of the increases. Where the area of the site limits formation of the stable slope profile, contoured benches or similar erosion control methods may be required. Slopes with an overall convex profile should always be avoided.

2.15.10. Where the size of the slope area to be rehabilitated is small, benches consisting of sandbags can be considered. These temporary structures should under no circumstances be left in a place beyond their projected life, as they will deteriorate in a very short period of time.

2.15.11. Benches are best located in the middle of the slope. Where long spaces cannot be avoided several benches may be required. In such cases the slope and run-off characteristics must be considered.

2.15.12. The site must be surveyed to maintain the contours. Where banks are graded to direct run-off to specific draw points ensure that run-off is dissipated or properly controlled.

2.15.13. Topsoil will commonly not adhere to slopes that are steeper than 27 degrees. The maximum slope for mechanically spreading topsoil is approximately 19 degrees.

2.15.14. Depending on the characteristics of the site, such as geology, the nature of the soils and other site specific topographical features, more gentle slopes may be necessary.

2.15.15. When contouring, always rip and scarify precisely along the contour. This prevents inadvertently creating down slopes channels.

2.15.16. The contour line should be surveyed and marked by posts, if necessary.

2.15.17. The ripping should normally be as deep as is possible depending on the material, the equipment that is available and the sub-surface conditions. However, some subsoil conditions (e.g. where boulders are present) may not permit ripping to these depths.

2.15.18. The spacing of the lines when ripping or scarifying should be such that they overlap each other.

2.15.19. When soil conditions are wet, soil will not break up so avoid ripping and scarifying under wet conditions.

2.15.20. Water discharge from small retention structures (e.g. earth embankments and artificially created pits that hold water) should be implemented. Where practical, it can be controlled via corrugated metal or plastic pipe/s that drain the water through the retention structures into a safe discharge area (i.e. one, which does not promote erosion or the creation of another artificial water pit).

2.15.21. These temporary structures should under no circumstances be left in place beyond their projected life, as they will deteriorate in a very short period of time.

2.15.22. The siting of any disposal sites for waste rock, within a specific borrow pit should be considered in the earliest plans. In many cases the filling and rehabilitation of any artificial water pits within the gravel pit could be considered. The site is covered by at least 0,5m of local gravel and then the available topsoil.

2.15.23. Access point to the borrow pit site is closed when not in use.

2.16. Run-off from construction camps

Management Action:

2.16.1. Pumps and other machinery requiring oil, diesel, etc., which are to remain in one position for longer than two days shall be placed on drip trays. The drip trays shall be watertight and shall be emptied regularly and the contaminated water disposed off-site at a facility capable of handling such waste liquid. Drip trays shall be cleaned before any possible rain events that may result in the drip trays overflowing.

2.16.2. A drainage diversion system is to be installed to divert runoff from areas of potential pollution, e.g. batching area, vehicle maintenance area, workshops, chemical and fuel stores, etc.

2.16.3. Contaminated runoff and wastewater is to be directed into a collection system (e.g. sump, attenuation dam, PVC porta-ponds, etc.) for treatment or collection and disposal. The final collection point (e.g. sump) is to be PVC lined.

2.16.4. Collected contaminated runoff/wastewater is to be pumped out of the final collection point and disposed of at an appropriate waste disposal site. Sump liners are to be treated in the same manner.

2.17. Fire

Management Action:

2.17.1. The Contractors shall take all the necessary precautions to ensure that fires are not started as a result of activities on site.

2.17.2. No open fires for heating or cooking shall be permitted on site.

2.17.3. Closed fires or stoves shall only be permitted at agreed designated safe sites in the construction camp.

2.17.4. Adequate suitable fire fighting equipment shall be provided at each fireplace or stove.

2.17.5. The Contractors shall be responsible for providing the necessary basic fire-fighting equipment.

2.17.6. All equipment shall be maintained in good operating order.

2.17.7. The Contractors shall supply all site offices, kitchen areas, workshop areas, material stores and other areas identified with suitable, tested and approved fire fighting equipment.

2.17.8. Workers are to be provided with gas for cooking and shall be prevented from burning fires.

2.17.9. No open fires shall be allowed anywhere on site.

2.17.10. The Contractors shall ensure he has the necessary fire fighting equipment on site in terms of SANS 1200. This shall include at least rubber beaters when working in 'veld' areas. A minimum requirement for construction in a high fire risk area shall be a water bowser/cart (minimum 5 000 litres) equipped with pump and hose (min 30m) which shall be permanently on site.

2.17.11. The construction site must also be protected against fire, and a sufficient fire break must be constructed, around the construction site.

2.17.12. A road to be constructed along the entire boundary of the site.

2.17.13. A firebreak to be made along the site boundary road.

2.18. **Accidents**

Management Action:

2.18.1. The Contractors shall comply with the Occupational Health and Safety Act.

2.18.2. The Contractors shall be responsible for establishing an emergency procedure for dealing with spills or releases of petroleum.

2.19. **Storm and wind conditions**

Management Action:

2.19.1. Special care will be taken during rainy periods to prevent the contents of sumps from overflowing.

2.19.2. The Contractors shall set up a procedure for rapidly emptying any collection points to prevent their filling with rainwater.

2.19.3. The Contractors shall ensure that rainwater does not run off areas containing pollutants and thus result in a pollution threat.

2.19.4. Stockpiles of the fine material such as sand, topsoil material, cement, etc. must also be protected from runoff and wind.

2.20. **Dust**

Management Action:

2.20.1. At all times the Contractors shall control dust on site.

2.20.2. Dust control shall be sufficient so as not to have significant impacts in terms of the biophysical and social environments. These impacts include visual pollution on gravel and earth roads.

2.20.3. A dust abatement programme shall be used. Standard dust abatement measures include watering or otherwise stabilising soils, covering haul trucks, employing speed limits on unpaved roads, minimising vegetation clearing, and promptly revegetating after construction is completed.

2.20.4. Revegetation plans should be developed for areas impacted by construction activities. Salvaged vegetation, rather than new planting or seeding, should be used to the extent possible.

2.20.5. Efforts to reduce dust and soil loss are to be undertaken, as appropriate, for all excavation, grading, construction, and other dust-generating and soil-disturbing activities.

2.21. Noise

Management Action:

2.21.1. Machinery and vehicle silencer units are to be maintained in good working order. Offending machinery and/or vehicles shall be banned from use on site until they have been repaired.

2.21.2. Noise levels shall e kept within acceptable limits for a protected area, and shall not be of such nature as to detract from the natural experience of other visitors to the protected area.

2.21.3. Music and other social noise to be controlled on site so as to not impose on others.

2.21.4. The Contractors shall at all times use equipment that is appropriate to the task in order to minimise the extent of damage to the environment and minimise noise levels.

2.21.5. Construction work will take place during the day as far as possible.

2.21.6. Work will only be undertaken at night in the case of emergencies.

2.21.7. Work hours will be from approximately 07:00 to 17:00

2.22. Visual

Management Action:

2.22.1. The type and colour of roofing and cladding materials are to be selected to reduce reflection.

2.22.2. Security lighting (both temporary and permanent) and lighting required for specific work activities must be placed such that it is not a nuisance to residents, visitors and the general public. Shields may be required to prevent lights from being visible from other parts of the area.

2.22.3. Construction will only take place at night during emergency situations and not as common practice.

2.22.4. Care will be taken when positioning the lights to ensure the least visual impact, while still providing a safe work environment for construction staff.

2.23. Loitering

2.23.1. The contractors shall ensure that loitering around the construction sites is not permitted. This includes job seekers, socialisers, food vendors, squatters, etc.

2.24. Site clean up

Management Action:

2.24.1. The Contractors shall ensure that all temporary structures, materials, waste and facilities used for construction activities are removed upon completion of the project.

PART 2.1A : 132KV OUTDOOR CIRCUIT BREAKERS

SPECIFICATION No. : CB.60/1-97 – Rev 2

CONTENTS

1. SCOPE

This specification covers the supply, erection and commissioning of circuit breakers of the gas insulated type for use in outdoor switch-yards on a three-phase 132 kV 50 Hz supply network.

2. STANDARDS

The Switchgear and associated equipment shall comply with the requirements of this specification, the particulars and guarantees stated by the tenderer in the Schedule of Particulars and Guarantees. See also section III -1.4 above.

3. SF_6 PRESSURE VESSEL ENCLOSURES

In terms of Instruction No OS/BV 0009/1 from the Chief Inspector of Factories, exemption may be granted from the provisions of Regulations C73 to C86, inclusive, in respect of enclosures containing SF_6 normally pressurised up to 500 kPa. Contractors shall obtain the test documentation from the manufacturers.

Unless otherwise specified elsewhere, the SF6 gas chambers shall have a gas density monitoring gauge with a low gas alarm, trip and lockout voltage free contacts wired out to terminals for remote monitoring, protection and control purposes

Facilities shall be provided on the gas gauge to allow complete end to end functional tests once the control system is in place and being commissioned. Provision shall also be made to prevent unauthorised operation of this facility.

The low pressure alarm must be initiated well before the switching lockout becomes necessary

The above monitoring gauge shall be suitably covered to be protected against all weather elements to the approval of the engineer. The gauge shall be clearly visible to a person standing on the ground.

The provisions for vessels under pressure which require that the enclosures are to be designed, tested and manufactured to an approved code and have to be inspected by an independent approved inspection authority, are to be complied with. The tenderers shall specify the relevant code.

This contract includes the supply and filling with sulphur hexafluoride (SF6) gas to the correct density and the subsequent supply and filling of any gas lost due to failure or during commissioning tests or maintenance during the maintenance period.

4. CIRCUIT-BREAKER REQUIREMENTS

4.1 General

The circuit-breakers shall comprise of three single break vertically mounted interrupters, mounted on suitable steel support structures supplied with the circuit-breakers.

Phase spacing and conductor terminations and their positions shall be as specified in the particulars and guarantees.

Circuit-breaker mechanisms are to be of unitary design, requiring only an external electrical power source as specified in the schedules. A common mechanism operating all three poles of the circuit-breaker at the same time will be preferred over three single mechanisms.

Each circuit breaker unit shall be provided with a control kiosk which shall be positioned on the circuit breaker structure at a convenient height above the ground.

Control coils/valves shall operate at the voltages specified in the schedules. Tripping circuits shall be duplicated electrically and, as far as possible, mechanically.

The circuit-breaker shall be of the SF_6 auto puffer type and shall be rated as specified in the schedules.

The minimum requirements for contacts from each of the gas pressure level monitors are as follows:

a) 1 x low gas pressure alarm (normally closed);

b) 4 x gas pressure trip and lockout (1 - control; normally closed), (1 - close circuit inhibit; normally open), (2 - trip circuit inhibit; normally open).

5. OPERATING MECHANISMS

Pneumatically operated drives, i.e. working with compressed air, will not be acceptable.

5.1 Electrically Operated Motor Wound Spring Operation

Control and operation mechanisms for motor-wound spring operation shall be arranged that the spring recharging takes place after a "close" operation. Local facilities shall however be provided to lock out or initiate spring recharging with the circuit-breaker in any position.

Sufficient energy storage shall be provided by the spring to carry out the duty cycle specified in the schedules.

Mechanical means shall prevent damage should the spring charge motor fail to stop. Spare contacts as detailed in the schedules shall be provided for indication and blocking of operation.

Contact operation and change-over during normal circuit breaker operation and spring charging must be clearly described. It has to operate in such a manner as to allow the substation control system to distinguish between a normal recharge operation and a mechanism failure.

Visible indication of the state of the spring as well as the circuit-breaker shall be provided in a position on the mechanism clearly visible to a person standing on the ground.

The operating mechanism shall be designed that it is possible to immediately trip the circuit-breaker after a closing operation, both mechanically and electrically. The mechanism shall ensure that once an operation has commenced it will always be completed.

Direct acting manual tripping and closing devices, not relying on any electrical circuit, shall be provided on the operating mechanism. Padlocking facilities shall be provided on these controls.

A means of manually recharging the operating springs shall be provided. A single person standing on the ground shall be able to do this without requiring undue strength. Unique winding handles which can only be utilised for winding of the circuit breaker spring etc. shall be mounted in the mechanism cubicle.

Means shall also be provided to inhibit any electrical or mechanical operation of the circuit breaker mechanism whilst the manual spring charging is in progress. Insertion of the winding handle shall “make” an auxiliary switch contact wired out to terminals for external control and indication purposes.

An auxiliary switch contact that “makes” when any latch or door or enclosure is open, shall be wired out to terminals for external control and indication.

Mechanism(s) shall be enclosed in a suitable weatherproof enclosure of rustproof construction. Stainless steel type enclosures are preferred. Enclosure class IP 54

Alarm indication and auxiliary contacts shall be provided to indicate mechanism failure.

5.2 Pneumo-Hydraulic Type Mechanisms

Pneumo-hydraulic mechanisms shall be of unitary type construction requiring only external power supply and control circuits as specified in the schedules.

Sufficient energy storage shall be provided by the operating system to carry out the duty cycle specified. The design of the energy storage shall be such that any cooling effects due to gas expansion during the required cycle shall not cause the mechanism to lock out.

Visible indication of the energy stored in the mechanism as well as the state of the circuit-breaker shall be provided in a position on the circuit-breaker and operating mechanism visible to a person standing on the ground. Means shall be provided by a two stage alarm/lockout relay monitoring the energy stored to electrically interlock the closing/tripping signals to the mechanism.

Alarm devices to detect loss of hydraulic oil and the energy storage gas, monitoring of the charging motor running time shall be provided.

The operation mechanism shall be so designed that it is possible to trip the circuit-breaker immediately after a closing operation, both mechanically and electrically. The mechanism shall also ensure that once an operation has commenced it will always be completed.

Direct acting manual tripping and closing devices, not relying on any electrical circuit shall be provided on the operating mechanism. Padlocking facilities shall be provided on these controls.

A means of mechanically recharging the operating mechanism by hand shall be provided. Such a manually operated hydraulic pump shall enable a single person to recharge the mechanism at ground level without requiring undue strength, or taking an excessively long time. The number of these pumps to be supplied shall be as stated in the schedules.

Mechanism(s) shall be enclosed in a suitable weatherproof enclosure of rustproof construction. The hydraulic pump, if subject to vibration, shall be mounted in a separate enclosure, with rubber type mountings to isolate any vibration. The enclosure shall be class IP54.

Alarm indication and auxiliary contacts shall be provided to indicate mechanism fail.

5.3 Mechanism Motors

The supply voltages for mechanism motors shall be as stated in the schedules..

Motors using brushes shall be supplied with two sets of spare brushes for each motor.

Unless otherwise approved, motors shall have ball or roller type bearings, lubricated for the expected life of the motor. The type of lubricant used shall not harden with long periods of non-use. All motors shall be easily accessible and removable from the mechanism for maintenance or repairs.

Motors shall be designed and rated to IEC standards. All motors shall be provided with suitable protective control gear, incorporating suitable overload devices including protection against loss of a phase in the case of three phase motors. A suitable alarm contact shall be provided for external alarm and indication purposes to indicate the motor "tripped" condition.

5.4 Closing Devices

All electrical mechanisms used in the closing circuit shall be suitable for safe operation at the voltage ranges specified in the schedules. The range will be between 80% and 120 % of normal rated control voltage.

A limit switch shall de-energise the close coil when the breaker closes to avoid burning out the closing coil under mall-operation conditions due to a sustained closing signal.

An approved means of mechanically closing the circuit-breaker, without recourse to any electrical circuit shall be provided. Padlocking facilities shall be provided on this control.

Provision shall be made by means of a Local-Off-Remote selector switch to select electrical closing control of the circuit-breaker. Spare contacts shall be provided on this switch and wired out to terminals for remote indication of the position of the switch.

5.5 Tripping Devices

Circuit-breakers shall be equipped with duplicate tripping mechanisms, electrically and mechanically separate as far into the mechanical mechanism as possible.

An approved means of mechanically tripping the circuit-breaker, without recourse to any electrical circuit, shall be provided.

A limit switch shall de-energise the open coil when the breaker opens to avoid burning out the opening coil under mall-operation conditions due to a sustained open signal.

All electrical mechanisms used in the tripping circuit shall be suitable for safe operation at the voltage ranges specified in the schedules.

Provision shall be made by means of a Local-Off-Remote selector switch to select electrical tripping control of the circuit-breaker. Spare contacts shall be provided on this switch and wired out to terminals for remote indication of the position of the switch.

Provision shall be made for remote trip circuit supervision of both the main and back-up trip circuits in the open **and** closed positions of the circuit breaker. These circuits shall be wired out to terminals for remote indication.

5.6 Interlocks

5.6.1 General

In the case of circuit-breakers with individual mechanisms for each phase interlocking shall be provided to prevent their closing unless all mechanisms are in a "ready to close" state.

Interlocks shall be designed to ensure the safety of operating personnel at all times i.e. no remote opening or closing of the breaker shall be possible with the local/off/remote selector switch in the local position

Door switches shall be provided on mechanism doors wired to terminals for remote supervision (non urgent alarm)

In the case of gas insulated circuit-breakers, mechanisms shall be blocked against operation should the internal gas pressure fall below the required minimum level ("lockout") as determined by the gas density monitor.

5.6.2 Motor wound spring mechanisms

The following interlocks shall be provided as a minimum requirement: :

a) Closing may not take place without the springs being in a fully charged state;

b) releasing of the springs shall only be possible with the circuit-breaker in the open position; and

c) it shall be impossible to overcharge the springs.

5.6.3 Anti-pumping devices

Approved means shall be provided to prevent "pumping" of the circuit-breaker whereby the "close" command shall fall away before a further "closing" operation may be initiated.

This protection shall form an integral part of the circuit-breaker mechanism, and shall be mounted in the circuit-breaker control cubicle.

5.7 Operation Counters

Each circuit-breaker mechanism shall be provided with a minimum of one digital operation counter, which shall increment by one unit every time the mechanism is tripped. It shall not be possible to reset this counter.

5.8 Auxiliary Switches and Contacts

Contacts shall be of a type that can be independently changed from a "normally open" to a "normally closed" type and vice versa, on site and without undue difficulty.

The number, type and rating of the contacts to be supplied shall be as specified in the schedules. Unless otherwise specified a minimum of 20% of spare contacts shall be supplied. The use of auxiliary relays to achieve the required number of contacts will not be accepted.

All contacts shall be independently wired out to the secondary terminal block, using a conductor with a cross section of at least 1.5 mm^2.

All multi-core terminals and all auxiliary switch contacts shall be permanently marked.

Auxiliary switches shall be readily accessible for maintenance and shall be properly adjusted where necessary.

6. INTERRUPTER UNIT

Interrupter ratings shall be as described on the schedule of particulars.

The SF6 gas-insulated interrupter unit shall be of the puffer type, utilising gas compressed during the tripping cycle to cool and extinguish the electrical arc.

The contacts shall be so designed to carry the current as specified in the schedules continuously without any adverse effects Multiple contacts shall be used for the main current carrying female contact, with each contact preferably having its own spring. Separate contacts shall be used for contacts subject to arcing.

The design of the interrupter shall be such as to enable easy inspection and replacement of the main and arcing contacts. Tenderers shall explain how this is achieved.

Insulated components used within the unit shall be capable of withstanding the effects of arcing.

Gas leakage shall be such that no recharging is necessary for a period of at least ten years. Suitable couplings shall be supplied for refilling and sampling of the SF_6 gas.

Tenders shall state the guaranteed leakage rates of the equipment offered.

Each gas compartment unless stated otherwise elsewhere, shall be provided with an individual density monitor. This monitor(s) shall have individually adjustable alarm levels, as depicted in Part 4.1 Each level shall be provided with individual contacts as specified in the schedules. The lowest pressure shall be utilised for mechanism lockout while the others will be utilised for trip and alarm purposes.

The monitor shall have an indicator with a clearly graduated scale indicating the normal, high, low and lockout gas pressures.

Interrupter units shall be provided with the initial filling of new SF_6 gas in accordance with IEC.

The porcelain insulator of the interrupter unit shall be designed in accordance with the regulations concerning pressure vessels. Porcelain sections shall be brown in colour and shall comply with the creepage and flash over distances specified. Where SF_6 gas seals are involved metal to metal flanges with gaskets are preferred to porcelain to metal seals.

A suitable means of pressure relief shall be provided to prevent excessive internal pressure that could lead to explosion of the interrupter. The tenderer shall give details of the pressure relief device offered.

Electrical connections to the interrupter shall be as specified in the schedules.

7. WIRING

The wiring shall be strictly in accordance with the general requirements in Part 1 of the Technical Specification.

7.1 MCB's and Isolators

Mcb's and isolators shall be provided as required for the protection and isolating of circuits. The arrangement, type and kA rating of Mcb's shall be to approval.

The Mcb's and isolators shall be mounted in such a way as to allow easy access and replacement from the front.

All Mcb's and isolators shall be suitably and permanently labelled, displaying the designation and identification number using the prefix "MCB" for circuit breakers and the prefix "ISOL" for isolators.

Current ratings shall also be displayed.

The labels shall not be fixed to removable parts of Mcb's or isolators.

7.2 Multi-Core Terminals

Multi-core terminal blocks shall be provided inside the control cubicles in an easily accessible position(s) for terminating multi-core cable tails and for connecting up with the internal wiring in the cubicles. Unless other-wise approved, terminal strips shall be mounted vertically in order that ferrule numbers may be read without difficulty.

All terminals and connections for secondary wiring shall be sufficiently large to accommodate at least two 2,5 mm² PVC insulated wires.

Terminal blocks shall either be of the double ended insertion type or the linked double terminal stud type with suitable provision made for mounting the terminal blocks on terminal boards or rails in rows or in strips. The insertion type is preferred.

Terminal blocks of the insertion type shall incorporate serrated clamping yokes of plated steel which clamp the wire ends onto a silver or nickel plated serrated current bar by means of plated steel clamping screws. The complete assembly shall be encased in a non-hygroscopic moulding of insulating material with high electrical and mechanical strength. Klippon type SAK 6/10 or type RSF 1 spring loaded terminals are preferred. The precise type of terminal used shall be approved by the Engineer.

Terminal boards or strips shall be mounted such as to allow sufficient space for cable tails and working on cable glands without impeding access to any other equipment.

Terminal boards or strips shall be wired such that all internal or incoming wiring enters from one side and all outgoing or external connections (multi-core cable tails) enter from the other side.

No more than two wires shall be connected to any one terminal.

At least 20% spare terminals shall be provided on all terminal boards or strips, with a minimum of ten (10) terminals.

Covers of transparent insulating material shall be fitted where necessary on terminal rows to prevent accidental contact with live equipment.

Each terminal shall be marked clearly, permanently and conspicuously and all terminal strips and boards shall be suitably identified with durable labels fixed in an approved manner.

7.3 Small Wiring

All cables and wiring shall be of approved types and sizes. Unless otherwise authorised, the minimum size of wire to be used internally in the control cubicles shall be multi-strand, 1,5 mm² copper wire.

Small wiring shall be insulated with at least 660 V grade insulation of approved material.

All wiring, external as well as internal, shall be ferrule marked to approval with suitable ferrules at both ends.

The type of ferrule marker to be used shall be to approval. Ferrule markers shall be of a durable insulating material having a reasonable glossy finish to prevent adhesion of dirt. Ferrule markers shall be marked clearly and permanently and shall not be affected by moisture or oil. Unless otherwise approved, ferrules shall be white with black marking.

If stud type terminals are employed, stranded conductors shall be terminated with tinned (not soldered) approved claw washer or lock-nuts, or with approved crimping lug. Separate washer or lugs shall be used for each conductor.

All wiring shall be taken to terminals and wires shall not be jointed or teed between terminal points.

7.4 Labels

Cubicles shall be provided complete with all labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotape labels or similar types of labels shall not be used.

All labels shall be mechanically fixed. Double sided tape or contact adhesive will not be accepted

All labelling and lettering shall be in English and shall be to the approval of the Engineer.

Fixing of labels on removable doors or lids will not be accepted.

See also Part 1.4.

7.5 Earthing

All potential free metal parts which do not form part of any electrical circuit, shall be earthed to an earth bar to be provided in the mechanism box.

8. CORONA

There shall be no audible or visible corona on the circuit-breakers as installed on site and energised to the maximum system voltage under the service conditions specified. In this connection it shall be observed that the circuit-breakers may be installed adjacent to earthed structures such as gantries with a minimum clearance of 2 400 mm in air between live metal on the circuit-breaker and earthed structures.

The circuit-breaker and conductor clamps shall be designed such that the voltage stress anywhere on the metal surface shall not exceed a value of 1,65 MV/m at sea-level with the circuit-breaker and clamps energised to maximum system voltage.

9. RADIO INTERFERENCE LEVEL

When energised to the maximum system voltage under the service conditions specified, the radio interference caused by the circuit-breakers or clamps at 1 MHz, when measured in accordance with IEC-270, shall not exceed 2 500 micro volt.

There shall be no sudden increase in the values of radio interference measured between the specified test voltage and 1,1 times the specified test voltage.

Recent test certificates shall substantiate the radio interference level claimed by the tenderer.

PART 2.1 B : 132KV OUTDOOR DISCONNECTING CIRCUIT BREAKERS

SPECIFICATION No. : DCB.60/1-08

CONTENTS

1. Scope

These specifications cover general requirements for the design, manufacture and testing of disconnecting circuit breakers.

2. Standards

The disconnecting circuit breakers shall be designed, manufactured and tested in accordance with IEC 62271-108 as well as IEC 62271-100 and IEC 62271-102.

3. Service conditions

The manufacturer shall ensure that the disconnecting circuit breakers will operate satisfactory in installations with service conditions as specified in “Ambient conditions and system data.”

4. Disconnecting circuit breaker ratings

The circuit breakers shall comply with the data indicated in “Technical data”.

5. General requirements

The disconnecting circuit breakers shall be of live-tank type for outdoor installation using SF6 gas as insulating and current extinguishing medium.

For rated voltages up to 300 kV three-pole with one common operating mechanism for the three poles is preferable.
For disconnecting circuit breakers with single pole operation local and remote three-pole operation shall be possible.
The operating mechanism should preferably be of motor charged spring type. However, other types of mechanisms can be considered, e.g. motor drives, hydraulic- and pneumatic operating mechanisms.

The manufacturer shall ensure trip-free operation.

In order to maintain system stability and reduce electrical, mechanical and thermal stresses the operating times for the switching of fault currents shall be as short as possible. Break time and closing time shall be maximum 40 ms and 70 ms respectively.

Apart from fault clearing duty the disconnecting circuit breakers shall be able to carry out special operations such as switching of reactor-banks, capacitor banks, no-load transformers and no-load transmission lines.

In order to limit the transient over voltages and surge-currents generated at intentional switching it is preferable that the constructions allow for controlled switching. Preinsertion resistors will not be accepted.

6. Design requirements

6.1 Disconnecting circuit breaker poles

The disconnecting circuit breakers should apply the SF6 single-pressure method for arc extinction.

The insulators should preferably be made of polymeric material. The polymeric insulators shall possess the same or better qualities than the corresponding porcelain insulators regarding mechanical and dielectric strength, pollution resistance etc.

It is of utmost importance that the polymeric insulation has hydrophobic quality and is insensitive to ultraviolet radiation

The high voltage terminals should be flat aluminum pads with drilling pattern in accordance with IEC-standards and preferably also NEMA-standards.

Disconnecting circuit breakers with more than one breaking element per pole shall comply with the specified data for insulation and current switching duty, without the provision of grading capacitors.

The disconnecting circuit breakers shall be provided with temperature compensated density meters for indication of low gas density. The density meters shall monitor gas pressure and provide outputs as follows, should the gas density fall to the recommended density levels for refill/low gas density and trip-close/lockout:
-Stage 1 Alarm
-Stage 2 Trip-close/Lockout

The outputs of the density meters shall include contacts for substation alarm and blocking of all operation of the disconnecting circuit breaker.

Each density meter should include a manometer, easily readable from ground level, preferably with a scale with indication of the absolute pressure in MPa.
For disconnecting circuit breakers with rated voltage of 245 kV and above each pole should be provided with a density meter.

For relief of excessive over pressure the poles should be provided with rupture discs or overpressure valves.

The disconnecting circuit breakers shall have a mechanically linked indicating system which at all times gives a clear and unambiguous representation of the position of the main contacts. The indication shall be easily readable from ground level.

6.2 Operating mechanisms

The operating mechanism should be located in a cabinet preferably made of aluminum sheets and should withstand corrosive actions due to marine and industrial environments. The cabinet shall comply with protection class IP 55 in accordance with IEC 60529.
The operating mechanism cabinets shall as a minimum contain the following features and equipment:

- A control panel with two selector switches; one for local ON -OFF operation and one with the positions LOCAL-REMOTE-DISCONNECTED. In the LOCAL position the disconnecting circuit breaker can be operated locally but shall even allow for signals from the remote protection system to trip the disconnecting circuit breaker.
  The panel shall be accessible from the ground level

- The springs shall be charged by an electric motor, preferably universal type. The motor shall be protected by a miniature circuit breaker with auxiliary contacts for indication. When the springs are charged a limit switch shall disconnect the motor-circuit.
  A mechanical or electrical indication, visible from outside the cabinet shall indicate when the springs are fully charged or un-charged.
  Under no conditions it shall be possible to perform closing or tripping operations without the particular springs being fully charged.

- The operating mechanism shall include features for charging the closing springs manually by means of a lever. When the lever is applied the motor circuit shall be de-energized.

- One closing coil and two trip coils, each trip coil having separate energy supply.
- One operation counter of the non-reversible type for recording the number of closing operations.
- Anti-pumping system
- Relays for blocking of all operation of the disconnecting circuit breaker in case the gas-pressure has dropped to the blocking level.
- Set of auxiliary contacts which assures a reliable function of the disconnecting circuit breaker and with a sufficient number of contacts available for the user. The auxiliary contacts shall be wired to the terminals in the operating mechanism cabinet.
- Heating elements; one element permanently energized and one operated by a thermostat or alternatively a humidity detector. The heating elements shall be protected by a miniature circuit breaker with auxiliary contacts.
- Terminals for connection of incoming cables for energy supply and signals. A sufficient number of free terminals shall be available for the user.
- The cabling in the cabinet should be carried out with stranded copper cable with sufficient cross-section area to withstand the currents flowing in auxiliary-, control - and motor-circuits.The cables should be marked in each end with non-vanishing marking corresponding to the indications given in the circuit diagram.

6.3 Earthing switch

The earthing switches shall be motor operated with manual operation as back-up.

The mode of operation should be the same as for the disconnecting circuit breaker, either three-pole or single pole.

The earthing switches should always be operated remotely, manual operation

should be applied only in case of failure of the voltage supply to the motor or the control system or for adjustment of the primary contacts of the earthing switch.

For personnel safety the design shall include an interlocking system which prevents closing operation of the earthing switch when the disconnecting circuit breaker is in closed position. Likewise the interlocking system shall prevent closing operation of the disconnecting circuit breaker when the earthing switch is in closed position.

6.4 Operating mechanism for earthing switch

The operating mechanism should be located in a cabinet made of aluminium sheets

with the same requirements for corrosion resistance and degree of protection as the cabinet for the circuit breaker.

The earthing switch shall be operated by a motor connected to the operating shaft, either directly or through a gear train.

The motor shall be operated locally or remotely and should be protected by a miniature circuit breaker.
When the earthing switch has reached its end positions the motor circuit shall be interrupted by a limit switch.
The mechanism shall be equipped with a mechanical lever for manual operation at maintenance and emergency operation. When the lever is adapted the motor circuit shall be isolated.

In order to avoid humidity in the cabinet a heating element shall be included.

The requirements specified for control panel, selector switches, terminals, auxiliary contacts and internal cabling in the circuit breaker operating mechanism are also valid for the operating mechanism for the earthing switch.

6.5 Cabinet for central control

In order to achieve local three-pole operation of single-pole operated disconnecting circuit breakers a central control cabinet should be provided.

The central cabinet should include selector switches for operation and position selection as described under “Operating mechanisms” above. In addition terminals should be included for connection of incoming cables for energy supply and signals and for connection to the operating mechanisms for three phases.
Otherwise the requirements for internal cabling and terminals in the operating mechanism cabinets are valid.
Alternatively, one of the operating mechanisms can be applied for central control, on condition that correct functioning of the disconnecting circuit breaker can be achieved.

6.6 Controlled switching

In order to ensure reliable operation with controlled switching the disconnecting circuit breaker shall have stable and predictable operating times.
The controlled switching device shall be of adaptive type where each controlled operation is based on feed-back information on previous operations.
For energizing of no load transformers it is preferable that consideration is taken to the remanent flux in the transformers.

Disconnecting circuit breakers applied for controlled switching shall be able to perform the specified switching operation of fault currents.

6.7 Support structures

Each disconnecting circuit breaker pole should be mounted on its separate support structure.
The support structure should be made of hot-dip galvanized steel. The thickness of the zink coating shall comply with EN-ISO 1461:1999, table NA.1, Fe/Zn115.
Alternatively, the three poles can be mounted on a common support beam.
The support structure should have sufficient height to assure personal safety in the installation when the circuit breakers are energized.

7 Tests

7.1 Type tests on disconnecting circuit breakers

The type tests should be carried out in accordance with IEC 62271-108, Clause 6. The following mandatory tests in accordance with IEC62271-100 should be carried out:

- -Terminal fault tests
- -Short-line fault tests
- -Out-of-phase switching tests
- -Capacitive current switching tests including line- charging current breaking tests and cable-charging current breaking tests in accordance with C1 requirements as per IEC62271-100, clause 6.111.9.2
- -Short time and peak current withstand tests
- -Temperature rise tests including measurement of the resistance of the main circuit
- -Dielectric tests including lightning impulse withstand tests, power frequency voltage tests and switching impulse withstand tests (when applicable).
  The lightning impulse withstand test on the isolating distance shall be carried out as a combined function test as described in IEC 62271-108, clause 6.114.
- -Radio interference tests
- -Mechanical endurance tests at ambient temperature

In addition the following tests should be carried out when applicable:

- -Capacitive current switching tests in accordance with C2-requirements as per IEC 62271-100, clause 6.111.9.1
- -Extended mechanical endurance tests in accordance with M2-requirements as per IEC 62271-100, clause 6.101.2.4
- -Switching of shunt-reactors in accordance with IEC TR 61233
- -Seismic withstand tests in accordance with IEC 61166. Alternatively calculations of the circuit breaker's withstand capability against seismic action will be accepted.

In case the disconnecting circuit breaker includes earthing switch the following tests should be performed on the switch .

- Short-time current and dynamic current test in accordance with IEC62271-102, Clause 6.5
- Mechanical endurance test in accordance with IEC62271-102, Clause 6.102.3

Type tests shall be performed in an independent accredited laboratory. If the manufacturer can show evidence by certified reports on performed type tests on the disconnecting circuit breakers, the requirements on execution of tests can be waved.

7.2 Routine tests on disconnecting circuit breakers

The disconnecting circuit breakers shall be routine tested in accordance with IEC 62271-108, Clause 7.

8 Switchgear Assemblies

8.1 Scope

These specifications cover general requirements for the design, manufacture and testing of Switchgear Assemblies.

8.2 Standards

The equipment shall fulfill the relevant requirements specified in the standard referred to for the apparatus.

8.3 Service conditions

The manufacturer shall ensure that the equipment will operate satisfactory in installations with service conditions as specified in “Ambient conditions and system data”.

8.4 Ratings

The electrical rating of the equipment shall apply to the ratings for adjacent Circuit breaker.

8.5 General requirements

Material for steel structure shall have suitable strength and shall be welded or bolted to form the structure. Steel structures shall be hot-dip galvanized. The thickness of the zink coating shall comply with EN-ISO 1461:1999, table NA.1, Fe/Zn115 Other material shall have a surface treatment of suitable description and strength for the application.
Electrical conductors shall be of cupper or aluminum-material suitable for electrical purpose.
It is preferable to combine supports and structures for different apparatus in order to minimize the number of foundations.

8.6 Design requirements

Minimum clearances shall be according to applicable standards unless the equipment is type tested as a complete unit, when other clearances can be accepted.
Safety clearances between apparatus and live parts shall be considered in order to make it possible to maintain and repair the different parts with lowest acceptable outage time.
Clamps for connection of steel structures to the earthing grid shall be included. Bolted or welded steel structures can form a part of the earthing system if it is proved that the earth fault current carrying capacity is sufficient.
Electrical conductors shall be of aluminum or copper and shall have sufficient area for normal and short circuit currents. Means to take care of occurring thermal length variations shall be installed.
Necessary clamps and connectors shall be included.

8.7 Tests

8.7.1 Type tests

Type test for the switchgear assemblies and complete bays is optional unless the manufacturer use clearances other than those stated in the applicable standard. In these cases the involved parts must be type tested.

Type tests must be performed in independent accredited laboratory. If the manufacturer can show evidence by certified reports on performed type tests on the equipment, the requirements on execution of tests can be waived.

8.7.2 Routine Tests

Routine tests for the circuit breaker and for withdrawable functions shall be carried out according to the circuit breaker specification.

9 Quality assurance

The supplier shall submit evidence that the design, manufacture and testing of the disconnecting circuit - breakers and the switchgear assemblies comply with ISO 9001 and ISO14001 including components sourced from sub-suppliers.

PART 2.2 : 132 kV GIS SWITCHGEAR

SPECIFICATION No. : GR.01/0-05

CONTENTS

Section 1 - General

1.1 Introduction

This specification provides for the supply and installation of SF_6 gas insulated switchgear (SF_6 GIS), at one or more of the substations in high voltage transmission and sub transmission networks operating at 145kV.

1.2 Extent of Main Contract Works

The contract works shall be carried out in accordance with the requirements of this specification and shall include the design, manufacture, supply, testing at works, transport to site, erection and testing, commissioning of SF_6 GIS and associated equipment, construction of the switch house, control room and complementary buildings and civil works as detailed in the specification section 4

Where specified the H.V. bushings, bus ducts, cable end units, overhead line terminations and cables shall be included in the tender and form part of the contract works.

1.3 Standard and Ratings

The switchgear and associated equipment covered for by this specification shall comply with the requirements of this specification, the particulars and guarantees stated by the tenderer in the Schedule of Particulars and Guarantees and the relevant requirements in the latest revision of the following standard specifications or publications:

ITEM	STANDARD SPECIFICATION OR PUBLICATIONS
Circuit-breakers	IEC Publication 56/BS 5311
Current Transformers	IEC Publication 185 and BS 5311
High-voltage metal-enclosed switchgear	IEC Publications 298, 517 and 694
SF6 gas	IEC Publication 376
Voltage transformers	IEC Publication 186

In particular the switchgear current rating as specified in the schedules corresponds to and ambient day time mean temperature between -5°C and + 43 C°.

The switchgear shall be designed for a maximum operating voltage of 170kV and a rated impulse withstand voltage of 650kV according to IEC. The design fault rating shall not be less than 40kA. The switchgear is to be installed in a city sub-transmission network with predominantly underground cable interconnection. Circuit breakers shall therefore be capable of interrupting line and cable charging currents of the magnitude indicated in the data schedules.

The SF_6 GIS shall be located in a permanent building which will be ventilated and maintained reasonably dust free.

Section 2 – Particular Requirements for SF 6 Metal clad Equipment

2.1 Design Concept of SF_6 GIS

It is understood that each manufacturer has his own particular SF_6 GIS design concept and it is not the purpose of the specification to impose unreasonable restrictions. However, in the interest of safety, reliability and easy service, the switchgear offered shall meet the following minimum requirements:

a. The switching station shall be modular design and capable of extension in the future by the addition of extra feeders, bus couplers, busbars, circuit breakers, disconnectors, and other switchgear components without necessarily dismantling any major parts of the equipment.

b. Where a double busbar system is specified it shall be possible to extend the switchgear by adding further feeders with at least one of the busbar systems and the existing feeders remaining in service continuously. The tenderer is required to demonstrate clearly in his submitted documents the suitability of the switchgear design in these respects.

c. Where a double busbar system is specified: In case of any internal arc fault in a busbar, busbar disconnector or sectionalizer, repair works must be possible without shutting down the complete substation and at least one busbar and the undisturbed feeders must remain in operation. In the submitted documents, clear demonstration concerning this requirement shall be given by the tenderer, i.e. sequence of repair work steps and description of necessary restrictions during these works.

d. Where a bus sectionalizer is specified: In case of any internal arc fault in a busbar, busbar disconnector or sectionalizer, repair works must be possible without shutting down the complete substation and at least one half of the substation must remain in operation. In the submitted documents, clear demonstration concerning this requirement shall be given by the tenderer, i.e. sequence of repair work steps and description of necessary restrictions during these works.

e. Automatic pressure relief shall be incorporated in the basic design of the enclosures as a precaution against explosion in the event of an internal arc fault. Pressure relief shall be by means of bursting discs with deflection devices to ensure that personnel who may be present will not be endangered.

2.2 Type Tests

Type tests shall be carried out on the metal enclosed switchgear components in accordance with the relevant standards.

The performance of the components of the switchgear shall be substantiated by test data relevant to the particular designs offered.

Evidence of type tests shall be submitted with the tender and shall include dielectric tests, temperature rise tests, short-time current tests and mechanical endurance tests together with evidence of tests to verify the making and breaking capacity of the included switching devices and other primary components. To ensure safety of operating personnel internal type tests under condition of internal arc must prove suitable design of the equipment to be installed.

2.3 Sectionalization

The switchgear gas enclosures must be sectionalized, with gas tight barriers between sections of compartments.

The section shall be so designed as to minimize the extent of plant rendered inoperative when gas pressure is reduced, either by excessive leakage or for maintenance purposes, and to minimize the quantity of gas that has to be evacuated and then recharged before and after maintaining any item of equipment.

The arrangement of gas sections or compartments shall be such that it is possible to extend existing busbars without to take out of service more than one busbar at any time. For limitation of any internal arc to the concerned bay and to reduce the extent of necessary gas works each busbar must be sectionalized bay by bay.

The electrical connections between the various gas sections shall preferably be made by means of multiple contact connectors so that electrical connections are automatically achieved when bolting one section to another. The surface of the connector fingers and conductor tubes on such connections shall be silver plated.

Each gas compartment must be independent, external gas pipe connections are not acceptable.

2.4 Support Insulators and Section Barriers

The support insulators and section barriers / insulators shall be manufactured from the highest quality material. They shall be free from all voids and the design shall be such as to reduce the electrical stresses in the insulators to a minimum. They shall also be of sufficient strength to ensure that the conductor spacing and clearances are maintained when short circuit faults occur.

Tests shall be carried out during the manufacture of the switchgear to ensure that all parts of the equipment are free of partial discharge with a partial discharge extinction voltage which is at least 10% higher than the rated voltage.

Gas section barriers including seals to the conductor and enclosure wall shall be gas-tight and shall be capable of withstanding the maximum pressure differential that could occur across the barrier, i.e. with a vacuum drawn on the one side of the barrier and on the other side, at least the maximum gas pressure that can exist under normal operating or maintenance conditions and in case of internal arc fault with a safety factor ≥ 2.0.

2.5 Gas Seals

All gas seals shall be designed to ensure that leakage rates are kept to an absolute minimum under all normal pressure, temperature, electrical load and fault conditions. All gas seals located in the flanges of the equipment enclosures shall be of the o-ring type. The material and method of sealing used and the maximum gas leakage rate that can normally be tolerated under working conditions shall be stated in the tender.

2.6 SF_6 Gas Density and Pressure

The rated pressure of the SF 6 insulating gas in the metal clad equipment shall be as low as is compatible with the requirements for electrical insulation and space limitations to reduce the effects of leaks and to ensure that there is no chance of the gas liquefying at the lowest ambient temperature. The initial gas pressure or density at the time of charging the equipment shall provide a sufficient margin above the minimum allowable operating pressure for the plant to be safely operated for a reasonably long period before recharging is necessary.

2.7 SF_6 Gas Purity

The SF_6 switchgear shall be designed for use with SF_6 gas complying with the recommendations of IEC 376 at the time of the first charging with gas. All SF 6 gas supplied as part of the contract shall comply with the requirements of IEC 376 as a minimum.

2.8 Gas Monitoring Devices

Gas density or pressure monitoring devices shall be provided for each gas compartment. The devices shall provide continuous and automatic monitoring of the state of the gas. The monitoring device shall have two alarm settings. These shall be set so that:

a. advanced warning can be given that the gas density / pressure is reducing to an unacceptable level;

b. after an urgent alarm, operative measures can be taken to immediately isolate the particular compartment electrically by tripping circuit breakers and opening disconnectors.

2.9 SF_6 Gas Treatment

Under normal operating conditions it shall not be necessary to treat the insulating SF_6 gas between major overhauls. Self sealing vacuum couplings shall, however, be provided on each individual equipment module to facilitate cycling and recharging. In all gas compartments permanent efficient filters and desiccants shall be installed to remove any residual impurities in the gas and to reduce the moisture content. The filters and desiccants shall be effective for the duration of time between major overhauls.

Notwithstanding this, the insulators in the circuit breaker shall be made of any epoxy resin composition that will resist decomposition products in contact with moisture in the circuit breaker.

External gas pipes between different gas compartments as well as any kind of centralized gas supply and/or gas control system are not acceptable.

2.10 Metal-clothing

The metal enclosures for the SF_6 gas insulated equipment modules shall be made from non-magnetic material which does not require protective painting, either internal or external, preferably aluminum alloy. The tenderer shall state the material used for his particular design. All enclosures shall be of three-phase common enclosure concept.

All flanges shall be directly connected with good metallic contact. Insulators or insulating material between the flanges shall be avoided in order to get the best electrical connection between the different enclosure modules.

The gas-filled enclosures shall conform to the pressure vessel code applied in the country of manufacturer.

2.11 Expansion Joints and Flexible Connections

If necessary, the number and position of expansion joints or flexible connections are to be determined by the manufacturer to ensure that the complete installation will not be subject to any expansion stresses which could lead to distortion or premature failure of any piece of the SF 6 equipment, support structures or foundations.

Expansion joints, flexible connections and adjustable mountings shall be provided to compensate for reasonable tolerance in the manufacture of associated equipment to which the SF_6 switchgear may be connected and to ensure that unreasonably excessive accuracy is not required when installing such equipment and constructing the associated foundations or support structures, e.g. transformers or the interconnection of isolated sections of switchgear by means of long SF_6 busbar or duct installations.

2.12 Finish of Interior Surfaces and Cleaning

The finish of interior surfaces of the metal clad enclosures shall facilitate cleaning and inspection. Any paints or other coatings that may be used shall be such that they will not deteriorate when exposed to the SF_6 gas and other vapors, arc products, etc., that may be present in the enclosures. They shall also net contain any substances which could contaminate the enclosed SF_6 gas or affect its insulating properties over a period of time.

The equipment shall be manufactured and assembled at the manufacturer's works under conditions of the utmost cleanliness.

In general, very dusty conditions will exist at all sites in the country of destination, so that wherever possible, at least complete feeders should be shipped as transport units.

Before the metal clad enclosed sections are joined together and charged with the SF_6 gas they must be thoroughly cleaned to the manufacturer's satisfaction.

2.13 Supply of SF_6 Gas

The contract shall include the supply of all SF_6 gas necessary for filling and putting into commercial operation the complete switchgear installation being supplied.

2.14 Gas Filling and Evacuating Plant

All apparatus necessary for filling evacuating, and recycling the SF_6 gas into and from the switchgear equipment shall be supplied by the contractor to enable any maintenance work to be carried out.

Where any item of the filling and evacuating apparatus is of such a weight that it cannot easily be carried by maintenance personnel, it shall be provided with facilities for lifting and moving with the overhead cranes.

The apparatus for filling, evacuating, and recycling all gases to be used shall be provided with all necessary pipes, couplings, flexible tubes and valves for coupling to the switchgear equipment.

The gas compartments shall preferably be fitted with permanent vacuum couplings through which the gas is pumped into or evacuated from the compartments.

Details of the filling and evacuating apparatus that will be supplied, as well as a description of the filling, evacuating, and recycling procedures, shall be provided at the time of tendering.

Section 3 – Particular Requirements of Primary Electrical Equipment

3.1 Circuit Breakers

3.1.1 General

The circuit breaker must be designed in accordance with the latest state of technology. Due to their advantageous switching and breaking behavior CB's of the self-blas or auto-puffer principle shall be offered.

The SF_6 metal clad circuit-breakers for the circuits detailed below shall comply with the following general requirements for circuit-breakers and the latest revisions of the relevant IEC specifications.

Circuit-breakers shall be equipped with factory assembled, spring operating mechanisms. Hydraulic pipe working on site or a common system for a substation is not acceptable.

Mechanical or pneumatically operating mechanisms are not acceptable.

The total break time from energizing the trip coil at rated control voltage to final arc extinction shall be as short as possible, but in any event not greater than 60 ms.

The circuit-breaker shall be capable of breaking all currents from zero up to the specified maximum fault current in accordance with the relevant IEC publications. Official test reports shall be submitted with the tender as evidence that the offered circuit-breaker meets the specified rating.

The breakers are to be restrike-free.

3.1.2 Auto-Reclosing

If auto-reclosing is required, the circuit-breakers shall be capable of tripping and reclosing according to the specified IEC duty cycle.

0 – 0.3s – C0 – 3 min – C0

The operating mechanisms shall have sufficient stored energy for completing an 0-C0-duty cycle with auxiliary power switched off.

3.1.3 Closing Devices

All electrically operated closing devices and any mechanism charging motors or devices shall be suitable for operation at any voltage between 110% and 85% of the nominal control voltage measured at the device terminals.

The breaker shall close correctly when an electrical closing pulse of 50 ms duration is applied to the closing solenoid.

The total wattage drawn by the closing solenoid at nominal control voltage when closing shall not exceed 500 W per circuit-breaker.

3.1.4 Tripping Devices

All electrical tripping devices shall be suitable for operation at any voltage between 110% and 85% of the nominal voltage, measured at the device terminals.

The tripping devices of a circuit-breaker, when the circuit-breaker is not carrying current, shall be capable of operating satisfactorily down to 50% of the normal control voltage, measured at the device terminals.

The total wattage drawn by the opening solenoid at nominal control voltage when tripping shall not exceed 500 W per circuit-breaker.

Each circuit-breaker shall be equipped with two shunt trip systems per mechanism. The one shut trip system shall be electrically separate from the other trip system.

An emergency hand tripping (mechanical) device shall be provided in the operating mechanism.

3.1.5 Anti-Pumping

All circuit-breaker mechanisms shall be provided with means to prevent pumping while the closing circuit remains energized, should the circuit breaker either fail to latch, or be ripped during closing due to the operation of the protective relays.

3.1.6 Operating Mechanisms

In order to reduce maintenance works and outage time pneumatic operating mechanisms will not be accepted. Hydraulic mechanisms shall be complete with all control equipment and the only external requirement for operation shall be electrical supply.

Operating oil pressure shall be maintained automatically and a high reliable device shall be provided to give indication of the available operating energy.

Low oil pressure shall be detected by some suitable method and dependent on the pressure of the oil, shall initiate one or more of the following operations:

a. start pump motor,

b. block auto-reclosing if pressure is insufficient to complete a break-make-break operation,

c. block closing if pressure is insufficient to complete a mak-break operation,

d. block tripping if pressure is insufficient to complete a break operation.

Circuit-breakers having independent operating mechanisms on each phase shall block tripping, closing and auto-reclosing of all phases if the operating oil pressure is low in one or more of the mechanisms.

Means shall be provided for detecting loss of nitrogen (or other accumulator gas) from the main accumulator(s) and, in the event of excessive loss, all hydraulic operations of the circuit-breaker shall be blocked. An alarm contact shall be provided to indicate this condition.

In any case hydraulic systems not using accumulator gas for energy storage will be preferred. Manual charging of the operating mechanism(s) shall be possible in the event of failure of the motor drive.

3.1.7 Auxiliary Switches

The minimum number of normally open and normally closed auxiliary contacts on each circuit-breaker auxiliary switch, additional to those required for control and interlocking, shall be as specified.

The fitting of additional auxiliary relays to achieve the number of auxiliary contacts required will not be acceptable.

3.1.8 Indicating Devices

Devices shall be provided to clearly indicate whether a circuit-breaker is open or closed.

Each circuit-breaker shall be provided with an operation counter per mechanism to record the number of tripping operations performed.

3.1.9 Testing Facilities

Facilities shall be provided with the switchgear to enable timing tests to be carried out after all switchgear has been charged with SF_6 gas. The facilities shall be such that it is not necessary to open up any gas section to make test connections to the circuit-breaker primary terminals.

All details of the test facilities to be provided with the switchgear shall be submitted with the tender.

3.2 Disconnectors and Earth Switches

3.2.1 General

The SF_6 metal clad disconnectors and earthing switches shall comply with the following general requirements of disconnectors and earthing switches and the latest revision of the relevant IEC publications.

All disconnectors and earthing switches shall be provided with motor-driven or motor-charged mechanisms as applicable. They shall also have facilities for manual operation and the necessary operating handles shall be provided.

Where specified, the busbar and line earthing switches shall be fully insulated and connected to earth by a removable bolted link in order that the earthing switch may be used for various test purposes. The insulation shall be capable of withstanding an applied power frequency voltage of 2kV.

In addition they must have fault making capacity and must be capable to switch capacitive currents not less than 5A at 30kV and inductive currents not less than 50A at 3kV. The continuous current carrying capacity at least should be suitable for rated busbar current and 15 min.

All main contacts, male and female, shall either be silver plated or shall have silver inserts.

3.2.2 Operating Mechanisms

Mechanisms shall be arranged either mechanically or electrically so that all three phases of any particular disconnector or earthing switch operate simultaneously.

a. Hand operation

Handles or levers shall be provided, together with all necessary operating rods and rod guides. The mechanisms shall be arranged for locking in the open or closed position.

b. Spring operation

Spring-operated mechanisms shall also be suitable for hand operation. The mechanisms shall be arranged for locking.

The mechanism of fault making earthing switches shall be equipped with a motor suitable for operation from the auxiliary supply specified, and a set of springs so arranged that energizing of the motors will cause the springs to be charged and then released. The springs in turn shall close the earthing switch.

Spring charging motors shall be suitable for operation at any voltage between 85% and 110% of the voltage specified, measured at the motor terminals.

c. Electric motor operation

Electric motor-operated mechanisms shall also be suitable for hand operation, independent of the power supply. Facilities shall be provided for locking the mechanism in each position.

For disconnectors and earthing switches having three mechanisms (i.e. one per phase) it shall be possible to electrically interlock all three phases to ensure that all three phases open or close if any one phase is to be electrically operated either by remote or local means.

3.2.3 Auxiliary Switches

Spare auxiliary switches shall be provided with the disconnectors and earthing switches as specified. The number of auxiliary switches specified shall be in addition to any switches required for interlocking, and any other control schemes being supplied as part of this contract.

3.3 Current Transformers

3.3.1 General

The current transformers shall be supplied in accordance with the following general requirements and the latest revisions of the relevant IEC publications.

Only current transformers with SF_6 high voltage insulation will be accepted.

3.3.2 Position of Current Transformers and Cores, Ratios and Characteristics

The position of the current transformers relative to the circuit-breakers, disconnectors and earthing switches shall be as detailed in the attached relevant Station Electric Diagram.

The number, rating, ratio, accuracy class, etc. for the individual current transformer secondary cores shall be as specified.

Where multi-ratio current transformers are required, the various ratios shall be obtained by changing the effective number of turns on the secondary winding.

3.3.3 Rating and diagram Plates

Rating and diagram plates shall be provided. The information to be supplied on each plate shall be as specified in the relevant IEC specification, which shall be given for the tapping for which the rated performance is specified and for each transformer core.

3.3.4 Secondary Terminals and Earthing

The beginning and end of each secondary winding and all secondary taps shall be wired to suitable terminals accommodated in a terminal box mounted directly on the current transformer section of the SF_6 switchgear.

All terminals shall be stamped or otherwise marked to correspond with the marking on the diagram plate.

Provision shall be made for earthing of the secondary windings inside the terminal box.

3.4 Voltage Transformers

3.4.1 General

The voltage transformers shall be supplied in accordance with the following general requirements and the latest revisions of the relevant IEC specifications.

The voltage transformers are to be connected as shown in the attached Station Electric Diagram.

Voltage transformers must be of the electromagnetic type, and with SF_6 gas foil insulation.

3.4.2 Ratios and Characteristics

The rating, ratio, accuracy class, connection, etc for the voltage transformers shall be as specified.

3.4.3 Rating and Diagram Plates

Rating and diagram plates shall be provided complying with the requirements of the IEC standards.

3.4.4 Secondary Terminals, Earthing and Fuses

The beginning and end of each secondary winding and all secondary taps shall be wired to suitable terminals accommodated in a terminal box mounted directly on the voltage transformer section of the SF_6 switchgear.

All terminals shall be stamped or otherwise marked to correspond with the marking on the diagram plate.

Provision shall be made for earthing of the secondary windings inside the terminal box.

3.5 Bushings

3.5.1 General

Outdoor bushings, for the connection of conventional external conductors to the SF_6 metal clad switchgear, shall be provided where specified.

Bushings shall generally be in accordance with the requirements of IEC.

Where specified, the SF_6 switchgear shall be connected via SF_6 insulated ducting directly to transformers and reactors. The basic bushings will be supplied by the transformer or reactor contractor as part of his contract.

The clamps or contact for connecting the switchgear conductor to the transformer or reactor busing and the metal clad enclosure coupling onto the busing flange shall be manufactured as part of this contract. The dimensional and clearance requirements for the metal clad enclosure will be in the responsibility of the busing designer/manufacturer in order that the design of the enclosure may be completed. The switchgear manufacturer shall in turn provide the busing designer / manufacturer with the necessary design details for the bushing flange to ensure that a suitable gastight connection for the metal clad enclosure can be obtained.

The switchgear contractor shall negotiate and collaborate directly with the transformer and reactor manufacturers when designing the above items of equipment. The names of the transformer and reactor manufacturers will be advised after the placing of the contract.

3.5.2 Insulation Levels and Creepage Distances

All bushings shall have an impulse and power frequency withstand level that is higher than or equal to the level specified. The levels are applicable to normal sea level atmospheric conditions.

The creepage distance over the external surface of outdoor bushings shall not be less than specified.

3.5.3 Bushing Types and Fittings

Bushings being SF_6 insulated will be preferred to the conventional condenser types. Due to the better mechanical and electrical behavior only a composite silicon bushing will be acceptable Bushing arc gaps are not required.

The terminals on the outdoor bushings shall be a solid circular stem with the dimensions specified. Stems shall be either copper or aluminum and the copper stems shall be electro tinned. The clamps for connecting the outdoor conductor(s) to the stem will be provided by others.

3.5.4 Mechanical Forces on Bushing Terminals

Outdoor bushings must be capable of withstanding a cantilever force applied to the terminal of at least 5000 N.

3.6 H.V. Power Cable Circuits

3.6.1 General

The following requirements are applicable to the switchgear equipment where the H.V. power cables are terminated directly in the SF_6 metal clad switchgear using cable sealing ends designed for use in SF_6 gas.

The H.V. power cables will be supplied and laid under other contracts, the type and size of cable being as specified. The final connection of the H.V. cable circuits in the switch house will be by means of individual single-phase cables, with one cable per phase.

All cable end modules shall be suitable for connecting single core, low pressure oil filled and XLPE cables for 170kV maximum continuous voltage and a core cross section up to 2000 mm^2. In case of XLPE cables a pluggable cable sealing termination, consisting of a gastight socket insulator and a completely dry, prefabricated cable plug connector, will be required. Exact details of the type and size of cable to be connected will be communicated to the supplier later. Where the H.V. power cable does not form part of the switchgear, the tenderer shall include in his offer the epoxy resin cone for fitting into the cable end unit.

3.6.2 Cable Test Facilities

The cable end unit design shall include a facility for H.V. DC testing of the connected power cable on site. The tenderer shall explain the method proposed. Where line disconnectors are provided, only the disconnector shall be opened during cable tests. Removable bolted links or similar connections will be accepted only in case of transformer feeders without line connectors. Design of the link and connections shall ensure that when removed the resulting gap can withstand the impulse and power frequency test voltages applicable to the switchgear and the cable H.V. DC test voltage, for a period of 15 minutes, when the chamber is filled to the minimum rated working SF 6 gas density or pressure.

3.7 Test Facilities for Switchgear Testing

After erection the complete switchgear shall be H.V. power frequency tested with a voltage level which is at least 80% of the rated insulation level.
The supplier is requested to provide all necessary test facilities and equipment, i.e. test bushing, test adapter, test transformer or resonant test set etc.

Section 4 – Secondary Electrical Equipment

4.1 Electrical Protection is specified under Section 4 par 12

4.1.1 Current Transformers Requirements

Current transformer are specified in the particulars and guarantees

The rating of the current transformer will be calculated in case of order under consideration of actual short circuit power, secondary wiring (length, cross-section) and relay burden.

This ensures correct operation of all protection schemes even under worst short circuit conditions.

If multiratio CT's are used, the calculation must be done at the actual tapping and only this tapping will be wired to the marshalling kiosk, it shall not necessary to wire all tappings to separate terminal blocks.

4.1.2 Test Facilities

All protective relays shall be equipped with test blocks or similar if no other test facilities (such as automatic testing units) are provided.

Suitable testing equipment (current injection sets, timers, meters etc) shall be offered optionally.

4.1.3 Protection Scheme Layout

The final layout of the protection scheme shall be approved by the Authority.

4.2 Local Control / Marshalling Kiosks

A local control and marshalling kiosk shall be provided with each primary circuit.

Each kiosk shall contain the local control and indication devices for the associated SF_6 circuit-breakers, disconnectors and earthing switches and the DC. Protection fuses, links and supervisory relays specified. The kiosk shall also be a marshalling or junction point for all protection, control, alarm, indication and DC. power supply circuits from the associated SF_6 circuit-breakers, disconnectors, earthing switches and gas monitoring, alarm and protection system. All cables being provided by the Authority will be terminated in the marshalling kiosks.

For the above facilities the local control/marshalling kiosk shall generally be provided with the following features:

a. A mimic diagram, on or adjacent to which shall be mounted the indicating switches and local / off / remote switches.

b. Any interposing relays associated with the circuit-breaker, disconnector etc. control switches.

c. The alarm and indication equipment specified.

d. Fuses and links. These shall be mounted in the interior of the local control/marshalling kiosk.

e. Cable terminal blocks for terminating and marshalling auxiliary supply cables, control, indication and alarm circuit cables from the switchgear and the remote control room.

A general arrangement drawing of the kiosk showing the position of all important features and the mounting position shall be submitted at the tendering stage.

All cable connections between control cubicle and circuit-breakers, disconnectors and earthing switches shall be by prefabricated multicore cables with multi-point plug-in connections on both ends.

The local control and marshalling kiosk will be installed indoors but care must be taken with the design to ensure that all kiosks are drip and splash proof. The kiosks shall also be dust and vermin proof.

4.3 AC Supplies and Circuits

410 V, 3-phase, 4-wire AC supplies will be derived from an AC distribution panel to be provided by the Authority in the switch house.

The normal maximum and minimum voltages that will occur in the supply are as specified. All equipment supplied shall be capable of running continuously or switching the AC current within the range of the normal maximum and minimum voltages specified.

4.4 DC Supplies and Circuits

DC supplies 110V will be provided by others for all control, protection, interlocking, alarm, indication and power supply circuits. The normal maximum and minimum voltage levels that will occur on the supply are specified.

Each control and protection panel to be provided by the Authority will have its own separately fused supply from the substation DC distribution board.

At least one single fused outlet from the substation DC distribution board will be provided for each local control and marshalling kiosk.

The design of all circuits must be such that separately fused or sub fused circuits are always kept electrically separate.

Section 5 – Inspection and maintenance

5.1 General

Due to the fact that the operational integrity of the fully metal clad SF_6 insulated switchgear is not subject to external influences, such as pollution, moisture, dust, etc. the switchgear should be practically maintenance-free.

Inspection should be made not often than every five years. During inspection it must be not necessary to open the switchgear enclosures, thus avoiding interruption of substation operations. Inspection involves as maximum checking the SF_6 gas densities or pressures, checking of hydraulic fluids and lubrication of the moving components in the operating mechanisms outside of the enclosure. Functional testing of the close and trip coils, auxiliary switches, pressure and control switches etc. should also be made.

As minimum the following maintenance period can be accepted:

- circuit breaker:	5000 closing and opening or 20 interruptions at max current
- disconnectors:	5000 closing and opening operations
- fast acting earthing switch:	2000 closing and opening operations or 2 making operations onto max rated fault current

Section 6 – Switch House Building

6.1 General

The main contractor will provide a switch house building of reinforced concrete or steel frame construction with brick or sheet steel clothing in which the SF_6 switchgear shall be installed.

The proposed arrangement of the switch house building and the positions(s) in which the switchgear shall be installed relative to lines, transformers and reactors, cable circuits and any other switchgear of other voltage ratings, are as shown in the general arrangement plan and section drawings(s) attached to the specification.

The width of the building and overall height will be as on the attached plan and section drawings. The overall height of the building shall allow for an overhead traveling crane.

6.2 Design Information to be Provided by the Contractor

The contractor shall provide a complete floor plan detailing the fixing positions, level and size of fixing bolt pockets and foundation rails required for all equipment to be installed under this contract. Drawings giving similar details for any fixing positions, bolt hole pockets and apertures in the walls of the switch house shall also be provided.

All static and dynamic loads plus dimensional tolerances shall be given on these drawings to enable the civil work designs to be completed.

The information must be provided in due time to ensure that the civil design work can be completed and the switch house and foundations built and finished in time for access to be granted as required for the erection of the SF_6 switchgear and associated equipment.

PART 3.1 : 132KV DISCONNECTORS & EARTHING SWITCHES

SPECIFICATION No. : IS.60/1-97 – Rev 2/B

CONTENTS

1. GENERAL

The specification covers disconnectors employing rotating insulators in the following categories of horizontal isolation. This type of disconnector shall have contacts of the free-entry / free exit type.

Double-break centre rotating post.

Single side-break.

Single centre-break.

Pantograph isolators or other isolators designed for vertical isolation such as the swinging arm and vertical arm type are also covered by this specification.

This specification also includes supporting steel structures, and isolator operating mechanisms.

2. STANDARDS

Equipment offered under this specification shall comply with:

a) IEC Publication 129 and this specification;

b) the particulars and guarantees stated in the tender forms; and

c) Rationalised User Specification NRS 031:1993 except where amended or amplified by this Specification. Pantograph isolators shall also comply with the requirements of NRS 031:1993 where applicable.

3. SERVICE CONDITIONS

Service conditions as defined in clause 1.3 of NRS 031:1993 shall apply with the exceptions of the applicable service conditions as defined in Part 1.1.

4. RATINGS

Equipment ratings are stated in Form 3A.

5. DRIVING MECHANISMS

Disconnectors shall be electrically operated unless otherwise specified in Form A. It shall be possible to operate the disconnectors with a manual crank handle in the event of motor failure or for maintenance. Insertion of the crank handle, shall “ make “ an auxiliary switch contact for control and indication purposes. Earthing switches shall be hand operated.

Should a flap be used to cover the manual crank handle opening, provision for remote indication shall be made by means of a switch wired out to terminals in the mechanism box.

During manual operation it shall not be possible to operate the disconnector electrically. (Local or remote)

Visual indication of the position of the isolator shall be provided in an approved position utilising green (O) for open and Red (I) for closed

6. INTERLOCKING

In addition to the interlocking between the disconnectors and the earthing switches on the same structure as called for in NRS 031:1993 it is necessary to provide interlocking with disconnectors and/or other equipment in remote positions. This remote interlocking may comprise mechanical sequential interlocking by means of suitable keys or electrical interlocking or a combination of both.

Earth switches shall be mechanically interlocked to prevent their closing while the disconnectors are closed. Similarly, disconnectors shall be mechanically interlocked to prevent their being closed if an earth switch is closed.

7. MECHANICAL KEY INTERLOCKS

To facilitate interlocking with other equipment, all mechanisms shall be designed to accommodate mechanical sequential key interlocks and shall be supplied fitted with such number and types of key interlocks as may be called for in Form A or on such drawings as may be issued with the Enquiry. These shall be to the approval of the Engineer.

When called for, suitable key interlocks shall be fitted to approval. Mechanical sequential interlocking shall positively prevent isolator or earth switch operation (as may be required) in the locked position by the action of a suitable bolt. Should the bolt of the interlock not be robust enough to withstand the strain that might be imposed thereon, suitable robust steel bolts or latches shall be controlled by the sequential interlocks.

Sequential key interlocks shall operate smoothly and without any difficulty. Keys and key interlocks shall be of weather-proof construction and shall be corrosion resistant. Key interlocks shall preferably be mounted inside the mechanism box.

When called for in drawings or elsewhere in the enquiry key type interlocks shall be fitted with one pair of normally open and one pair of normally closed contacts changing over when the key is turned to release it.

The contacts shall be suitable for accommodating 1,5^{2}mm stranded copper wire and shall be capable of making, breaking and carrying continuously a current of 10 A at 110 V DC. The above contacts shall be wired to suitable terminal blocks in the mechanism box. When mounted externally, the contacts shall be housed in a suitable weather-proof box (IP54) with gland plate.

8. ELECTRICAL INTERLOCKS

The operating mechanisms of hand-operated disconnectors and earth switches shall be fitted with an electro-magnetically operated locking device, such as a bolt or latch which engages with a cam, or slot or hole in a disc attached to the main drive shaft or drive arm. The mechanical interlock shall be positively displaced by the mechanism, and shall not depend on spring force for operation.

The electrically operated locking device shall be used to lock the switch in the open and closed positions and when de-energised shall positively prevent operation by hand.

The electrical locking device shall be of robust construction and shall operate smoothly and without any difficulty even after several attempts to manually operate the switch with the locking device engaged.

The solenoid of the electrical locking device shall be designed to operate from a nominal 110 V DC interlock supply but it shall operate satisfactorily at any voltage between limits of 80% to 120% of the nominal supply voltage.

The electromagnetic locking device shall be operated electrically by means of a robust push-button wired as shown in the Enquiry drawing. Visual indication to the approval of the Engineer (e.g. a lamp) shall be provided to positively indicate whether the mechanism is locked or freed for operation. The push-button shall be located such that it is accessible by one hand while operating the handle with the other.

Provision shall be made for a “Local - Off - Remote” selector switch to select local or remote closing or opening of the disconnector. Spare contacts shall be provided on this switch wired out to terminals for remote indication of the switch position.

Provision shall also be made by means of push buttons for the electrical closing and opening of the isolator in the local position.

During manual operation it shall not be possible to operate the disconnector electrically

Provision shall be made by means of a door switch wired to terminals for remote indication of it's position. (non urgent alarm)

9. SMALL WIRING

The wiring shall be strictly in accordance with the general requirements in Part 1 of the Technical Specification.

10. LABELS

Refer to Technical Requirements Part 1.4.

11. MULTI-CORE TERMINALS

The multi-core terminals shall be strictly in accordance with the general requirements in Part 1 of the Technical Specification.

12. AUXILIARY CONTACTS

The auxiliary contacts required in the isolator mechanism box shall exclude the contacts required for the internal motor control and operation and are depicted in the schedule of particulars and guarantees.

13. OPERATING AND MAINTENANCE INSTRUCTIONS

Clear and detailed documentation shall be submitted for the operation, maintenance and setting up of the disconnectors and earthing switches.

PART 4.1 : 132KV SURGE DIVERTORS & INSULATING BASES

SPECIFICATION No. : SD.60/0-97 – Rev 1/A

CONTENTS

1. STANDARDS

The surge diverters shall comply with the requirements of this specification, (see Section III Part 1.3) the particulars of guarantees stated in the attached Schedules and the relevant requirements of the latest revision of IEC 99/1.

2. GENERAL

The metal oxide gapless surge diverters are required for protecting step-down transformers, switchgear and associated equipment in an outdoor switchyard fed by 132 kV overhead busbars and on 132 kV transmission lines.

The surge diverters will be located in an area prone to severe lightning and light pollution levels.

This tender is based on surge diverters of gapless ZnO (zinc oxide) type.

The surge diverters shall be of the heavy duty station type.

The surge diverters shall be supplied complete and suitable for outdoor mounting on steel structures, including structures and foundations.

The surge diverters shall be supplied complete with all bolts, nuts and washers required for mounting. The thickness of steel sections on which the equipment is to be mounted shall be taken as 12 mm.

The rated impulse crest discharge current shall be as specified.

3. HOUSING

The surge diverter housing shall be constructed of porcelain.

The porcelain shall be sound, free from defects and shall be thoroughly vitrified. The glaze, which shall not be depended upon for insulation, shall be smooth and hard, of a uniform shade of brown and shall completely cover all exposed parts of the porcelain.

The sum of the creepage distances over the external insulation of the diverter units shall coincide with light pollution levels.

All necessary bolts, nuts and washers required for bolting the surge diverter units together shall be supplied with the units.

4. INSULATED BASE

Insulating bases are not needed.

5. GRADING RINGS

Surge diverters with rated voltages of more than 120 kV shall be fitted with grading rings if required.

The Tenderer shall state his recommendation.

6. SURGE DIVERTER TERMINALS AND CLAMPS

The top terminal of surge diverters having a rated voltage of 132 kV, shall be provided with an approved clamp of the bolted type suitable for accommodating a stranded circular aluminium conductor with a nominal overall diameter of 25 mm. If necessary this clamp shall be of the bi-metallic type to prevent electro-galvanic action between dissimilar metals.

All top clamps shall be arranged for vertical approach.

7. BOTTOM OR EARTH TERMINAL

The bottom or earth clamp of all surge diverters shall be suitable to accommodate galvanised steel earthing strap equivalent to a 50 mm by 3 mm flat copper strap. Unless otherwise agreed the clamp shall be of the four bolt fixing type and shall be tinned or cadmium-plated.

The earth terminal shall preferably be arranged for horizontal approach.

All terminals and clamps shall have a minimum short time current rating of 40 kA for one second.

8. DISCHARGE COUNTERS

Discharge counters are not needed.

PART 4.2 : 33 kV SURGE DIVERTERS AND INSULATING BASES

SPECIFICATION No. : SD.40/0-97

CONTENTS

1. STANDARDS

The surge diverters shall comply with the requirements of this specification, (see Section III Part1.3) the particulars of guarantees stated in the attached Schedules and the relevant requirements of the latest revision of IEC 99/1.

2. GENERAL

The metal oxide gapless surge diverters are required for protecting step-down transformers, switchgear and associated equipment in an outdoor switchyard fed by 33 kV overhead busbars and on 33 kV transmission lines.

The surge diverters will be located in an area prone to severe lightning and light pollution levels.

This tender is based on surge diverters of gapless ZnO (zinc oxide) type.

The surge diverters shall be of the heavy duty station type.

The surge diverters shall be supplied complete and suitable for outdoor mounting on steel structures, including structures and foundations.

The surge diverters shall be supplied complete with all bolts, nuts and washers required for mounting. The thickness of steel sections on which the equipment is to be mounted shall be taken as 12 mm.

The rated impulse crest discharge current shall be as specified.

3. HOUSING

The surge diverter housing shall be constructed of porcelain.

The porcelain shall be sound, free from defects and shall be thoroughly vitrified. The glaze, which shall not be depended upon for insulation, shall be smooth and hard, of a uniform shade of brown and shall completely cover all exposed parts of the porcelain.

The sum of the creepage distances over the external insulation of the diverter units shall coincide with light pollution levels.

All necessary bolts, nuts and washers required for bolting the surge diverter units together shall be supplied with the units.

4. INSULATED BASE

Insulating bases are not needed.

5. SURGE DIVERTER TERMINALS AND CLAMPS

The top terminal of surge diverters having a rated voltage of 33 kV, shall be provided with an approved clamp of the bolted type suitable for accommodating a stranded circular aluminium conductor with a nominal overall diameter of 25 mm. If necessary this clamp shall be of the bi-metallic type to prevent electro-galvanic action between dissimilar metals.

All top clamps shall be arranged for vertical approach.

6. BOTTOM OR EARTH TERMINAL

The bottom or earth clamp of all surge diverters shall be suitable to accommodate galvanised steel earthing strap equivalent to a 50 mm by 3 mm flat copper strap. Unless otherwise agreed the clamp shall be of the four bolt fixing type and shall be tinned or cadmium-plated.

The earth terminal shall preferably be arranged for horizontal approach.

All terminals and clamps shall have a minimum short time current rating of 20 kA for one second.

7. DISCHARGE COUNTERS

Discharge counters are not needed.

PART 5.1 : VOLTAGE TRANSFORMERS 132KV

SPECIFICATION No. : SUPPLEMENTARY SPECIFICATION

CONTENTS

1. SCOPE

This Supplementary Specification and the NRS specification indicated in clause 3 cover the manufacture, supply, test and delivery of type tested and works manufactured 132 kV electromagnetic Voltage Transformers.

2. DEFINITIONS

For the purpose of this specification the definitions referred to in clause 3 of NRS 030:1993 or latest apply.

3. STANDARDS

The voltage transformers shall comply with the requirements of this Supplementary Specification, the particulars and guarantees stated by the tenderer in the Schedule of Particulars and Guarantees, the relevant requirements of NRS 030:1993, First Edition : Electromagnetic Voltage Transformers, and the relevant requirements of the Standards referred to in this NRS specification. Tenderers must ensure that they obtain the correct revisions of these NRS specifications and prepare their submissions accordingly. Where applicable, the requirements of this NRS specification and referred standards shall be amended, augmented or qualified by the requirements of this Supplementary Specification, which reflect requirements particular to Tshwane's standards, and which shall take precedence over the NRS specification and referred standards.

NRS 030 is presently under revision, and is based on a set of defined standards, which may have been revised or amended. The supplier may wish to incorporate some of the changes into his equipment, for the benefit of both the supplier and the purchaser. The Supplier is therefore requested to review the latest versions and amendments and to incorporate these where possible and agreeable to both parties.

4. DELIVERY AND OFFLOADING

The price for the voltage transformers shall include the cost of delivery and offloading on site.

PART 5.2 : CURRENT TRANSFORMERS 132KV

SPECIFICATION No. : SUPPLEMENTARY SPECIFICATION

CONTENTS

1. SCOPE

This Supplementary Specification and the NRS specification indicated in clause 3 cover the supply, test and delivery of type tested and works manufactured 132 kV Current Transformers for outdoor use.

2. DEFINITIONS

For the purpose of this specification the definitions referred to in clause 3 of NRS 029:1993 apply.

3. STANDARDS

The current transformers shall comply with the requirements of this Supplementary Specification, the particulars and guarantees stated by the tenderer in the Schedule of Particulars and Guarantees, the relevant requirements of NRS 029:1993, First Edition : Outdoor Type Current Transformers, and the relevant requirements of the Standards referred to in this NRS specification. Tenderers must ensure that they obtain the correct revisions of these NRS specifications and prepare their submissions accordingly. Where applicable, the requirements of this NRS specification and referred standards shall be amended, augmented or qualified by the requirements of this Supplementary Specification, which reflect requirements particular to Tshwane's standards, and which shall take precedence over the NRS specification and referred standards

NRS 029 is presently under revision, and is based on a set of defined standards, which may have been revised or amended. The supplier may wish to incorporate some of the changes into his equipment, for the benefit of both the supplier and the purchaser. The Supplier is therefore requested to review the latest versions and amendments and to incorporate these where possible and agreeable to both parties.

The BS 3938 standard specification for current transformers has been superseded by BS 7626, which is technically identical to IEC 185 (or, as it has been renumbered, IEC 60185). However, since the NRS 003 still indicates BS 3938, and the new current transformers have to match certain existing ones, some current transformers will still be specified accordingly. (SABS IEC 60185:1987 has been replaced by SABS IEC 60044-1:1996).

4. DELIVERY AND OFFLOADING

The price for the current transformers shall include the cost of delivery and offloading on site.

PART 6.1 : 132 KV CONNECTIONS & CONNECTION CLAMPS

SPECIFICATION No. : BR.60/0-97

CONTENTS

1. BUSBARS, CONNECTIONS AND CONNECTION CLAMPS

The busbar arrangement shall be of the low-profile type.

Busbars and connections shall be high conductivity copper or aluminium and shall be stranded or tubular as required.

The current ratings shall be suitable for the application. The minimum outer diameter shall be 80mm where tubing is used.

All clamps and connectors shall have a current carrying capacity not less than conductors joined.

All clamps shall be specifically designed for the particular application such as to avoid deformation of the conductors.

The loading details and factors of safety for all conductors and connections shall comply to the relevant specification. The successful Tenderer shall prove to the Engineer how the static and dynamic strengths of the equipment to a safety factor of 2.5.

The strength of the conductors shall be such that they and the various insulators will withstand the maximum dynamic forces exerted by short circuit currents, wind and other loading with a safety factor of at least 2,5. The contractor shall prove to the Engineer how the figures were derived.

Solid busbars shall be of sufficient dimension and suitably supported so that the sag will not exceed normally acceptable values. The Tenderer shall indicate what these values are.

Strain clamps for use with disc insulator strings shall be made of certified iron and steel and the minimum ultimate strength shall suit the loading details and factors and shall comply to the relevant specification.

All ferrous parts shall be hot dip galvanised.

Rigid busbar shall be clamped at one end only and have flexible connections at the other end to allow for expansion and contraction.

All sliding clamps must be provided with potensial clips.

The successful Tenderer will have to prove his electrical and mechanical design to the approval of the Engineer.

2. LABELLING

For open busbar, phase identification discs shall be fitted where practical, i.e. for strung busbar on the gantry beam below every string insulator set and for solid busbar on post insulator support pedestals. These shall be 150 mm diameter discs and shall be coloured red, yellow or blue according to phase and shall be fitted to be visible from ground level.

All such labelling shall be securely fixed to the satisfaction of the Engineer.

For solid busbar, the phase colours shall be painted directly on the busbar to the satisfaction of the Engineer.

PART 7.1 : 132KV & 33KV INSULATORS

SPECIFICATION No. : IN.60/0-97

CONTENTS

1. INSULATORS

1.1 String Insulators

String insulators shall be of composite material and shall be designed, manufactured and tested in accordance with the latest revisions and amendments of IEC (Secretariat) 65-Draft: Tests on composite insulators for AC overhead lines with nominal voltages greater than 1000 V.

The design shall be such as to ensure that the core is totally encapsulated and fully sealed from end by an insulating material. This requirement is to ensure that the ingress of moisture does not occur through environmental conditions.

The end fittings shall be of the ball and socket type to IEC 120 and the security clips shall be stainless type "W" to I.E.C. 372.

All ferrous parts shall be hot dip galvanised.

All accessories, including strain clamps, suspension clamps, arcing horns, turnbuckles, yoke plates, etc. shall be manufactured to SABS 178 - 1970.

1.2 Post Type Insulators

All post type insulators of the same voltage rating shall be identical, whether used for the support of busbars or as a part of other equipment.

The post insulators shall be capable of withstanding any shock loading which may be encountered in service and the deflection under the conditions of assumed maximum working loads shall not result in the misalignment of the contacts of isolators.

PART 8.1 : 11KV CABLE CONNECTIONS BETWEEN 20/35/40MV TRANSFORMER & 11KV SWITCHGEAR

SPECIFICATION No : PC.20/0-97 – Rev 2/A

CONTENTS

The following procedures shall apply unless specific instructions to the contrary are issued.

1. CABLE TYPE AND SIZE

1.1 20MVA Transformers

11kV, 630 mm² copper conductor, single core, non drain PILC and served cable.

Six cables connected two in parallel per phase, per transformer circuit.

1.2 35MVA Transformers

11kV, 630 mm² copper conductor, single core, non drain PILC and served cable.

Nine cables connected three in parallel per phase, per transformer circuit.

1.3 40MVA Transformers

11kV, 630 mm² copper conductor, single core, non drain PILC and served cable.

Nine cables connected three in parallel per phase, per transformer circuit.

2. INSULATED CABLE GLANDS

The transformer and switch-gear cable terminating boxes are provided with insulated cable glands. Care must be taken to check that the lead sheath passing through the gland plate is at least 5 mm clear of the gland plate.

If clearance is insufficient steps must be taken to increase the clearance or the lead sheath shall be insulated with three half-lapped layers of empire tape.

3. BONDING AND EARTHING

Single point bonding shall be employed on each trefoil group (red, yellow, blue) of cables. (Maximum cable runs do not exceed 150 m).

Near the 11kV switch-gear at the most convenient point, which may or may not be in the ground, split each trefoil group and make a trefoil bond by wrapping with lead sheath having a minimum cross-sectional area equal to the cross section of one cable sheath.

(Use redundant cable sheath), and plumbing to the cable sheaths.

Bond all trefoil earths together and earth to the local substation earth using 70 mm² minimum size bare copper conductor.

Where such bonds are made in the ground they shall be sealed with bituminous Hessian wrap basted on and protected with adhesive PVC tape.

a) N.B. Do not bond directly onto the cable glands!

b) The sheaths must be insulated from each other except at the single bond point.

4. CABLE LAID DIRECT IN THE GROUND

4.1 Laying, Bedding, Slabbing and Back-Filling

4.1.1 Depth

The depth of laying over the top of the cables shall exceed 0,8 m unless otherwise specified.

4.1.2 Bedding

An 80 mm deep layer of selected bedding soil, screened if necessary, shall be placed in the clean cable trench before cable is laid.

4.1.3 Covering (Blinding)

Immediately after laying the cable trench shall be filled with the same selected screened soil to a depth of 80 mm above the cable.

4.1.4 Slabbing

Approved concrete cable slabs shall then be placed to overlap the outside edges of cable groups by at least 75 mm .

4.1.5 Back-filling

Final back-filling shall be reasonably free of stones and foreign matter and shall be consolidated in layers.

4.2 Selected Bedding Soil

A soil thermal resistivity of g = 1,2 C m/W has been assumed for the required cable rating.

If the local soil is not judged to be good thermal conducting material suitable for bedding and blinding an approved quality of imported soil shall be used.

Sandy or granular soils are generally poor thermal conductors whilst soils exhibiting a degree of "fattiness" are generally satisfactory.

4.3 Cable Formation

Trefoil touching (A red, yellow and blue phase in each trefoil group).

Trefoil Group Spacing Centres for each and Adjacent Transformer Circuits 450 mm .

Spacing Between Each Transformer Circuit and Adjacent Transformer Circuits:

a) Transformers of the same substation stage

   As far as possible circuits shall be separated by at least 1 250 mm clearance between the nearest cables of each circuit.

   Where absolutely necessary this clearance can be reduced to 500 mm.

b) Transformers of Different Substation stages different routes and maximum separation shall be used as far as possible.

   Where absolutely necessary, except where circuits cross each other, 1 750 mm clearance between the nearest cables of adjacent circuits must be maintained.

Crossings of transformer circuits :

a) Crossings involving a transformer circuit and any other cables shall be as near to 90° as possible and shall provide a vertical separation of at least 350 mm.

4.4 Cables in Pipe Ducts

Pipe ducts shall be avoided unless absolutely necessary when a maximum length of 2,0 m in pipe may be permitted.

Eg. : Through a concrete foundation.

5. CABLES IN AIR IN CABLE TUNNELS

5.1 Cable Formation

Trefoil touching (A red, yellow and blue phase in each trefoil group).

5.2 Trefoil Group Spacing

Centres : 200 mm.

5.3 Vertical Clearance

A vertical clearance of at least 200 mm shall be maintained to all other cables and to the floor and ceiling, except for short distances at crossing points.

6. FIRE PROTECTION ADJACENT TO TRANSFORMERS AND SWITCH-GEAR

The single core transformer cables may have either a compounded fibrous serving which may be highly inflammable or a PVC serving.

6.1 Compound Fibrous Serving

If the serving is of flammable material such as bituminised Hessian or jute it shall be stripped from the single core cable tails inside the switch chamber and adjacent to the transformer, except where it is underground, and the lead sheath shall be cleared of compound and re-served with fire-proof material such as asbestos tape.

6.2 PVC Serving

Do not strip PVC servings except where necessary for jointing or bonding.

PART 8.2 : UNDERGROUND PVC-INSULATED MULTI-CORE CONTROL CABLE

SPECIFICATION No. : CC.01/0-97

CONTENTS

1. SCOPE

This specification covers multi-core, general purpose control cable having PVC-insulated stranded copper conductors, impermeable PVC-sheath, single wire armouring and an impermeable and fully insulating PVC-over sheath.

2. STANDARDS

The cable shall be manufactured to comply strictly with the appropriate requirements laid down in the latest version of SABS-150.

3. OPERATING CONDITIONS

The cable is intended for use in switchgear and transformer control circuits as well as for protection and indication circuitry.

The cable will normally be laid directly in the ground or in open cable ducts along with power cables. In certain instances it can be expected that the cable will be continuously submerged under seepage water.

The cable shall be suitable for operation at a continuous maximum temperature of 65°C down to a continuous minimum temperature of minus 5°C.

4. VOLTAGE AND FREQUENCY

The cable will be used for protection, remote control, indication and signalling circuits and the cable cores may be subjected to a maximum working voltage of 230V direct current or 400/230V, 50Hz, alternating current between cores.

The control cable shall have an assigned voltage rating of 600/1 000V in accordance with SABS-150 - 1970.

5. CONDUCTORS

The stranded conductor of each core shall have a rated conductor cross-sectional area of 2,5 or 4 mm^2 as specified, and shall consist of at least seven un-tinned plain annealed copper wires, and shall comply with the requirements of SABS-150.

6. INSULATION OF CONDUCTORS

The core dielectric shall consist of homogeneous, impermeable PVC in full compliance with all the relevant requirements of SABS-150.

The thickness of insulation, when measured in accordance with SABS-150, Clause 9.1, shall not be less than the appropriate value laid down in Table L.

7. CORE IDENTIFICATION

Core identification shall be such that each core in the cable can be identified no matter where the cable is cut. Core identification shall be permanent, clear, distinctive and shall not have any deleterious effect on the core insulation. Preference is given to core identification by means of contrasting printed numbers at frequent intervals not exceeding 75 mm .

Tenderers may wish to offer alternative methods of core identification, such as colouring or colour coding, in which case full particulars of their proposals for core identification shall be submitted with their tenders for approval.

8. LAYING UP OF CORES

The insulated cable cores shall be laid-up together in accordance with SABS-150 - 1970, Clause 5.6 to form a compact and circular cable.

9. BINDER

A suitable binder tape or tapes of suitable non-hygroscopic material shall be applied over the laid-up cores. The core covering shall serve as a heat barrier to prevent softening of the core insulation during sheath extrusion. There shall be no adhesion between the core insulation and the binder or between the core sheath and the binder.

10. PVC SHEATH

The wrapped up cores shall be sheathed with a continuous, impermeable, close fitting extruded sheath of homogeneous black PVC in accordance with the requirements of SABS-150 - 1970.

The PVC sheath shall be of uniform radial thickness and shall be free from pinholes, splits, joints, repairs, blisters and other defects.

The minimum radial thickness and the minimum average thickness of the PVC sheath, when determined in accordance with Clause 9.1 of SABS-150 shall not be less than the values laid down in Table T of SABS-150.

11. STEEL WIRE ARMOURING

The cable shall be armoured with one layer of galvanised steel wires applied with a left-hand lay. The proper-ties of the galvanised armouring shall comply with that laid down in SABS-150 -1970.

The galvanised steel wires shall all be continuous throughout the length of the completed cable. When it is necessary to join wires to achieve this continuity, the joints shall be made in a workmanlike manner by brazing or electric welding and shall be finished smooth.

Armouring wires shall be free from kinks, bends, sharp edges, protruding points, zinc flaking and other defects which may damage or penetrate into the bedding or serving.

12. OUTER SHEATH

The anti-corrosion protective covering over the armouring shall consist of a layer of homogeneous black PVC applied in the form of an extruded close fitting over sheath.

The over sheath shall be free from pinholes, joints, repairs and other defects and shall be impervious to moisture.

The outer sheath shall be of uniform radial thickness and the minimum radial thickness, measured in accordance with SABS Method 495, shall not be less than 2,8 mm .

13. MANUFACTURER'S IDENTIFICATION

The following information shall be clearly and indelibly embossed on the serving of the cable at intervals not exceeding 0,5 m:

a) manufacturer's name and/or trademark;

b) year of manufacture; and

c) the cable length shall be clearly and indelibly marked on the outer PVC sheath at intervals of 2 m over the full length of the cable starting from the drum spindle end in order to determine the length of cable remaining on the drum after cutting of cable.

14. REQUIREMENTS FOR FINISHED PRODUCT

The electrical and physical requirements shall comply with the appropriate requirements laid down in Section 6 of SABS-150.

15. TESTS

The following routine tests shall be carried out on each cable length in the factory and the cost of testing shall be included in the price of the cable.

Conductor resistance test.

The conductor DC resistance of each core in each cable shall be measured at ambient temperature and corrected to a temperature of 20°C. The value so obtained shall not exceed the figure laid down in Table C of SABS-150.

Insulation resistance test.

The insulation resistance shall be measured for each core with all other conductors bunched and earthed. Insulation resistance shall be measured at a voltage not less than 500 V DC at ambient temperature allowing one minute charging time.

The measured value shall be corrected to 20°C and the value so obtained shall not be less than the appropriate value laid down in Table L of SABS-150.

High-voltage withstand test.

Each core of each cable shall withstand for 10 minutes, without break-down of the dielectric, an applied test voltage of 2 000 V, 50Hz to all other conductors.

The voltage withstand test shall be carried out with alternating current of approximately sine wave form. The voltage shall be increased gradually to the required level and shall be maintained at the level continuously for the stipulated period.

A sufficient number of sample tests shall be carried out at regular intervals to effectively control the uniformity of manufacture and to check compliance with this specification.

Test Certificates.

Duplicate test certificates of all routine tests and of sample tests shall be submitted direct after completion of such tests, to the Engineer.

16. SEALING OF CABLE

After completion of the works tests, each end of each cable length shall be effectively sealed to prevent the ingress of moisture.

17. PACKING AND MARKING

The cable shall be supplied in continuous lengths of 300 m on new wooden drums of solid and substantial construction which are resistant to biological attack.

All drums shall be suitable for loading on a 100 mm diameter spindle.

Packing and marking of the cable to be supplied to this specification shall comply with the requirements of Section 7 of SABS 150 - 1970.

In addition to the information called for in Clause 7.2.2(b) of SABS-150, each drum shall be clearly marked as indicated below:

CTMM ENQUIRY (NUMBER)

The maximum overall dimensions of drums shall not exceed the following dimensions:

a) Overall diameter 2 800 mm; and

b) overall width 1 520 mm.

18. ADDITIONAL INFORMATION REQUIRED

The Schedule of Particulars, shall be completed in detail and any additional information relating to the cable offered shall be submitted with the tender.

19. GUARANTEE

The cable to be supplied against this specification shall be guaranteed by the successful tenderer against failure due to faulty design, inferior materials or bad workmanship for a period of two years from the date the cable is to be delivered.

PART 8.3 : TERMINATION & CONNECTING UP OF CABLE AND CABLE ACCESSORIES

SPECIFICATION No : CG.01/1-97 – Rev 1/A

CONTENTS

1. SCOPE OF WORK INCLUDED IN THE QUOTED PRICE RATES:

The supply and installation of:

a) Cable glands and core lugs;

b) cable and core identification labels and marking material; and

c) cable cleats, strapping and fixing material.

The removal, drilling and re-filling of equipment gland plates, and touching-up of gland plate paint work where necessary.

The testing of glanded-off cables and the recording of test results.

The removal of surplus material.

The connecting-up of cables.

2. CABLE GLANDS

PVC SWA PVC cables shall be terminated using patent adjustable cable glands.

Unless otherwise stated all cable glands shall be of the captive cone type such that the wire armouring is held firmly by the gland, and at the same time electrically bonded via the body of the gland to the metallic gland plate.

Glands shall be supplied complete with lock nuts made of the same material as the gland.

The gland material shall be compatible with the cable armouring material.

Where cable glands are installed out doors they shall be provided with a suitable shroud or boot to prevent the ingress of moisture between the wire armouring and outer sheath of the cable where it enters the gland.

The fitting of cable glands shall be carried out in accordance with the manufacturer's instructions, copies of which shall be furnished to the Engineer.

The cost of supplying and installation of cable glands shall be included in the rates for the glanding-off of cables.

3. CORE LUGS

The individual cable cores shall be fitted with insulated crimped lugs of the size designed for the relevant cross sectional cable core size.

Fitting of the core lugs shall be carried out with an appropriate crimping tool in accordance with the manufacturer's instructions, copies of which shall be furnished to the Engineer.

The cost of supplying and installation core lugs shall be included in the rates for the connecting-up of cables.

4. CABLE AND CORE IDENTIFICATION

4.1 Cable Identification

All cables shall be marked at each end with a unique number in accordance with the Council's standard cable numbering system implemented for distribution substations.

The number shall be displayed in 4 mm high lettering.

Outdoor labels	stamped on a brass, copper or aluminium strip fixed to the cable by means of galvanised steel wire
Indoor labels	printed or embossed on a PVC identification label (in black on a white back-ground) fixed to the cable by means of self-locking PVC straps.

Cable identification labels shall be fixed around and at 90° to the axis of the cable.

The supply and erection of cable identification labels shall be included in the rates for the glanding-off of the cables.

Cables terminating in equipment shall also be marked with *Indoor Labels* as described above.

In floor mounted panels, such labels shall be located at the point where the inner sheath of the cable emerges from the gland.

4.2 Core Identification

Cable core identification shall be strictly in accordance with the general requirements in Part 1 of the Technical Specification.

5. CABLE CLEATS

Cleats may be defined as single way or multi-way clamping type units for the purpose of securing cables at a series of points on a vertical surface, typically structural steelwork or masonry.

For the purposes of securing cables to structural steel-work, the use of patent adjustable metal cleats which do not require special holes to be drilled in the steel work and which allow a vertical cable to be secured to a diagonal steel work member, are preferred. However, the use of suitable alternatives will be considered by the Engineer.

The use of steel or plastic banding or strapping as a means of fixing cables to structural steel work will only be considered where the use of a cleat is precluded.

Steel components of cleats shall be galvanised.

Where cables are to be fixed to concrete or masonry surfaces (either vertical or horizontal) the use of galvanised trays or stainless steel saddles are preferred. Saddles shall be secured to the concrete or masonry by means of expanding bolts.

The intervals at which cables are secured to vertical and horizontal surfaces shall not exceed 500mm .

The cost of supplying and erecting cable or cable cores, cleats and accessories shall be included in the rates for the installation of cables in the appropriate price schedules.

Cables run as trefoil groups shall additionally be clamped in trefoil arrangement every two metres over the entire length (including where buried in the ground).

Clamping of trefoil groups on cable supports shall be by means of wooden blocks and clamping in made trenches or in the ground shall be done by means of a stainless steel bonding strap bonded over scrap PVC serving wrapped around the trefoil groups.

Where mechanism box cables cannot be fixed to a structure, a separate galvanised support structure shall be provided to prevent the cables from hanging on the cable glands.

Where cables are to be terminated onto a 132/11kV power transformer a cable support structure of steel and hard wood shall be provided as referred to on drawing C-53.

6. GLANDING-OFF OF CABLES

Blank cable gland plates shall be supplied with the various items of plant and equipment.

The Contractor shall, unless otherwise stated:

a) Supply all cable glands.

b) Drill all gland plates (removing them from the equipment for this purpose and replacing after drilling).

c) Gland-off all multi-core control and power cables in accordance with the gland manufacturer's directions for use in a position which shall be appropriate to the points where the cable tails are to be terminated.

7. TERMINATIONS

The rates for terminations to be inserted in the Price Schedule shall allow the following lengths for preparation of tails at each end of the cable.

High voltage cables to suit equipment terminations.

PVC insulated power cables	1,5 m .
PVC insulated control cables	2,2 m .

The Contractor shall strip away all bedding or sheathing collectively surrounding the cable cores and shall leave the skins of cores neatly rolled-up inside the panel, terminal box, etc., as the case may be. The Contractor shall also replace or close any terminal box or kiosk covers or door on outdoor equipment which he might have removed or opened in order to gain access for glanding-off the cables.

The Contractor shall, in the process of glanding of the cables:

a) Fit the cable identification labels described below after having verified by means of an end-to-end check on at least 2 separate cores in the cable that both ends belong to the same cable;

b) perform the insulation and continuity checks described in the Specification and record the results in an approved manner;

c) touch-up the paint work on gland plate surfaces where this might have been scratched or damaged; and

d) remove all surplus PVC bedding, sheathing and armouring material to a scrap bin which shall be provided for this purpose on the site.

Each terminated core shall have sufficient slack to be re-terminated if required. (For example: In the event of a badly crimped lug having to be replaced).

8. TRUNKING AND WIRING CHANNELS

The connecting-up of cables shall include the whipping, strapping, lacing and harnessing of cable tails, the identification of the tails by means of ferrules or markers, the termination of each core by means of crimped lugs and the connection of cores to equipment terminals or terminal blocks (maximum of two lugs per terminal).

All wiring shall be taken to terminals and wires shall not be jointed or teed between terminal points.

After glanding the cable cores of each individual cable shall be unwound, straightened and strapped together to form a neatly bound group.

Grouped cable routes between the glands and the trunking shall be parallel to the front, back and sides of the cubicle. All bends along the grouped routes shall be at right angles. Direct routes between the glands and the trunking will not be accepted.

In cubicles the control wiring between devices and terminals shall be run in plastic, non-flammable trunking with snap-on cowers. To enable additional wires to be added in future, the channels shall not be more than 60% full at time of delivery.

Control and instrumentation / signal wires shall be run in trunking as far separated from each other and from power supply leads as possible to eliminate influence on each other.

PART 8.4 : TRENCHING, LAYOUT AND THE INSTALLATION OF MULTICORE CABLES

SPECIFICATION NO : CI.01/1-97 – Rev 3/C

CONTENTS

1. SCOPE OF WORK INCLUDED IN THE QUOTED PRICE RATES

The laying and installation of cable shall include:

a) The excavation and back-filling of all trenches in the ground;

b) the supply and installation of:

  i. Riddled earth for bedding of cables;

  ii. protective slabs;

  iii. cable markers; and

  iv. cable marker tapes.

c) the removal of excavated surplus, rocks, debris and spoil from the site;

d) the laying and pulling-in of cables in trenches, ducts, pipes etc. of the various descriptions contained in the Specification;

e) the supply of all cable cleats, saddles, cantilevers and trays required to fix cables to the various surfaces and in the various planes required together with the installation of the cleats and saddles, cantilevers and trays and the fixings associated therewith;

f) the proper recording of the number and actual length of each cable installed on the regular basis prescribed by the Specification and in a format approved by the Engineer;

g) the removal and replacement of cable trench covers;

h) the sealing of cut ends which will not be glanded-off within 24 hours of being cut;

i) all and any steps to ensure that outdoor equipment is not left exposed to the elements by virtue of doors opened or covers removed during cable installation;

j) the sealing of apertures in made-trench walls;

k) testing on site, after installation; and

l) the measurement of the actual "as installed" quantities for payment.

2. CABLE TRENCHES IN GROUND

Cable trenches in the ground shall not be wider than 450 mm for one HV power cable or for one trefoil group of HV power cables or 1 250 mm for three trefoil groups of HV power cables or 300mm for one LV power cable or group of control cables and shall be excavated to the following depths:

a) For control cables : 500 mm;

b) for low voltage power cables : 800 mm; and

c) for high voltage power cables : 1 100 mm.

The excavation of cable trenches shall form part of the contract works. Prices for trenching shall be based on the following classifications of the ground:

a) **Very Hard Rock** **:Sha**ll mean rock that can be excavated only by means of explosives.

b) **Hard Rock** **:** Shall mean granite, quartzitic sandstone, slate and rock of similar or greater hardness, solid slabs and boulders over 0,03 m^3 in volume.

c) **Soft Rock** **:** Shall mean rock that can be loosened by hand pick and include hard shale, compact decomposed shale and boulders from 75 mm in diameter up to 0,03 m^3 in volume.

d) **Earth** **:** Shall mean ground that can be removed by pick and hand shovel and includes loose gravel, clay, made-up ground, loose or soft shale, loose decomposed shale and boulders less than 75 mm in diameter.

The prices for the laying and installation of cables in ground shall, unless otherwise stated, be based on excavation and back-filling in earth as defined above.

No allowance shall be made for the breaking away of the trench sides, other earth movements or for trenches excavated in excess of the stipulated dimensions, other than as agreed with the Engineer.

No guarantee is given or implied that blasting shall not be required, but should this method of removal be necessary and permitted, then the contractor shall take all responsibility and observe all conditions set forth in Government and Local Authority Regulations.

Power driven mechanical excavators may be used for trenching operations provided that they are not used in close proximity to other plant liable to be damaged by the use of such machinery. They may not be used within the boundaries of live switch yards. Their use along sections of the route must in each case be approved by the Engineer.

The bottom of the trench shall be level and clear and the bottom and sides free from rocks or stones liable to cause damage to the cable. Payment for cable trenching having greater volume than that specified for the purpose will not be considered except where extra excavations are necessary to bypass obstacles such as water pipes, drains, large boulders etc. In all such instances the amount of the extra excavations shall be agreed upon on site between the Engineer and the Contractor.

The Contractor must take all necessary precautions to safeguard all pipe work, structures, roads, sewerage works, earthing conductors, electrical cables or other property on the site from any risk of subsidence and damage.

3. MADE CABLE TRENCHES

Made cable trenches inside equipment buildings shall form part of the building and will be provided on other parts of the contract. The steel covers shall be removed during cable installations.

Made cable trenches between various items of outdoor equipment will be provided on other contracts and will consist of a concrete floor and walls of either masonry or re-enforced concrete in which apertures are provided at regular intervals to permit cables to enter the surrounding earth. The trenches will be fitted with removable reinforced concrete covers.

Two types of made, outdoor cable trenches will be provided, both of which will have an internal depth of approximately 450 mm, and the following widths, measured internally:

a) Type A trench 600 mm wide;

b) type B trench 400 mm wide.

4. DUCTS AND PIPES

Where the amount of ducts in which cable is to be laid is significant, full particulars of the type, material and dimensions of such ducts and pipes will be given in the Schedule forming part of this Specification and/or on the tender drawings.

The Contractor shall satisfy the Engineer as to the effect of the duct on the thermal rating of the cable.

5. LAYING AND INSTALLATION OF CABLES

The general installation of cables shall conform with the guidelines contained in the relevant SABS Specification regarding the handling of drums on site and minimum installation bending radii.

5.1 Laying of Cables in Ground

When laying cables in trenches excavated in soft or hard rock or containing sharp stones, rocks or other items likely to injure cables, the following precautions shall be taken:

Before laying the cables all injurious items and sharp objects shall be removed from the bottom of the trench. The floor of the trench shall be evenly covered with a layer of sifted backfill, or sandy loam to a level which is 100 mm above the highest unevenness of the trench.

The backfill used for this purpose shall have passed through a screen having a 6 mm square mesh.

The laying of cables shall not be commenced until the trenches have been inspected and approved. The cable shall be removed from the drum in such a way that no twisting, tension or mechanical damage is caused, and must be adequately supported a short intervals during the whole operation.

The cables shall then be covered with a 150 mm layer of sifted backfill, or sandy loam. The backfill shall be well consolidated.

Backfilling shall then be continued with proper grading of material to ensure settling without voids, and the material is to be stamped down after the addition of every 150 mm layer. The surface is to be made good to approval, and in the case of roadway crossings the excavations must be consolidated to original stability. Where cables pass under road-ways they shall be laid in concrete trenches provided or in pipes at a depth not less than 1 100 mm below the surface.

Should the specified backfill not be available at any particular section of the trench, the contractor shall transport the backfill from elsewhere. The cost for this shall be included in the unit rates for excavation.

Where cables are cut and are not intended to be made off within 24 hours the ends are to be sealed without delay.

Where more than one horizontal layer of cable is laid, the level of the upper layers of cable shall be gauged from the level of the finished bottom of the trench and marked on the side on the trench at frequent intervals before the installation of the lower layers, to ensure that the correct vertical spacing is maintained.

The Contractor shall take all reasonable steps to ascertain where the cables and associated metallic pipes or corrodable materials may be subjected to chemical or electrolytic action and shall submit his recommendations for special precautions to the Engineer for approval.

The Contractor shall, before commencing with any excavation work, satisfy himself as to the location of any buried cables, water pipes, earthing conductors or other underground service which might be damaged during excavation.

Any damage inflicted on other services by the Contractor shall be immediately reported to the Engineer and shall be made good by the Contractor or by others at the Contractor's expense.

Unless otherwise approved control cables shall be laid in the same trench as the power cables where the latter are laid direct in the ground. Where power cables are laid otherwise than direct in the ground the control cables shall be laid separately in an approved manner.

Where control cables are laid in the same trench as power cables, there shall be at least 200 mm of riddled earth between the two types of cables and to form a definite division, approved concrete slabs shall be installed on edge between the power and multi-core cables

All surplus ground, rocks and spoil shall be removed from the site or shall be spread and the cost of same shall be included in the prices for laying and installing the cables.

5.2 Laying of Cables in Made Trenches

Before the commencement of laying cables in made trenching the Contractor shall remove any loose material and shall ensure that the exit apertures in the walls of the trench allow clear and free access to surrounding earth for the cable route involved.

Cable covers which have been removed to gain access to the trench shall be stowed alongside the trench in the sequence in which they were removed.

All cables (except large power cables) shall be laid directly on the floor of the cable trench and shall touch one another. A second layer of cables shall not be started until the first layer is complete.

Cable crossover points within the trench shall be kept to a minimum and cables shall be laid such that they are conveniently located to enter and leave the trench when this is necessary.

Cable ladders shall be installed in the main 11kV cable trench in the switch room to provide crossover points for control cables.

Ends not yet glanded-off shall be sealed and shall not be left laying in the open trench where they might become submerged in accumulated rainwater.

On completion of the cable installation the Contractor shall be responsible for:

Clearing trenches of all rubble and foreign matter and removing it to a refuse dump.

Sealing-up all used and unused apertures in the trench walls with a weak cement mix to prevent ingress of soil and water from the surrounding earth.

Ensuring that all weep-holes and trench drainage points are clear and unobstructed.

Before handing over a weak plaster mix 30 mm thick shall be poured and floated over the cables in the trenches.

Replacing the cable trench covers.

5.3 Cables Installed in Ducts and Pipes

Unless otherwise specified, ducts and pipes will be provided under a separate contract. The Contractor is however to remove any loose material from the ducts, and prove them by drawing through a mandrel of slightly less diameter than the duct, immediately before pulling in the cables. Any lubricant used shall have no deleterious effect on the cables.

Metal or impregnated fibre pipes or earthenware ducts may be used for three-core cables.

Impregnated fibre pipes or earthenware ducts may be used for single-core cables. The Contractor shall ensure that all pipes are clear of obstructions before cables are drawn in. Where specified by the Engineer split pipes shall be fitted round the cable after its installation.

All ducts or pipes not used shall be sealed by wooden plugs before backfilling, or at the end of the Contract.

Where required by the Engineer, the ducts, floor bushings, etc., shall be sealed after drawing in the cables by caulking with an approved fire resistant compound, followed by not less than 35 mm of soft vermiculite cement, or other material as the Engineer may direct.

Rates for plugs and sealing ducts and holes shall be entered into the Schedules, where called for.

Particular care must be exercised where it is necessary to draw cable through pipes and ducts to avoid abrasion, elongation, or distortion of any kind. The ends of such pipes and ducts shall be sealed to approval after drawing in of the cables.

Where holes and slots have been provided through floors for the installation of cables the Contractor shall arrange to seal these holes and slots when the total number of cables to pass through any slot or hole has been installed. Rates for sealing such holes and slots shall be given in the Schedules.

The seal shall prevent the spread of fire, access by vermin, and shall not permit the passage of dust through the hole when sealed. The material used for sealing shall not be detrimental to either cable sheaths or copper conductors and it shall be possible to remove the seal without damaging either cables or copper conductors.

5.4 Cables Installed Against Walls.

Cable racks shall be installed against walls or the sides of cable trenches where control cables are to be routed against walls or the sides of cable trenches.

6. PROTECTIVE SLABS AND MARKERS

Where cables are laid in the ground they shall be protected by means of slabs and the cable route, shall, where directed by the Engineer, be suitably marked.

Protective slabs shall consist of reinforced concrete or other approved material and shall have the following dimensions:

a) Length : 900 mm;

b) width : 225 mm; and

c) thickness : 50 mm.

The top of the slab shall be installed at the following minimum depths:

a) For control cables only : 275 mm;

b) for low voltage power cables and control cables : 500 mm; and

c) for high voltage (greater than 1kV) power cables : 800 mm.

The underside of the slab shall not be less than 150 mm above the cable which it protects.

For high voltage (voltages exceeding 1 kV) power cables a colour plastic marking tape shall be installed 400 mm above the buried cable. The tape shall be yellow with a skull and crossbones motif and the words ELECTRIC CABLE / ELEKTRIESE KABEL embossed in red at regular intervals of not more than 1 metre apart along the whole length of the tape.

Cable markers shall consist of concrete blocks in the shape of truncated pyramids with the following dimensions:

a) Height (approximately) : 300 mm

b) Base dimension : 250 x 250 mm .

c) Top dimension : 150 x 150 mm .

Brass plates shall be cast into the tops of the blocks in such a manner that they cannot be prised loose. The wording "ELECTRIC CABLE/ELEKTRIESE KABEL" shall be stamped on the brass plates as well as direction arrows and the cable voltage rating.

Cable markers shall be installed on the surface along all underground routes and shall project 35mm above normal ground level unless the projected markers could be a hazard to pedestrian or other traffic in which case they shall be installed flush with the surface.

Cable markers shall be installed at the beginning and end of a cable run (e.g. where a cable enters a substation or building) at all changes or direction, above all joints, above cable pipe entries and exits and at intervals not exceeding 50 m along the cable route.

The position of cable markers shall be as indicated on the "as built" drawings.

7. CABLE JOINTS

No joints shall be permitted in multi-core cables or cable cores used for control purposes.

Joints in power cables shall be restricted to an absolute minimum. The type of joint employed shall be to the approval of the Engineer and the permission of the Engineer shall be obtained for every proposed joint.

8. TERMINATION OF MULTICORE CABLES

Cores, including spares, shall be long enough to reach the terminal.

The spare cores shall not cut off but folded and tied back.

All cores shall be ferrules marked according to the schematic drawing.

All spare cores shall be ferrule marked with their associated cable number.

9. TESTS ON SITE

The following tests shall be carried out on site:

a) All PVC sheathed cables shall, after laying and backfilling, but prior to being glanded-off be subjected to a 2000V Megger test to prove the soundness of the outer PVC sheath;

b) control cables and low voltage power cables shall, after glanding off, be subjected to the following Megger tests:

   i. 1000 volts applied between cores; and
   ii. 1000 volts applied between each core and earth.

c) all site test results shall be recorded in a form approved by and acceptable to the Engineer and test results shall be submitted on a daily basis to the Engineer's site representative who shall then call for tests to be repeated at random if he so wishes in order to check the values recorded.

d) Low voltage power cables, shall, after glanding-off be subjected to the test voltages appearing in Appendix D of SABS 150 for a period of 15 minutes.

e) High voltage cables shall be pressure tested in the presence of the Engineer in accordance with the applicable standards.

10. LENGTHS AND QUANTITIES

10.1 Estimated Lengths and Quantities

Unless otherwise indicated the lengths and quantities set out in the Schedule of Quantities are estimated for tendering purposes only. The Council does not undertake that the whole of these estimated lengths and quantities will in fact be required. Surplus or waste material will not be taken over or paid for by the Council except where, at the time when it was reasonable for the material to be provided or manufacture to be put in hand it was not possible to accurately determine the quantity of material required.

The Contractor shall be responsible for providing detailed cable schedules on which the estimated length of each run of cable shall be set out. The contractor shall also be responsible for ascertaining the exact lengths, by measurement on the Site or otherwise, before putting in hand the manufacture of the cables. Any surplus cable after completion will not be taken over or paid for by the Council unless the Council so decides.

The Contractor will be paid for actual "as installed" quantities, as measured on Site.

10.2 Measurement of "as Installed" Quantities

All measurement for the purpose of payment shall be made by the Contractor in the presence of the Engineer. The Contractor shall be responsible for obtaining the Engineer's signature approving such measurement not later than one week after the measurements have been made.

All measurements shall be to the nearest standard unit for which rates are given in the appropriate schedule. The sum payable in respect of each such part of the Contract Works shall be ascertained according to the price or rate shall be a fair or reasonable price or rating into account any price or rates that may be specified in the Contract for similar work. Such reasonable price or rate shall be settled by agreement between the Engineer and the Contractor.

A copy of the proposed cable plans shall be marked-up with as installed cable lengths and sizes. Final payment will not be made unless this drawing is handed to the engineer.

10.3 Method of Measurement

The supply and erection of material shall be measured as follows:

10.3.1 Supply and delivery of cables

The length of each cable shall be deemed to be the length between the end of the longest conductor at one end of the cable to the end of the longest conductor at the other end of the cable. The length shall be measured to the nearest metre, i.e. lengths up to and including 500 mm downwards to the last complete metre, and in excess of 500 mm upwards to the next complete metre.

Where, by written agreement with the Engineer excess lengths of cable are supplied (for example in cases where the position of the associated plant is not determined) the total length of such cable will be paid for. In such circumstances any surplus after completion shall, if required by the Council, be taken over by the Contractor at prices to be agreed.

Off-cuts of whole pieces of cable too short to be of any practical use shall be strenuously avoided. Where such off-cuts are unavoidable they shall be paid for at the supply rate only. Off-cuts shall be deposited in a special bin for this purpose and shall remain the property of the Council.

10.3.2 Laying of cables in trenches.

Measurement of cables laid in trenches shall be of the actual length of that part of a cable laid in the trench when the cable is finally installed.

Drawing cables into ducts, pipes and conduits (excluding supply and installation of ducts, pipes and conduits).

Measurement of cables drawn into ducts, pipes and conduits shall be of the actual length of that part of a cable laid in ducts, pipes or conduits when the cable is finally installed.

Supply, delivery and erection of all supports, racks, trays, cleats and clips and installation of cables.

Measurement of supports, racks, trays, cleats, clips and installation of cables shall be determined by measurement from the underside of the cable gland at one end of the cable to the underside of the cable gland at the other end of the cable after due allowance has been made for the sections of the cable that may be installed by methods other than the above, i.e. drawn into ducts, in concrete trenches or in open trenches.

PART 8.5 : MEDIUM VOLTAGE CABLE SEALING ENDS, TERMINATIONS AND CABLES

SPECIFICATION No. : TC.40/0-97 – Rev 1/A

CONTENTS

1. SCOPE

This specification covers the requirements for indoor and outdoor MV (11 kV and 33 kV) cable sealing ends, as well as the 33 kV and 11 kV cables connecting transformers to the switchgear.

2. DEFINITIONS

Pluggable cable sealing ends shall mean MV cable sealing ends which can be made off outside the switchgear, and which shall be capable of being connected to the switchgear without using special tools and without opening a cable connection compartment of the switchgear to do the connection.

3. STANDARDS

All equipment shall be made in accordance with the relevant SABS, IEC or British Standards and with the applicable Parts 8 of this specification. Tenderers shall state to which standards their products conform.

4. CABLE SEALING ENDS

The cable sealing ends shall be of the dry, air insulated type for use on single core medium voltage cables.

The sealing ends may be of the cold cast, heat shrink or lead-wiped type. The sealing ends shall be made of material which is free from voids and shall be partial discharge free at the working voltages.

The sealing ends shall be type tested to approved standards. The Tenderer shall state to which standards his products conform, and be able to produce type test certificates if requested by the Engineer to do so.

The sealing ends shall be correctly dimensioned with respect to current carrying capacity, short circuit thermal withstand and dynamic forces.

The Tenderer shall include a description of his product, cross sectional drawings, including details of making off the earthing point of the sealing end, as well as installation instructions.

Terminal lugs shall be to the approval of the Engineer and may be crimped or sweated

The clearances flash over and creepage distances shall be approved by the Engineer and shall be to IEC standards.

4.1 INDOOR CABLE SEALING ENDS

Indoors, the sealing ends shall be of the pluggable type for 33 kV switchgear and of the fixed type for the 11 kV terminations in the switchgear.

Tenderers shall include a reference list of installations of their products in South Africa.

4.1.1 Pluggable sealing ends for 33 kV cable

For single core XLPE cables connected to indoor 33 kV switchgear described in Part 11, pluggable sealing ends shall be supplied. As many ends as are necessary shall be supplied to give the needed current carrying capacity.

The Tenderer shall give details of the construction of the sealing ends, as well as a description of how they are made off. They shall further indicate the minimum space and bending radius needed to make off and install the sealing ends.

Ease of installation and of connection to the switchgear will be an important factor. Tenderers shall indicate how they intend to achieve these aims. They shall also supply drawings showing details of they products offered, and the maximum cable size which can be accommodated.

The Tenderer shall indicate how the ends have been dimensioned.

He shall further show how these ends are to be installed in the 33 kV switchgear specified in Part 11.

The Tenderer shall include a list of references preferably in South Africa.

4.1.2 Fixed sealing ends for 11 kV switchgear and transformers

The sealing ends are to be installed onto single core PILC non draining cables, with air insulation. At the switchgear end and at the transformer end they will be in bolted enclosures. They may be of the heat shrink or other approved system. The Tenderer shall indicate what system he intends using.

All the materials necessary for the making off and termination of the cables onto the equipment shall be supplied by the tenderer and be to the approval of the Engineer. The tenderer shall indicate how he intends to compensate for the expansion and contraction at the cable-ends during operating conditions

4.2 OUTDOOR CABLE SEALING ENDS

4.2.1 33 kV SEALING ENDS

The outdoor sealing ends shall be installed at the transformer end of the cable. These may be of the composite type, and shall preferably have silicone rubber sheds.

The Tenderer shall give the same dimensioning, constructional and reference data as indicated above for the indoor 33 kV sealing ends.

5. 33KV CABLE

The 33 kV cable shall have insulation of the cross-linked polyethylene type. It shall be dimensioned to carry the -full load current of the transformer continuously, as well as withstand the thermal and dynamic load effects of short circuits. The voltage requirements are shown in Section lll Part 1.

5.1 11 kV paper cable

The 11 kV cable is specified in Section 4 Part 8.1.

5.2 33 kV single-core cross-linked polyethylene cable

The 33 kV cable shall be single-core cross-linked polyethylene cable with the cable sheath earthed at one end.

It shall conform to the parameters stated in Section lll Part 1.

The Tenderer shall include a description of the construction of the cable, as well as how he intends supporting the cable and the sealing ends at both ends.

He shall also, if requested by the Engineer, be able to show how the cable size was dimensioned.

PART 9.1 : EARTHING GRID

SPECIFICATION No. : EG.01/0-04

CONTENTS

1. SCOPE

This specification shall include the design, supply, installation, connection and testing of the substation earthing system and ancillary works described below.

This specification includes the supply of copper conductor, lightning masts, earth spikes, earth mats etc. and the necessary excavation and civil works to install the earthing system and the replacement of stolen earth trails in substations.

The required general layout of the substation yard is shown on the drawings attached to this specification.

This specification describes all major components, but the Contractor shall supply and install all minor items and labour as may be necessary to complete the installation.

2. QUALITY OF WORK AND STANDARDS

All work shall be carried out strictly in accordance with the Code of Practice for earthing. (CP 1013)

The following SABS standards must be adhered to:

1. Earth rods, couplers and clamps shall be supplied and installed in accordance with SABS 1063-1985 and SABS 0199.
2. The two pack zinc-rich epoxy primer must be in accordance with SABS 926: 1968
3. The zinc and aluminium coatings for the protection of iron and steel against atmospheric corrosion must be in accordance with SABS 1391: 1983.
4. The replacement or new earth tail shall be two copper-plated steel earth rods according to SABS 1063: 1985.
5. Each earth rod shall have a diameter not less than 14.5mm, equivalent M16, according SABS 1063: 1985. The thickness of the copper plating on the earth rod shall not be less than 250μm.

3. DESIGN AND APPROVAL

The Contractor shall allow for soil resistivity tests to be performed on site. A detailed report on the resistivity tests shall be submitted to the Engineer together with a preliminary earthing scheme showing how the Contractor envisages installing the earth mat before commencing installation of the earth mat. The Contractor shall employ a specialist to investigate, plan and install the earthing installation.

The earth mat installation shall incorporate earthing electrodes at the extreme corners of the station, in the vicinity of earthing switches and transformer neutrals. The fences shall also be earthed at regular intervals. The installed maximum earth resistance shall be 1 Ω, or as agreed by the Engineer. Copper rod, 10mm² shall be used for the earth grid. The earth conductors shall generally be laid at a depth of more than 500 mm below the finished surface.

The complete earth mat design shall be submitted for written approval. The Engineer may then add or delete equipment and change the design of the earth system if he so requires. The installation of the earth mat shall be so arranged as not to cause delays in civil works.

4. EARTH RESISTANCE SURVEY

The Contractor will be responsible to have an earth resistance survey carried out on site by a specialist in this field, to be approved by the Engineer. The test shall be done on the undisturbed site, i.e. before earth works, trenching, building etc. commence.

The Engineer shall attend the survey. The Contractor shall inform the Engineer in good time when the test is scheduled to take place. If it is done without his or his representative being present, the test shall be repeated in the Engineer's presence at no additional cost to the Council.

The results of this survey will be used to adjust the earthing system as specified herein, if necessary, on the basis of the quoted rates.

Payment for the services of the specialist shall be by the Contractor who may recover such costs out of the provisional amount allowed for this purpose. The recoverable amount will be the nett invoice amount charged by the specialist, plus a 5% mark-up to cover the Contractor's administrative overhead and profit.

5. STOLEN AND NEW EARTHING FOR OUTDOOR EQUIPMENT

To discourage theft of copper bar or conductor, no bare earthing copper shall be visible above ground. For all visible outdoor connections to equipment or structures, copper plated solid steel rods having an equivalent resistance as the copper it replaces, shall be used. Sizes and cross sections shall be according table 1 (see appendix A) and be approved by the Engineer

Connections shall either be bolted directly to the earthing conductor, or bolted to a copper flag silver soldered or exothermically welded to the earth conductor to the approval of the Engineer. Alternatively, each joint shall be made with adequate bolts to the approval of the Engineer

The copper plated earth rod must be exothermic welded onto the structure as well as the copper earth mat. The reason is to enable a temperature rise up to 800°C for the copper plated earth rod. This provides for higher current capability for 3 seconds. The galvanising of the structure must be removed with a grinder and the surface cleaned where the exothermic weld is to be preformed. Failing to remove the galvanising will cause holes in the exothermic weld, which will result in poor contact and poor current carrying capability. After completion of the exothermic weld, the area on the structure, where the galvanizing was removed, must be covered with cold galvanizing. All exothermic weld joints are to be hammered tested to ensure that the mechanical strength of the joints are adequate. It is very important to use the correct weld metal power for the correct joint.

After connection the Engineer shall inspect all joints before the joints are sealed or trenches closed.

The following equipment needs to be earthed and the standard practices for earthing this equipment are as follows:

a) Transformer earthing:

Transformers need to be earthed on the top cover on two different places and by using double earth rods.

b) Surge arresters:

Insulated surge arrestors will be earthed on the surge arrestors base where non-insulated surge arrestors will be earthed on the structure exothermically.

c) Voltage and current transformers:

Voltage and current transformers will be earthed on the structure exothermically.

d) Earth switches and isolator earthing:

Earth switches and isolator earthing will be earthed on the structure exothermically on two different ends. The handle of the earth switches shall be earthed through a flexible earth.

e) Fences:

All steel fencing must be earthed with in every 20M

f) Mechanism boxes and kiosks:

Mechanism boxes and kiosks shall be earthed independently of the associated device or steel structure on which they are supported.

6. INDOOR EQUIPMENT EARTHING AND CABLE TRENCHES

Control panels, battery chargers, cable racking and other indoor auxiliary equipment shall be bonded by earth rod.

An earth rod shall be laid in the cable trench together with the multicore cables. This earth strap shall be run into the building and serve as the building earth to which all equipment in the building is connected. The building earth shall be connected to ground rods or bonding bar at diametrically opposite ends of the building.

7. EARTHING ELECTRODES

The number and lengths of earthing electrodes shall be determined from the resistivity tests above. Earthing electrodes shall be of the extendible rod type. The rods shall be of copper clad steel and the copper to steel weld shall be a true molecular bond according SABS 1063.

8. LIGHTNING CONDUCTORS

Lightning conductor aerial masts shall be designed according to SABS 0160 with a safety factor of 2.5. They shall be hot-dip galvanised to SABS 763.

Masts shall be joined and hinged at ground level and shall be supplied complete with foundations.

9. TESTING OF EARTH RODS

SANS 1885: 2004

10. DRAWINGS REQUIRED

After completion of the Works, the Contractor shall supply the necessary drawings as agreed upon with the Engineer

11. ANNEXURES

Annexure A:

Copper earthing conductor sizes.

Fault current	**Copper area required mm^2**		**Main earth grid (Rod)**		**Connections to equipment support (50 × 3 strap)**		**Connections to equipment support (2 × 10mm rod)**	
I (kA)	**Grid**	**Earth lead**	**No. of directions**	**Actual area mm^2**	**No. of connections**	**Actual area mm^2**	**No. of connections**	**Actual area mm^2**
12.5	125	150	2	160	1	150	1	160
16	160	190	4	320	2	300	2	320
20	200	240	4	320	2	300	2	320
25	250	300	4	320	2	300	2	320
31.5	315	375	4	320	3	450	3	480
40	400	480	6	480	4	600	3	480
50	500	600	8	640	4	600	4	640

Table 1: The table above illustrates the conductor arrangements required to meet standard fault levels.

PART 9.2 : EARTHING

SPECIFICATION No. : EG09/01

1. EXTENT OF WORK

An earthmat (copper band/conductor) needs to be installed in the new trenches and the new Control Building to match the existing earthmat configuration. The new earthmat needs to be connected to the existing earthmat by an isothermic welding process (Cad-welding). Where existing earthmat sections are damaged or removed, they should be replaced.

The substation earth resistance and bonding of equipment must be tested and proved. Where abnormalities occur, it must be rectified and tested to the approval of the Engineer.

Tenderers are referred to the applicable requirements of Part 9.1 “Earthing Grid”, Part 1.6 “Project Specification : Substation Testing and Re-Commissioning”, as well as the price items in the Schedule of Prices.

PART 10.1 : 5MVA 33/11kV TRANSFORMER

SPECIFICATION No. : PT.61.1/0-08 – Rev 0

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 5 MVA 33/11 kV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with this the current editions of specification **NRS 054 The transformer shall also comply with the following items other wise specified as in the NRS 054**

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in NRS 054 the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. TAPCHANGER DETAIL

The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type.

The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

The OLTC(s) shall be mounted into it's own tank. The diverter switches with selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

Tapchanger Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.	
b)	Make and Carry for 1 sec	10 Amp	
c)	Continuous carry	5 Amp	
d)	Breaking capacity for d.c. when the control circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

5 Transformer earthing and connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

a) from the high-voltage neutral to the earth point on the bottom of the transformer;

b) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

c) two (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

d) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800°C or approved clamping to withstand the specified fault levels

6 Main Terminals

The transformers shall be provided with outdoor type bushing insulators on the HV and LV terminals mounted on the top main cover.

7 Bushings

All bushings for 22kV voltages and higher including the neutral bushing/s shall be supplied with a capacitor cap.

8 Cable Boxes

If specified in the particulars and guaranties LV cable boxes for PILC 650mm single core cables three per phase shall be provided with suitable armour clamps. Suitable I0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

All cable boxes shall be air ventilated, as specified in Schedules of particulars Cable boxes shall have inspection covers to remove and disconnect the cables and links when required

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables to a flexible clamp.

9 Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

10 Conservator Tank

IF not other wise specified in the particulars and guaranties an air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

11 Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

12 Designation

Each transformer shall be provided with two easily-legible Stainless steel or aluminium label with the designation specified in Schedules of particulars - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A	**TRF-R**

13 Surge Arrestor/Divertor Brackets

Removable HV surge arrestor brackets shall be fitted at the HV side on top of the radiators. LV surge arrestor brackets shall be fitted on the LV side of the transformer if specified in Schedules of particulars. The surge arrestor bracket must be fitted with two earth conductors down to the base of the transformer tank.

14 Control and Protection

Control and protection equipment shall be provided under another specification, but provision must be made for the following control and protection functions:

a) A voltage regulating relay according to specification 12;

b) tap position indicators;

c) supervisory tap position indication according to specification 12;

d) selector switch for manual/remote operation of the tap changer, i.e. “raise” and “lower” voltage; and

e) with alarms and trip contacts for each of the following:

ALARMS:

i) 110V AC tap-changer control supply fail alarm;

ii) tap changer fail alarm; (out of stop)

iii) voltage regulating relay fail alarm;

iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

15 Marshalling Kiosks

A sheet steel, vermin-proof, well ventilated and weather proof marshalling kiosk of approved construction shall be mounted on the transformer with suitable rubber mountings to ensure no vibration. The kiosk interior and exterior painting shall be as specified.

A lockable door with “lift-off” type hinges and adequate sealing to prevent the ingress of water in the kiosk, shall be provided in the kiosk.

To prevent internal condensation an approved type of metal-clad heater shall be provided controlled by a 5A circuit-breaker inside the kiosk. Ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. Door-operated switches shall control interior illumination.

All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

The kiosk shall be divided into separate compartments for the mounting of the following groups of equipment and shall be clearly labelled on the outside of the kiosk to identify the compartments:

a) Temperature indicators, test links and ammeter for the winding temperature indicator circuits as specified;

b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. (35mm^2 cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

16 Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

17 INSPECTION AND TESTS

17.1 Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

17.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

17.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

17.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

17.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

17.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

17.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification.

18 MISCELLANEOUS

18.1 Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

PART 10.2 : 10MVA 33/11kV TRANSFORMER

SPECIFICATION No. : PT.61.2/0-07

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 10 MVA 33/11 kV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with this the current editions of specification **NRS 054 The transformer shall also comply with the following items other wise specified as in the NRS 054**

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in NRS 054 the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. TAPCHANGER DETAIL

The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type.

The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

The OLTC(s) shall be mounted into it's own tank. The diverter switches with selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

Tapchanger Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.	
b)	Make and Carry for 1 sec	10 Amp	
c)	Continuous carry	5 Amp	
d)	Breaking capacity for d.c. when the control circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

5 Transformer earthing and connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

a) from the high-voltage neutral to the earth point on the bottom of the transformer;

b) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

c) two (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

d) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800°C or approved clamping to withstand the specified fault levels

6 Main Terminals

The transformers shall be provided with outdoor type bushing insulators on the HV and LV terminals mounted on the top main cover.

7 Bushings

All bushings for 22kV voltages and higher including the neutral bushing/s shall be supplied with a capacitor cap.

8 Cable Boxes

If specified in the particulars and guaranties LV cable boxes for PILC 650mm single core cables three per phase shall be provided with suitable armour clamps. Suitable I0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

All cable boxes shall be air ventilated, as specified in Schedules of particulars Cable boxes shall have inspection covers to remove and disconnect the cables and links when required

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables to a flexible clamp.

9 Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

10 Conservator Tank

IF not other wise specified in the particulars and guaranties an air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

11 Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

12 Designation

Each transformer shall be provided with two easily-legible Stainless steel or aluminium label with the designation specified in Schedules of particulars - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A

TRF-R

13 Surge Arrestor/Divertor Brackets

Removable HV surge arrestor brackets shall be fitted at the HV side on top of the radiators. LV surge arrestor brackets shall be fitted on the LV side of the transformer if specified in Schedules of particulars. The surge arrestor bracket must be fitted with two earth conductors down to the base of the transformer tank.

14 Control and Protection

Control and protection equipment shall be provided under another specification, but provision must be made for the following control and protection functions:

a) A voltage regulating relay according to specification 12;

b) tap position indicators;

c) supervisory tap position indication according to specification 12;

d) selector switch for manual/remote operation of the tap changer, i.e. “raise” and “lower” voltage; and

e) with alarms and trip contacts for each of the following:

ALARMS:

i) 110V AC tap-changer control supply fail alarm;

ii) tap changer fail alarm; (out of stop)

iii) voltage regulating relay fail alarm;

iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

15 Marshalling Kiosks

A sheet steel, vermin-proof, well ventilated and weather proof marshalling kiosk of approved construction shall be mounted on the transformer with suitable rubber mountings to ensure no vibration. The kiosk interior and exterior painting shall be as specified.

A lockable door with “lift-off” type hinges and adequate sealing to prevent the ingress of water in the kiosk, shall be provided in the kiosk.

To prevent internal condensation an approved type of metal-clad heater shall be provided controlled by a 5A circuit-breaker inside the kiosk. Ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. Door-operated switches shall control interior illumination.

All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

The kiosk shall be divided into separate compartments for the mounting of the following groups of equipment and shall be clearly labelled on the outside of the kiosk to identify the compartments:

a) Temperature indicators, test links and ammeter for the winding temperature indicator circuits as specified;

b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. ($35mm^2$ cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

16 Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

17 INSPECTION AND TESTS

17.1 Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

17.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

17.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

17.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

17.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

17.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

17.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification.

18 MISCELLANEOUS

18.1 Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

PART 10.3A : 20MVA 132/11kV TRANSFORMER

SPECIFICATION No. : PT.61.4/0-07

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 20 MVA 132/11 kV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with this the current editions of specification **NRS 054 The transformer shall also comply with the following items other wise specified as in the NRS 054**

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in NRS 054 the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. TAPCHANGER DETAIL

The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type. The OLTC operation principle should use vacuum cells instead of copper tungsten arcing contacts and this OLTC should be maintenance free up to 300.000 switching operations. No time or condition based maintenance intervals are applicable, no additional equipment shall be necessary to achieve this limit.

The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

The OLTC(s) shall be mounted into the transformer. The diverter switches with vacuum cells or selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

Tapchanger Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.	
b)	Make and Carry for 1 sec	10 Amp	
c)	Continuous carry	5 Amp	
d)	Breaking capacity for d.c. when the control circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

5 Transformer earthing and connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

a) from the high-voltage neutral to the earth point on the bottom of the transformer;

b) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

c) two (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

d) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800°C or approved clamping to withstand the specified fault levels

6 Main Terminals

The transformers shall be provided with outdoor type bushing insulators on the HV and LV terminals mounted on the top main cover.

7 Bushings

All bushings for 22kV voltages and higher including the neutral bushing/s shall be supplied with a capacitor cap.

8 Cable Boxes

If specified in the particulars and guaranties LV cable boxes for PILC 650mm single core cables three per phase shall be provided with suitable armour clamps. Suitable I0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

All cable boxes shall be air ventilated, as specified in Schedules of particulars Cable boxes shall have inspection covers to remove and disconnect the cables and links when required

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables to a flexible clamp.

9 Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

10 Conservator Tank

IF not other wise specified in the particulars and guaranties an air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

11 Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

12 Designation

Each transformer shall be provided with two easily-legible Stainless steel or aluminium label with the designation specified in Schedules of particulars - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A	TRF-R

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iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

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All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

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b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. (35mm^2 cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

16 Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

17 INSPECTION AND TESTS

17.1 Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

17.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

17.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

17.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

17.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

17.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

17.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification.

18 MISCELLANEOUS

18.1 Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

PART 10.3B : 20 MVA 132/11KV TRANSFORMER

SPECIFICATION No : PT.61.3/01-2007 – Rev 0 (Previous No: PT.61/0-98)

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 20 MVA 132/11 kV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with this specification and the current editions of the following standards, except where otherwise specified:

	IEC	SABS
Power transformer	76-1,60076-2,60076-3	NRS 054
Bushings	137	102, 1037
Oil	296, 296A,156	555
Motors	72	
Current transformers	185	
Tap changers	214	
Cable sealing boxes		
Corrosion prevention and paint protection systems		679
Insulation		
High voltage testing	52, 60, 270	
Relay and contacts	255	

Sound levels emitted by transformer NEMA TR1-0.06

Sound measurements NEMA TR1-9.04

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in BS 171, the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. ERECTION

The tender price shall include for off-loading and erecting of the transformers. The tender price shall include for first filling the complete transformers and associated oil filled equipment, with oil to the correct temperature level and it shall include for the undertaking of drying-out process which may be necessary to ensure that the transformers are ready for operation before handing over.

Erection shall include off-loading, lifting, handling, positioning, oil filling, earthing and installation of the transformers together with all materials and ancillary equipment supplied on the contract works for a complete installation, including levelling, grouting and any provision deemed necessary to prevent movement of transformer on its base in service, and also the provision of all necessary staging, sleepers and lifting tackle and appliances.

Erection shall further include filtering of oil and drying out and testing and checking processes which may be necessary to ensure that the transformers are ready for operation before handing over, together with the provision of the necessary materials, apparatus and instruments for these processes. All items provided for erection shall be removed from site when erection is completed. All site installation, testing and commissioning work shall be subject to the approval of the Engineer in all respects and shall be carried out strictly in accordance with the Conditions of Contract.

5. DESIGN DETAILS

Rating

The transformers shall be capable of operating continuously and without injury under the stated service conditions on any tapping, with the primary winding carrying the full CMR stated in the Schedule of Particulars and Guarantees at the no-load voltage corresponding to the tapping in use. With the -5% tapping in use and the voltage on the untapped winding maintained at the specified LV voltage, the limits of temperature rises specified in BS 171 shall not be exceeded.

Tenderers shall state in the particulars and guarantees the maximum period, for which the transformers can be operated at l00% of CMR, after continuously operating at CMR at an ambient temperature of 25 °C in the minimum tap position.

Thermal Design Requirements

The transformer shall be of the oil-immersed type fitted with a conservator and shall be suitable for outdoor and indoor installation respectively and shall generally comply with the requirements of BS171.

The type of cooling system that is required for these transformers is ONAN for the full loading conditions specified.

The radiators for outdoor transformers are to be tank mounted or shall be separately mounted radiator banks if specified.

The transformer shall be designed for a continuous maximum rating (C.M.R.) of 20 MVA for 3 hours on the 132 kV minus 5% tap supplying 11 kV without exceeding the temperature rise limits specified in IEC 60076-2 Clause 4.2.

The transformer shall further be designed to operate at 23 MVA for 3 hours on the 132 kV minus 15% tap, and after operating for several hours at 20 MVA at an ambient temperature of 30deg.C, without exceeding the limitations specified in Clause 3 of IEC Publication 60076-2

The transformer radiators shall be designed to fit a cooling fan if required for the abnormal condition of loading the transformer with 25 MVA for 3 hours

Voltage Regulation and Tappings

Variation of the normal ratio of the transformer from 132 kV plus 5%/11 kV to 132 kV minus 15%/11 kV to minus 15%/11 kV shall be provided by on-load-tap-changing in 12 discrete steps of 1,667% each.

Notwithstanding any provision made elsewhere under this clause, not less than 11 000 V shall be maintained between phases at the low-voltage terminals for an input of 132 kV minus 5% applied to the high-voltage terminals at C.M.R. and unit to 0,8 lagging power factor when the 132 kV minus 15% tapping is selected.

The voltage regulation from no load to C.M.R with a constant voltage on the high-voltage side, at unity and 0,8 lagging power factor respectively shall be stated by Tenderers in the Schedule of Particulars and Guarantees.

All tappings shall be designed and rated for continuous operation at constant maximum rating (CMR) with the minimum input voltage at the HV windings -5 %.

a) The remote control switches and remote tap position indicator shall be supplied as loose apparatus. They will be mounted and wired under a separate contract, unless a remote control panel is specified in the Schedules.

b) All indicating devices shall operate correctly at any voltage between the limits of 85 percent and 115 percent of nominal value.

c) Any enclosed compartment not oil filled shall be adequately ventilated. A metal clad heater shall be provided in the driving mechanism chamber and connected in parallel with the heater in the marshalling kiosk. All contractors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation.

d) The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type. The OLTC operation principle should use vacuum cells instead of copper tungsten arcing contacts and this OLTC should be maintenance free up to 300.000 switching operations. No time or condition based maintenance intervals are applicable, no additional equipment shall be necessary to achieve this limit.

e) The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

f) The OLTC(s) shall be mounted into the transformer. The diverter switches with vacuum cells or selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

g) If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

h) An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

i) The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

j) The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

k) Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

l) The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

m) Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

n) A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

o) The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

p) Tap change mechanism should have a local remote switch.

Impedance

The minimum positive sequence impedance on any tap shall be the value that will limit the low-voltage three-phase symmetrical fault power to 250 MVA if the voltage applied to the primary winding of the transformer equals the tapping voltage terminals and that the source impedance is zero.

The ohmic impedance on a tap divided by the square of the tap voltage shall be constant for all taps.

In order to reduce the zero sequence impedance, the transformer shall be provided with a delta tertiary winding. The tertiary winding shall be able to withstand, without damage, the effect of all possible through fault conditions affecting the main windings, as well as single-phase to earth fault on its own terminals.

One corner of the delta winding shall be brought out to two separate bushings placed adjacent to the high-voltage winding neutral bushing. The delta winding shall be closed by means of a removable bolted link of suitable rating and design.

The transformer shall be designed with particular attention to the suppression of harmonic voltages. The third harmonic shall not exceed 2% of the fundamental in amplitude.

Fault Levels

With fault levels as specified under system particulars and normal voltage maintained on the high or low-voltage terminals respectively, the transformer should withstand for three seconds an external phase-to-phase or phase-to-earth short circuit on the secondary side of the transformer. In the case of the phase-to-earth short-circuit it shall be assumed that the neutral point on the high-voltage winding is connected directly to earth and the low-voltage neutral point is connected to a NER of 3,2 ohms.

Noise and Vibration

The transformers, tap-changing equipment and supplementary cooling equipment, shall operate without undue noise and vibration and every care shall be taken in the design and manufacture to reduce noise and vibration to the level of that obtained by good modem practice.

The transformer shall be designed so that the average sound level will not exceed the values given in NEMA TRI-0.06, 1971 when measured at the factory in accordance with the conditions outlined in NEMA TRI-9.04, 1971.

In the case that the average sound level exceeds the values given in NEMA TRI-0.06, the Employer reserves the right to:

a) Reject the transformers;

b) require the contractor to take remedial measures; and

c) require the Contractor to bear the cost of any remedial measures the Employer may decide to take.

The level of vibration shall not adversely affect any connections or clamps on the transformer or cause excessive stress on any portion of the transformer.

Radio and Television Interference

The design of the transformer shall be such that they will not cause any objectionable interference with radio and television reception in the vicinity of the transformers either by direct radiation or by transmission through the power lines and system to which the transformers may be connected, when energized at full rated voltage and when delivering any load up to the continuous maximum rating.

Internal Connections

All internal connections shall be so supported to maintain clearances to each other and to earthed metal during transport and under short-circuit conditions, and to be free from vibration in normal service.

Electrical Clearances

Adequate electrical clearances shall be provided and care shall be taken to ensure that no fittings are located so as to interfere with the external connection to the bushings.

The clearances between live metal and oil pipe work, including the conservator and oil pressure relief valve, shall be adequate to withstand the assigned impulse withstand test voltage. In all cases the transformer bushings shall be tank top mounted and the above clearances shall be maintained under all operating conditions.

Cross-sectional Area of Earthing Connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations.

External earthing conductors rated in accordance with the specified fault levels shall be installed as follows:

a) From the high-voltage neutral current transformers to the earth point on the bottom of the transformer;

b) from the low-voltage neutral bushing to the low-voltage neutral current transformer to the earth point on the other bottom end of the transformer;

c) from the high-voltage neutral current transformer, the tertiary bushing and the core-earth bushing to the four earthing terminals at the base of the transformer; and

d) earth strips running down the side of the transformer must be insulated from the earth clamp.

6. CURRENT TRANSFORMERS

General

Current transformers shall be mounted in the main tank, preferably as part of the bushings. Neutral CT's shall also be mounted in the main tank providing a bolted inspection cover to remove and replace faulty current transformers. Separately mounted internal current transformers(eg.WTI CT's) shall have adjacent hand holes in the tank.

All current transformer secondary and tapping leads shall be brought out to the secondary wiring terminal box and marked for identification. A minimum of 7 strands shall be used for these leads both internally and externally to the tank.

Rating and Performance of Current Transformers

Current transformers shall comply with IEC 185. The rating and performance shall be as specified in the Particulars and Guarantees.

The following information on current transformers shall be submitted for approval before manufacturing commences:

a) Magnetization curve for one ratio.

b) Exact turns ratio on each tapping.

c) Secondary resistance on each ratio at:
   i. 20 °C; and
   ii. 70 °C.

d) Secondary leakage reactance for each ratio.

All current transformers shall be designed to mechanically and thermally withstand the short time current ratings corresponding to the fault ratings of the associated windings of the power transformer.

Current transformers shall also have impulse strength equal to that of the section of the winding in which they are located.

Current Transformer Terminal Markings

The terminal markings for the current transformers shall indicate both the polarity of the secondary terminals (also primary terminals where these exist as an integral part of the current transformer) and the current transformer designation which shall indicate the phase or neutral connections in which they appear and the sequence relative to other current transformers in that connection.

7. CONSTRUCTIONAL DETAILS

Cores

All core steel shall be selected, treated and handled with great care to ensure that finally assembled core is free from distortion and each lamination shall be insulated with a material that will not deteriorate due to pressure and the action of hot oil.

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned-copper-bridging strips shall be inserted to maintain electrical continuity between sections.

The magnetic circuit shall be earthed to the core clamping structure at one point only through a removable link placed in an accessible position beneath an inspection cover on the same side of the core as the main earth connection between the core structure and tank.

Core bolt insulation shall withstand a test voltage of 2kV at 50Hz for one minute.

The core and core clamping structure shall be of adequate strength to withstand, without damage, the stresses to which it may be subjected during handling, transportation, installation and service. All nuts shall be effectively locked by means of standard machined lock nuts. Peening of bolt ends and/or threads alone or the use of tempered pressed steel nuts, will not be acceptable.

Lifting lugs or other means shall be provided for conveniently lifting the core, and when lifting, no stress shall be imposed on any core bolt or its insulation. Unless otherwise approved, vertical tie rods shall be provided between top and bottom clamping structures.

Windings

The insulation of all windings for system voltages of 66kV and below shall not be graded and shall be fully insulated as specified in BS 171.

The insulation of all star connected windings for system voltages of 132kV and above, shall be partially graded as specified in BS 171.

All transformers shall be capable of withstanding without damage:

a) A three-phase fault on any terminals assuming that the fault level on the remaining terminals is that specified in Schedule of Particulars and Guarantees for a period of five seconds; and

b) a line to ground fault on any terminals assuming that the fault level on the remaining terminals, is that specified in Schedule of Particulars and Guarantees and that the earthed neutral of the transformer is the only earth point on the system, for a period of five seconds.

All winding insulation shall be treated to ensure that there will be no appreciable shrinkage after assembly.

Main Terminals

The transformers shall be provided with outdoor type bushing insulators or cable boxes as specified in Schedules of particulars.

Bushings

Unless otherwise specified, bushing terminals shall be copper or copper alloy cylinders capable of carrying the rated full load current and short circuit currents specified in clause 5.2.4, without any damage to the bushing or its components.

Bushings shall comply with the electrical characteristics specified in Schedules of particulars.

For systems voltages of 44 kV and above, only condenser bushings shall be supplied.

Rigid tubular conductors shall be used for the electrical connections to the HV and/or LV bushings. The bushings shall be furnished with suitable conductor clamps to support the tubular conductors and to allow for the expansion and contraction thereof.

The tubular conductors shall be connected to the bushing terminals by means of flexible copper or aluminium conductors.

If specified in the schedules of particulars and guarantees a composite type bushing must be supplied with light colour silicon shed

All bushings for 44kV voltages and higher shall be supplied with a capacitor cap.

Cable Boxes

Cable boxes for armoured cables shall be provided with suitable armour clamps.

Suitable l0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

Cable boxes shall be either oil or compound filled, or air ventilated, as specified in Schedules of particulars.

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables specified in Schedules of particulars. (Part 4A)

Disconnecting Chambers

Where disconnecting chambers are specified in Schedules of particulars, the cable box bushing shall be attached to the back-plate of the cable box (or a separate backing-plate) to permit removal of the disconnecting chamber from the cable box (and cables) without the necessity of draining oil or compound from the cable box.

The disconnecting chambers shall be fitted with easily removable bolted links to facilitate separate testing of the cable without disturbing its connections, and a suitable and easily accessible earthing terminal for connection of the transformer windings to earth during this process. It shall be possible to get access to the links from the outside by means of inspection opening(s).

General

For identical transformers, the cable boxes and disconnecting chambers shall be jig-drilled and fabricated so as to permit interchange-ability of the transformers.

Tanks and Radiators

Corrugated tanks are not acceptable. The main tank cover joint shall be welded with a fireproof gasket preventing dirt of entering during welding or removal of the weld.

Tanks and fittings shall be of such a shape that water cannot collect at any point on the outside surfaces. It must also not be possible for gas to collect inside the tank unless such voids are connected by means of pipes to the main explosion ventilator pipe.

Guides shall be provided inside each tank to locate the core and windings centrally.

The base and tank of each transformer shall be so designed that it shall be possible to move the complete transformer, filled with oil, in any direction or to jack it up without structural damage or impairment of the oil-tightness of the transformer. A design, which necessitates slide rails being placed in a particular position or special detachable under base, shall not be used unless specifically approved.

Suitably proportioned manhole covers shall be provided in the tank cover to afford easy access to the lower ends of bushings and upper portions of the core and winding assembly.

The radiators shall be detachable with lifting eyes and shall be provided with drain plugs or valves at their lowest points and vent plugs at the highest point. Isolating valves shall be provided immediately adjacent to the main tank to enable the radiators to be removed without draining the oil in the transformer tank or cooler bank.

All oil pipe connections above 12 mm diameter shall be fitted with flanges.

The transformer tank, radiators and complete tap changer (including barrier boards) shall be capable of withstanding a full vacuum (i.e. 760 mm of mercury at sea level).

In addition to the requirements of the test prescribed in IEC Publication 137: Clause 25, "Test for the efficiency of the seal", which shall be met by all bushings to which it is applicable, the sealing of the bushings against the ingress of atmospheric air and moisture via the surface of the bushing stem, to the transformer tank, shall be proved by a test on one bushing of each type used.

The bushing mounted on a tank as described in IEC Publication 137: Clause 25 A2, shall be tested by drawing a full vacuum on the (empty) tank and then sealing off the tank from the means used to evacuate it.

The stem or terminal shall be considered satisfactory, if, after a lapse of two hours, the vacuum has been fully maintained.

The tank and cooling equipment shall be so designed that the vacuum treatment can be done on site.

Tank stiffeners shall not be installed in position where welded seams can be covered up. The tank and cover shall be designed so that local heating due to stray flux in any Structural parts shall not exceed the temperature limit specified for the transformer, and shall not cause temperature indication errors in the thermometer pockets.

All radiators shall be hot dipped galvanised.

No holes shall be drilled to bolt the cover to the tank. The main tank/cover joint shall be welded. A fireproof gasket shall be included to prevent foreign matter entering the transformer during welding or dewelding. The joint shall be designed to permit removal of the weld with minimum damage to the mating flanges, and to leave them adequate for rewelding.

Prior to above and to enable oil filling and tests to be done, a suitable seal shall be placed between the cover and the tank and two shall then be clamped together to form an oil tight sealed unit.

Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

The Contractor shall submit details of gaskets material for approval.

Main Terminal Markings

All terminals shall be marked to correspond with the markings on the diagram plate.

Characters shall be marked in relief adjacent to their appropriate terminals. The characters may be of brass, steel or other acceptable metal and shall be permanently fixed to the tank, by means of brazing or welding.

Painting and Galvanising

All interior and exterior metal surfaces subject to corrosion shall be thoroughly cleaned by sand-blasting, shot-blasting or other approved methods before painting. All exterior surfaces shall be given a priming coat of anti-corrosion and oil-resisting paint, followed by two coats of weather and oil-resisting paint of good quality to colour No 632 of BS 381, having a minimum total dry film thickness of 0.127 mm. The interior surfaces of the conservators shall be finished with a coat of light-coloured oil-resisting paint.

Conservators should be painted white for all sizes of transformers.

All cabinet interior shall have at least one priming coat and one finishing coat of gloss-white paint or enamel.

Should any paintwork be damaged during transit or erection, this shall be made good on site.

All interior and exterior surfaces subject to corrosion that cannot readily be painted, shall be heavily galvanised (0.1079mm average thickness) by the hot-dip process. Bolts and nuts associated with galvanised parts shall be hot-dipped galvanised, electro-galvanised or sheradized and shall meet the test prescribed in BS 729, that is, four dips in copper sulphate solution.

8. FITTINGS

The transformers shall be supplied complete with all fittings required by BS 171 including the following:

Conservator Tank

The conservator tank shall be fitted with a removable end on which the oil gauge shall be mounted. The conservator tank shall be mounted to slope slightly downwards towards the drain valve, which shall be adjacent to the removable end and shall contain no pocket, which is not drained by the drain valve.

The pipe connecting the conservator to the tank shall extend at least 50 mm into the conservator and shall be brought out from the highest point of the main tank cover. A valve shall be provided immediately adjacent to the conservator. All pockets and bushing turrets of the main tank and tap changer selector switch chamber, where this is separate from the main tank, shall be connected into this pipe between the transformer and the Buchholz relay.

The capacity of the conservator shall be such that the oil will not overflow or fall below the Buchholz relay floats for oil temperatures from -10°C to 100°C.

Brackets attached to the tank for the purpose of supporting the oil conservator, shall be arranged to be independent of the tank cover.

An air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

Dial Type Oil Gauges

Dial type oil gauges shall be of the magnetically operated type, in which breakage of the gauge glass will not release any oil. Such gauges shall clearly indicate the oil level when viewed from ground level through the temperature range of -10°C to 90°C. The gauge shall be fitted with an ungrounded low oil level alarm contact.

Silica Gel Breathers

Silica gel breathers shall have a window for inspection of the condition of the silica gel and oil cup or other device to prevent continuous contact of the silica gel with the air outside the transformer. The quantity of silica gel shall be equal to 0,3 kg per 1000 litres of total oil content, unless otherwise approved by the Engineer.

Pressure Relief Device

The pressure relief valve(s) shall be fitted to the transformer tank wall in the vertical plane and arranged to be self-resealing and provide with contacts to indicate the “operated" condition, and also a mechanically operated, manually reset operation indicator.

A pressure relief device must be fitted on the tap-changer tank and shall provide a free contact for tripping.

Buchholz Relays

Buchholz relays shall be of the double float or bucket type and shall be of approved manufacture.

The gas release cock for the relay shall be placed within easy reach from ground level and connected to the relay by small-bore non-ferrous tubing. The sight window of the relays shall be readily visible from ground level. The relay shall be fitted with tripping and alarm contacts and shall be so designed that the relay can be mechanically operated for testing purposes.

The relays shall be mounted in a straight run of pipe at least 350mrn long on the transformer side and 230mm long on the conservator side, rising at an angle of 3 to 7 degrees to the horizontal.

Winding Temperature Indicators

Winding temperature indicators shall be of the dial type, preferably compensated for changes in ambient temperature, and shall have a load temperature characteristic approximately the same as the hot-spot of the windings. The current transformer for operating the indicator shall be built into the main transformer tank and shall be located to reflect the maximum hot spot temperature of the transformer. The CT leads shall be wired out to the indicating instrument and the compensation shall be done in the instrument.

The indicators are to be provided with a dial indicating the temperature in degrees Celsius and fitted with a resettable maximum temperature indicator. A pair of adjustable alarm contacts, one for alarm and one for trip, shall be provided. It shall be possible to set each contact to close at a predetermined temperature.

The instruments shall be mounted on a non-vibrating mounting, which shall be provided by the Contractor.

Dial Type Oil Thermometers

Dial type oil thermometers shall be graduated in °C for registering "top oil" temperatures. The instrument shall be provided with a resettable maximum temperature indicator and a pair of adjustable alarm contacts shall be provided for tripping purposes.

The thermometer for each transformer shall be mounted adjacent to the winding temperature indicator in the same floor mounted cubicle.

The oil, temperature instrument must be supplied with a PT100 transducer able to read 0 - 150°C with a output of 0 - 5mA (100 ohm at 0°C)

Thermometer Pockets

Thermometer pockets shall be fitted with a captive screw cap.

Alarm and Trip Contacts and Auxiliary Relays

All alarm and trip contacts and auxiliary relays shall comply with the relevant requirements of IEC 255.

Alarm and tripping contacts shall be provided with electrically independent and ungrounded circuits and shall be insensitive to vibration and earth tremors.

Alarm contacts shall be suitable for making and breaking up to 20 W DC, inductive load- at the specified alarm voltage. Trip contacts shall be suitable for making and carrying for 0.2 seconds a current corresponding to 150 W at the specified tripping voltage.

Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

Rating and Diagram Plate

Rating and diagram plates shall be to BS 171 and shall be engraved, stamped or embossed on brass or stainless steel.

The following information shall also be indicated on the rating and diagram plates:

a) Connection diagram;

b) insulation levels; and

c) full details of each current transformer's location, polarity, secondary terminal markings for each ratio, test winding terminal markings, test winding current rating and the maximum permissible test duration, also, all the information required IEC 185, as applicable, with the provision that no information need be duplicated.

The diagram plate shall be fixed to the transformer in such a position that it can be easily read by a person standing at ground level.

Designation

Each transformer shall be provided with two easily-legible brass or aluminium label with the following designation - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A	TRF-R

Earthing Terminal

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

e) from the high-voltage neutral to the earth point on the bottom of the transformer;

f) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

g) tow (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

h) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800deg.C or approved clamping to withstand the specified fault levels

Lifting Lugs

Lifting lugs shall be designed to lift the complete assembled transformer with oil.

Jacking Pads

Not less than four suitably and symmetrically placed jacking pads shall be provided in positions, which will not be impeded when the transformer is loaded onto the transport vehicle.

Each jacking pad shall be designed to support at least half of the total mass of the transformer complete with oil.

Unless otherwise approved, the heights of the jacking pads above the bottom of the transformer base and the unimpeded working surface of the jacking pads, shall be as follows:

a) Minimum/maximum height of jacking pad above base: 650/700 mm;

b) unimpeded working surface: 300 x 300 mm; and

c) the provisions made for transporting the transformer shall leave the lifting lugs and the jacking pads clear of obstructions so that their function may be fulfilled when the transformer is in position on the transporting vehicle.

Surge Arrestor/Divertor Brackets

Removable HV surge arrestor brackets shall be fitted at the HV side on top of the radiators and LV surge arrestor brackets shall be fitted on the LV side of the transformer.

9. AUTOMATIC VOLTAGE CONTROL

If specified in Schedules of particulars, each transformer shall be provided with an automatically operated "on-load" tap changer on the high voltage windings of the transformer.

General

The tap changer shall be capable of altering secondary the voltage in the steps specified in Schedules of particulars. This may be adjusted to fit the manufacturer's standard equipment. Such tap changers shall work on the "step-by-step" principle.

Tap changing equipment shall be oil immersed, readily accessible and capable of carrying the same currents due to external short-circuit as the transformer windings and shall withstand the impulse and di-electric tests of the associated winding. Mercury type switches shall not be used.

The tap-changer shall be easily removable and shall be installed in an oil-filled tank isolated from the oil in the main transformer tank, and will operate with a direct drive from the drive mechanism.

Should a single compartment tap changer be supplied, a separate oil conservator (or a separate compartment in the main oil conservator) shall be provided.

The tap changer conservator shall meet the requirements applicable to the main conservator.

Drop-down tanks, which necessitate the provision of pits in the foundations, are not acceptable.

A tap position indicator and non-resettable operation counter shall be provided on each tap change drive mechanism.

Tap positions shall be numbered such that, for any given applied voltage, an increase in tap number means an increase in controlled voltage and vice versa.

The terms "raise" and "lower" shall be deemed to mean, "raise voltage and tap position number" and "lower voltage and tap position number" respectively and all drawings and instructions shall clearly indicate this fact.

A diagram or chart shall be provided for the tap changer drive giving the relative timing of all contacts for a normal tap step operation and for a transition step.

The Contractor shall indicate, preferably on the OLTC drive schematic diagram, which requirements each device is intended to satisfy.

The equipment shall also be arranged to ensure that when a tap change has been commenced, it shall be completed independently of the operation of the control relays or switches. If a failure of the auxiliary supply during a tap change or any other contingency would result therein that the movement not be completed, approved means shall be provided to safeguard the transformer and its auxiliary equipment.

A contact, wired out to separate terminals, shall be provided for monitoring of the tripping of the HV circuit breaker controlling the transformer in the event of an over-current occurring simultaneously with the operation of the tap changer diverter switch. This monitoring contact shall be arranged to:

1.) Close not less than 0.12 seconds and not more than 2.0 seconds before the diverter switch contacts part and shall be arranged so that, if the diverter switch is going to operate, they will close within the specified period; and

2.) open as soon as possible but not less than 0.15 seconds after the diverter switch contacts have opened fully.

Where it is necessary to remove parts or the whole of the on-load tap changer for transport purposes, it shall be possible to complete erection on site with the transformer windings covered with oil.

Tap Transfer Equipment

The tap transfer equipment shall be so designed that it will not be possible for a portion of the main transformer windings to be short-circuited, except through a current limiting resistance or reactance, or for the main winding to be open-circuited.

Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.
b)	Make and Carry for 1 sec	10 Amp
c)	Continuous carry	5 Amp
d)	Breaking capacity for d.c. when the control	

	circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

Control and Protection Equipment Detail

Control and protection equipment shall be provided under another specification, but provision must be made for the following control and protection functions:

a) A voltage regulating relay according to specification 12;

b) tap position indicators;

c) supervisory tap position indication according to specification 12;

d) selector switch for manual/remote operation of the tap changer, i.e. “raise” and “lower” voltage; and

e) with alarms and trip contacts for each of the following:

ALARMS:

i) 110V AC tap-changer control supply fail alarm;

ii) tap changer fail alarm; (out of stop)

iii) voltage regulating relay fail alarm;

iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

Marshalling Kiosks

A sheet steel, vermin-proof, well ventilated and weather proof marshalling kiosk of approved construction shall be mounted on the transformer with suitable rubber mountings to ensure no vibration. The kiosk interior and exterior painting shall be as specified.

A lockable door with "lift-off" type hinges and adequate sealing to prevent the ingress of water in the kiosk, shall be provided in the kiosk.

To prevent internal condensation an approved type of metal-clad heater shall be provided controlled by a 5A circuit-breaker inside the kiosk. Ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. Door-operated switches shall control interior illumination.

All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

The kiosk shall be divided into separate compartments for the mounting of the following groups of equipment and shall be clearly labelled on the outside of the kiosk to identify the compartments:

a) Temperature indicators, test links and ammeter for the winding temperature indicator circuits as specified;

b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. (35mm^2 cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

10. SECONDARY WIRING AND TERMINAL BOXES

All secondary wiring used on the transformer or on auxiliary equipment attached to the transformer shall be stranded conductor (minimum 7 strands) to avoid fracture due to vibration. The wiring shall be PVC insulated and shall conform to SABS 150. Wiring from current transformers shall have a minimum cross-sectional area of $4mm^2$. All other wiring shall have a minimum cross-sectional area of 2,5 mm^2.

All wiring from alarm and tripping contacts or any other equipment on the transformer requiring connection to external circuits, shall be either armoured, in conduit, or in metal protective channel and brought onto a terminal box situated at a convenient height on the transformer.

To prevent entry of water into the terminal boxes, the secondary wiring from the Buchholz relay and current transformers shall be arranged for bottom entry or side entry with a down loop into these boxes.

All terminal boxes shall be provided with 25 mm dia gauze covered drain hole.

All cabling between the transformer and the instrument cubicle, local control equipment and the control panel in the substation, shall be the responsibility of the Contractor.

Provision shall be made on the transformer terminal boxes and control equipment cabinets for outgoing connections of PVC/PVC/SWA/PVC cable according to SABS 150. An undrilled removable gland plate to accommodate a compression type gland shall be provided for this purpose.

Terminal boards shall be made of moulded insulating material and suitable barriers shall be provided between adjacent terminals.

Terminals shall have "Klippon" connectors. Terminals of the type where clamping screws are in direct contact with the wire are not acceptable.

Each terminal board shall be provided with not less than 10 per cent spare terminals with a minimum number of 2, unless otherwise approved. Terminal boards shall not be covered by compound.

The arrangement of the terminal boards in the boxes or panels shall be such to facilitate the entry of the incoming control or other cables. An earthing stud shall be provided in each terminal box for the earthing of current and voltage transformer secondaries.

All wiring shall be marked at each terminal according to the schematic diagram by means of interlocking numbered ferrules. The type of ferrule and the numbering used shall be to the approval of the Engineer.

11. INSPECTION AND TESTS

Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

11.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

11.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) Corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

11.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

11.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

11.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

11.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification

12. MISCELLANEOUS

Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

Instruction Manuals

Four (4) copies of Instruction Manuals in English shall be supplied the acceptance certificate will be issued. The manuals shall be complete with all relevant drawings to enable the equipment to be assembled, checked and overhauled.

Information shall be included on the following:

a) Mechanical operation of tap changers for parallel operation;

b) electrical operation of the "master follower" scheme of ap changers for parallel operation of transformers; and

c) setting and testing of winding temperature and oil temperature indicators and Buchholz relay.

Spares

The following spares shall be supplied if required in the schedule of Particulars and Guarantees:

a) One 3-phase set of tap changer current breaking transfer switch contacts per unit;

b) one set of contacts and coils for each type and size of relay and Contractor; and

c) spares shall be packed in separate cases and clearly labelled "SPARES". Each item of spares in a case shall be suitably identified by means of a metal label. The Client's order or contract number shall appear on all cases containing spares and each case shall be provided with a detailed packing list.

Oil

The transformers and tap changers shall be provided complete with oil. The oil shall comply with IEC 60296, 60296A and 156 and shall be clean and free of any trace of moisture and corrosive sulphur. Nynas 10XN is recommended

Transport

All shafts, bearings and other machined surfaces exposed for transport to site shall be given a temporary protective coating to prevent corrosion. If it is necessary to remove bushings, radiators, pipe work or any other items involving flanged joints, for transport, suitable blank flanges or covers shall be provided for both mating flanges, and these shall be gasketted and bolted in position for transport. Spare gaskets shall be provided for each such joint. All metal blanking plates shall be handed over to the Client upon completion of erection.

Where transport weight limitations permit, the transformer shall be transported with sufficient oil to cover the core and windings. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not practical, the transformer shall be maintained continuously during transport under slight positive pressure of inert gas. The pressure and the temperature at the time of filling shall be communicated to the Client and unless otherwise approved, a pressure gauge suitably protected is to be fitted to the transformer to facilitate inspection of the gas pressure on arrival at site. Every precaution shall be taken to ensure that the transformers arrive at site in a satisfactory condition without the necessity for further drying out. Transformers exceeding a transport mass of 50 000 kg must be fitted with an impact recorder.

PART 10.4 : 35 MVA 132/11KV TRANSFORMER

SPECIFICATION No. : PT.61/0-2005 (Previous No: PT.61/0-98)

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 35 MVA 132/11 kV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with this specification and the current editions of the following standards, except where otherwise specified:

	IEC	SABS
Power transformer	76-1,60076-2,60076-3	NRS 054
Bushings	137	102, 1037
Oil	296, 296A,156	555
Motors	72	
Current transformers	185	
Tap changers	214	
Cable sealing boxes		
Corrosion prevention and paint protection systems		679
Insulation		
High voltage testing	52, 60, 270	
Relay and contacts	255	

Sound levels emitted by transformer NEMA TR1-0.06

Sound measurements NEMA TR1-9.04

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in BS 171, the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. ERECTION

The tender price shall include for off-loading and erecting of the transformers. The tender price shall include for first filling the complete transformers and associated oil filled equipment, with oil to the correct temperature level and it shall include for the undertaking of drying-out process which may be necessary to ensure that the transformers are ready for operation before handing over.

Erection shall include off-loading, lifting, handling, positioning, oil filling, earthing and installation of the transformers together with all materials and ancillary equipment supplied on the contract works for a complete installation, including levelling, grouting and any provision deemed necessary to prevent movement of transformer on its base in service, and also the provision of all necessary staging, sleepers and lifting tackle and appliances.

Erection shall further include filtering of oil and drying out and testing and checking processes which may be necessary to ensure that the transformers are ready for operation before handing over, together with the provision of the necessary materials, apparatus and instruments for these processes. All items provided for erection shall be removed from site when erection is completed. All site installation, testing and commissioning work shall be subject to the approval of the Engineer in all respects and shall be carried out strictly in accordance with the Conditions of Contract.

5. DESIGN DETAILS

Rating

The transformers shall be capable of operating continuously and without injury under the stated service conditions on any tapping, with the primary winding carrying the full CMR stated in the Schedule of Particulars and Guarantees at the no-load voltage corresponding to the tapping in use. With the -5% tapping in use and the voltage on the untapped winding maintained at the specified LV voltage, the limits of temperature rises specified in BS 171 shall not be exceeded.

Tenderers shall state in the particulars and guarantees the maximum period, for which the transformers can be operated at l00% of CMR, after continuously operating at CMR at an ambient temperature of 25 °C in the minimum tap position.

Thermal Design Requirements

The transformer shall be of the oil-immersed type fitted with a conservator and shall be suitable for outdoor and indoor installation respectively and shall generally comply with the requirements of BS171.

The type of cooling system that is required for these transformers is ONAN for the full loading conditions specified.

The radiators for outdoor transformers are to be tank mounted or shall be separately mounted radiator banks if specified.

The transformer shall be designed for a continuous maximum rating (C.M.R.) of 35 MVA for 3 hours on the 132 kV minus 5% tap supplying 11 kV without exceeding the temperature rise limits specified in IEC 60076-2 Clause 4.2.

The transformer shall further be designed to operate at 38 MVA for 3 hours on the 132 kV minus 15% tap, and after operating for several hours at 35 MVA at an ambient temperature of 30deg.C, without exceeding the limitations specified in Clause 3 of IEC Publication 60076-2

The transformer radiators shall be designed to fit a cooling fan if required for the abnormal condition of loading the transformer with 25 MVA for 3 hours

Voltage Regulation and Tappings

Variation of the normal ratio of the transformer from 132 kV plus 5%/11 kV to 132 kV minus 15%/11 kV to minus 15%/11 kV shall be provided by on-load-tap-changing in 12 discrete steps of 1,667% each.

Notwithstanding any provision made elsewhere under this clause, not less than 11 000 V shall be maintained between phases at the low-voltage terminals for an input of 132 kV minus 5% applied to the high-voltage terminals at C.M.R. and unit to 0,8 lagging power factor when the 132 kV minus 15% tapping is selected.

The voltage regulation from no load to C.M.R with a constant voltage on the high-voltage side, at unity and 0,8 lagging power factor respectively shall be stated by Tenderers in the Schedule of Particulars and Guarantees.

All tappings shall be designed and rated for continuous operation at constant maximum rating (CMR) with the minimum input voltage at the HV windings -5 %.

5.3.1 The remote control switches and remote tap position indicator shall be supplied as loose apparatus. They will be mounted and wired under a separate contract, unless a remote control panel is specified in the Schedules.

5.3.2 All indicating devices shall operate correctly at any voltage between the limits of 85 percent and 115 percent of nominal value.

5.3.3 Any enclosed compartment not oil filled shall be adequately ventilated. A metal clad heater shall be provided in the driving mechanism chamber and connected in parallel with the heater in the marshalling kiosk. All contractors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation.

5.3.4 The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type. The OLTC operation principle should use vacuum cells instead of copper tungsten arcing contacts and this OLTC should be maintenance free up to 300.000 switching operations. No time or condition based maintenance intervals are applicable, no additional equipment shall be necessary to achieve this limit.

5.3.5 The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

5.3.6 The OLTC(s) shall be mounted into the transformer. The diverter switches with vacuum cells or selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

5.3.7 If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

5.3.8 An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

5.3.9 The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

5.3.10 The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

5.3.11 Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

5.3.12 The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

5.3.13 Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

5.3.14 A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

5.3.15 The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

5.3.16 Tap change mechanism should have a local remote switch.

Impedance

The minimum positive sequence impedance on any tap shall be the value that will limit the low-voltage three-phase symmetrical fault power to 250 MVA if the voltage applied to the primary winding of the transformer equals the tapping voltage terminals and that the source impedance is zero.

The ohmic impedance on a tap divided by the square of the tap voltage shall be constant for all taps.

In order to reduce the zero sequence impedance, the transformer shall be provided with a delta tertiary winding. The tertiary winding shall be able to withstand, without damage, the effect of all possible through fault conditions affecting the main windings, as well as single-phase to earth fault on its own terminals.

One corner of the delta winding shall be brought out to two separate bushings placed adjacent to the high-voltage winding neutral bushing. The delta winding shall be closed by means of a removable bolted link of suitable rating and design.

The transformer shall be designed with particular attention to the suppression of harmonic voltages. The third harmonic shall not exceed 2% of the fundamental in amplitude.

Fault Levels

With fault levels as specified under system particulars and normal voltage maintained on the high or low-voltage terminals respectively, the transformer should withstand for three seconds an external phase-to-phase or phase-to-earth short circuit on the secondary side of the transformer. In the case of the phase-to-earth short-circuit it shall be assumed that the neutral point on the high-voltage winding is connected directly to earth and the low-voltage neutral point is connected to a NER of 3,2 ohms.

Noise and Vibration

The transformers, tap-changing equipment and supplementary cooling equipment, shall operate without undue noise and vibration and every care shall be taken in the design and manufacture to reduce noise and vibration to the level of that obtained by good modem practice.

The transformer shall be designed so that the average sound level will not exceed the values given in NEMA TRI-0.06, 1971 when measured at the factory in accordance with the conditions outlined in NEMA TRI-9.04, 1971.

In the case that the average sound level exceeds the values given in NEMA TRI-0.06, the Employer reserves the right to:

a) Reject the transformers;

b) require the contractor to take remedial measures; and

c) require the Contractor to bear the cost of any remedial measures the Employer may decide to take.

The level of vibration shall not adversely affect any connections or clamps on the transformer or cause excessive stress on any portion of the transformer.

Radio and Television Interference

The design of the transformer shall be such that they will not cause any objectionable interference with radio and television reception in the vicinity of the transformers either by direct radiation or by transmission through the power lines and system to which the transformers may be connected, when energized at full rated voltage and when delivering any load up to the continuous maximum rating.

Internal Connections

All internal connections shall be so supported to maintain clearances to each other and to earthed metal during transport and under short-circuit conditions, and to be free from vibration in normal service.

Electrical Clearances

Adequate electrical clearances shall be provided and care shall be taken to ensure that no fittings are located so as to interfere with the external connection to the bushings.

The clearances between live metal and oil pipe work, including the conservator and oil pressure relief valve, shall be adequate to withstand the assigned impulse withstand test voltage. In all cases the transformer bushings shall be tank top mounted and the above clearances shall be maintained under all operating conditions.

Cross-sectional Area of Earthing Connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations.

External earthing conductors rated in accordance with the specified fault levels shall be installed as follows:

a) From the high-voltage neutral current transformers to the earth point on the bottom of the transformer;

b) from the low-voltage neutral bushing to the low-voltage neutral current transformer to the earth point on the other bottom end of the transformer;

c) from the high-voltage neutral current transformer, the tertiary bushing and the core-earth bushing to the four earthing terminals at the base of the transformer; and

d) earth strips running down the side of the transformer must be insulated from the earth clamp.

6. CURRENT TRANSFORMERS

General

Current transformers shall be mounted in the main tank, preferably as part of the bushings. Neutral CT's shall also be mounted in the main tank providing a bolted inspection cover to remove and replace faulty current transformers. Separately mounted internal current transformers(eg.WTI CT's) shall have adjacent hand holes in the tank.

All current transformer secondary and tapping leads shall be brought out to the secondary wiring terminal box and marked for identification. A minimum of 7 strands shall be used for these leads both internally and externally to the tank.

Rating and Performance of Current Transformers

Current transformers shall comply with IEC 185. The rating and performance shall be as specified in the Particulars and Guarantees.

The following information on current transformers shall be submitted for approval before manufacturing commences:

a) Magnetization curve for one ratio.

b) Exact turns ratio on each tapping.

c) Secondary resistance on each ratio at:
   i. 20 °C; and
   ii. 70 °C.

d) Secondary leakage reactance for each ratio.

All current transformers shall be designed to mechanically and thermally withstand the short time current ratings corresponding to the fault ratings of the associated windings of the power transformer.

Current transformers shall also have impulse strength equal to that of the section of the winding in which they are located.

Current Transformer Terminal Markings

The terminal markings for the current transformers shall indicate both the polarity of the secondary terminals (also primary terminals where these exist as an integral part of the current transformer) and the current transformer designation which shall indicate the phase or neutral connections in which they appear and the sequence relative to other current transformers in that connection.

7. CONSTRUCTIONAL DETAILS

Cores

All core steel shall be selected, treated and handled with great care to ensure that finally assembled core is free from distortion and each lamination shall be insulated with a material that will not deteriorate due to pressure and the action of hot oil.

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned-copper-bridging strips shall be inserted to maintain electrical continuity between sections.

The magnetic circuit shall be earthed to the core clamping structure at one point only through a removable link placed in an accessible position beneath an inspection cover on the same side of the core as the main earth connection between the core structure and tank.

Core bolt insulation shall withstand a test voltage of 2kV at 50Hz for one minute.

The core and core clamping structure shall be of adequate strength to withstand, without damage, the stresses to which it may be subjected during handling, transportation, installation and service. All nuts shall be effectively locked by means of standard machined lock nuts. Peening of bolt ends and/or threads alone or the use of tempered pressed steel nuts, will not be acceptable.

Lifting lugs or other means shall be provided for conveniently lifting the core, and when lifting, no stress shall be imposed on any core bolt or its insulation. Unless otherwise approved, vertical tie rods shall be provided between top and bottom clamping structures.

Windings

The insulation of all windings for system voltages of 66kV and below shall not be graded and shall be fully insulated as specified in BS 171.

The insulation of all star connected windings for system voltages of 132kV and above, shall be partially graded as specified in BS 171.

All transformers shall be capable of withstanding without damage:

a) A three-phase fault on any terminals assuming that the fault level on the remaining terminals is that specified in Schedule of Particulars and Guarantees for a period of five seconds; and

b) a line to ground fault on any terminals assuming that the fault level on the remaining terminals, is that specified in Schedule of Particulars and Guarantees and that the earthed neutral of the transformer is the only earth point on the system, for a period of five seconds.

All winding insulation shall be treated to ensure that there will be no appreciable shrinkage after assembly.

Main Terminals

The transformers shall be provided with outdoor type bushing insulators or cable boxes as specified in Schedules of particulars.

Bushings

Unless otherwise specified, bushing terminals shall be copper or copper alloy cylinders capable of carrying the rated full load current and short circuit currents specified in clause 5.2.4, without any damage to the bushing or its components.

Bushings shall comply with the electrical characteristics specified in Schedules of particulars.

For systems voltages of 44 kV and above, only condenser bushings shall be supplied.

Rigid tubular conductors shall be used for the electrical connections to the HV and/or LV bushings. The bushings shall be furnished with suitable conductor clamps to support the tubular conductors and to allow for the expansion and contraction thereof.

The tubular conductors shall be connected to the bushing terminals by means of flexible copper or aluminium conductors.

If specified in the schedules of particulars and guarantees a composite type bushing must be supplied with light colour silicon shed

All bushings for 44kV voltages and higher shall be supplied with a capacitor cap.

Cable Boxes

Cable boxes for armoured cables shall be provided with suitable armour clamps.

Suitable I0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

Cable boxes shall be either oil or compound filled, or air ventilated, as specified in Schedules of particulars.

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables specified in Schedules of particulars. (Part 4A)

Disconnecting Chambers

Where disconnecting chambers are specified in Schedules of particulars, the cable box bushing shall be attached to the back-plate of the cable box (or a separate backing-plate) to permit removal of the disconnecting chamber from the cable box (and cables) without the necessity of draining oil or compound from the cable box.

The disconnecting chambers shall be fitted with easily removable bolted links to facilitate separate testing of the cable without disturbing its connections, and a suitable and easily accessible earthing terminal for connection of the transformer windings to earth during this process. It shall be possible to get access to the links from the outside by means of inspection opening(s).

General

For identical transformers, the cable boxes and disconnecting chambers shall be jig-drilled and fabricated so as to permit interchange-ability of the transformers.

Tanks and Radiators

Corrugated tanks are not acceptable. The main tank cover joint shall be welded with a fireproof gasket preventing dirt of entering during welding or removal of the weld.

Tanks and fittings shall be of such a shape that water cannot collect at any point on the outside surfaces. It must also not be possible for gas to collect inside the tank unless such voids are connected by means of pipes to the main explosion ventilator pipe.

Guides shall be provided inside each tank to locate the core and windings centrally.

The base and tank of each transformer shall be so designed that it shall be possible to move the complete transformer, filled with oil, in any direction or to jack it up without structural damage or impairment of the oil-tightness of the transformer. A design, which necessitates slide rails being placed in a particular position or special detachable under base, shall not be used unless specifically approved.

Suitably proportioned manhole covers shall be provided in the tank cover to afford easy access to the lower ends of bushings and upper portions of the core and winding assembly.

The radiators shall be detachable with lifting eyes and shall be provided with drain plugs or valves at their lowest points and vent plugs at the highest point. Isolating valves shall be provided immediately adjacent to the main tank to enable the radiators to be removed without draining the oil in the transformer tank or cooler bank.

All oil pipe connections above 12 mm diameter shall be fitted with flanges.

The transformer tank, radiators and complete tap changer (including barrier boards) shall be capable of withstanding a full vacuum (i.e. 760 mm of mercury at sea level).

In addition to the requirements of the test prescribed in IEC Publication 137: Clause 25, "Test for the efficiency of the seal", which shall be met by all bushings to which it is applicable, the sealing of the bushings against the ingress of atmospheric air and moisture via the surface of the bushing stem, to the transformer tank, shall be proved by a test on one bushing of each type used.

The bushing mounted on a tank as described in IEC Publication 137: Clause 25 A2, shall be tested by drawing a full vacuum on the (empty) tank and then sealing off the tank from the means used to evacuate it.

The stem or terminal shall be considered satisfactory, if, after a lapse of two hours, the vacuum has been fully maintained.

The tank and cooling equipment shall be so designed that the vacuum treatment can be done on site.

Tank stiffeners shall not be installed in position where welded seams can be covered up. The tank and cover shall be designed so that local heating due to stray flux in any Structural parts shall not exceed the temperature limit specified for the transformer, and shall not cause temperature indication errors in the thermometer pockets.

All radiators shall be hot dipped galvanised.

No holes shall be drilled to bolt the cover to the tank. The main tank/cover joint shall be welded. A fireproof gasket shall be included to prevent foreign matter entering the transformer during welding or dewelding. The joint shall be designed to permit removal of the weld with minimum damage to the mating flanges, and to leave them adequate for rewelding.

Prior to above and to enable oil filling and tests to be done, a suitable seal shall be placed between the cover and the tank and two shall then be clamped together to form an oil tight sealed unit.

Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

The Contractor shall submit details of gaskets material for approval.

Main Terminal Markings

All terminals shall be marked to correspond with the markings on the diagram plate.

Characters shall be marked in relief adjacent to their appropriate terminals. The characters may be of brass, steel or other acceptable metal and shall be permanently fixed to the tank, by means of brazing or welding.

Painting and Galvanising

All interior and exterior metal surfaces subject to corrosion shall be thoroughly cleaned by sand-blasting, shot-blasting or other approved methods before painting. All exterior surfaces shall be given a priming coat of anti-corrosion and oil-resisting paint, followed by two coats of weather and oil-resisting paint of good quality to colour No 632 of BS 381, having a minimum total dry film thickness of 0.127 mm. The interior surfaces of the conservators shall be finished with a coat of light-coloured oil-resisting paint.

Conservators should be painted white for all sizes of transformers.

All cabinet interior shall have at least one priming coat and one finishing coat of gloss-white paint or enamel.

Should any paintwork be damaged during transit or erection, this shall be made good on site.

All interior and exterior surfaces subject to corrosion that cannot readily be painted, shall be heavily galvanised (0.1079mm average thickness) by the hot-dip process. Bolts and nuts associated with galvanised parts shall be hot-dipped galvanised, electro-galvanised or sheradized and shall meet the test prescribed in BS 729, that is, four dips in copper sulphate solution.

8. FITTINGS

The transformers shall be supplied complete with all fittings required by BS 171 including the following:

Conservator Tank

The conservator tank shall be fitted with a removable end on which the oil gauge shall be mounted. The conservator tank shall be mounted to slope slightly downwards towards the drain valve, which shall be adjacent to the removable end and shall contain no pocket, which is not drained by the drain valve.

The pipe connecting the conservator to the tank shall extend at least 50 mm into the conservator and shall be brought out from the highest point of the main tank cover. A valve shall be provided immediately adjacent to the conservator. All pockets and bushing turrets of the main tank and tap changer selector switch chamber, where this is separate from the main tank, shall be connected into this pipe between the transformer and the Buchholz relay.

The capacity of the conservator shall be such that the oil will not overflow or fall below the Buchholz relay floats for oil temperatures from -10°C to 100°C.

Brackets attached to the tank for the purpose of supporting the oil conservator, shall be arranged to be independent of the tank cover.

An air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

Dial Type Oil Gauges

Dial type oil gauges shall be of the magnetically operated type, in which breakage of the gauge glass will not release any oil. Such gauges shall clearly indicate the oil level when viewed from ground level through the temperature range of -10°C to 90°C. The gauge shall be fitted with an ungrounded low oil level alarm contact.

Silica Gel Breathers

Silica gel breathers shall have a window for inspection of the condition of the silica gel and oil cup or other device to prevent continuous contact of the silica gel with the air outside the transformer. The quantity of silica gel shall be equal to 0,3 kg per 1000 litres of total oil content, unless otherwise approved by the Engineer.

Pressure Relief Device

The pressure relief valve(s) shall be fitted to the transformer tank wall in the vertical plane and arranged to be self-resealing and provide with contacts to indicate the “operated" condition, and also a mechanically operated, manually reset operation indicator.

A pressure relief device must be fitted on the tap-changer tank and shall provide a free contact for tripping.

Buchholz Relays

Buchholz relays shall be of the double float or bucket type and shall be of approved manufacture.

The gas release cock for the relay shall be placed within easy reach from ground level and connected to the relay by small-bore non-ferrous tubing. The sight window of the relays shall be readily visible from ground level. The relay shall be fitted with tripping and alarm contacts and shall be so designed that the relay can be mechanically operated for testing purposes.

The relays shall be mounted in a straight run of pipe at least 350mrn long on the transformer side and 230mm long on the conservator side, rising at an angle of 3 to 7 degrees to the horizontal.

Winding Temperature Indicators

Winding temperature indicators shall be of the dial type, preferably compensated for changes in ambient temperature, and shall have a load temperature characteristic approximately the same as the hot-spot of the windings. The current transformer for operating the indicator shall be built into the main transformer tank and shall be located to reflect the maximum hot spot temperature of the transformer. The CT leads shall be wired out to the indicating instrument and the compensation shall be done in the instrument.

The indicators are to be provided with a dial indicating the temperature in degrees Celsius and fitted with a resettable maximum temperature indicator. A pair of adjustable alarm contacts, one for alarm and one for trip, shall be provided. It shall be possible to set each contact to close at a predetermined temperature.

The instruments shall be mounted on a non-vibrating mounting, which shall be provided by the Contractor.

Dial Type Oil Thermometers

Dial type oil thermometers shall be graduated in °C for registering "top oil" temperatures. The instrument shall be provided with a resettable maximum temperature indicator and a pair of adjustable alarm contacts shall be provided for tripping purposes.

The thermometer for each transformer shall be mounted adjacent to the winding temperature indicator in the same floor mounted cubicle.

The oil, temperature instrument must be supplied with a PT100 transducer able to read 0 - 150°C with a output of 0 - 5mA (100 ohm at 0°C)

Thermometer Pockets

Thermometer pockets shall be fitted with a captive screw cap.

Alarm and Trip Contacts and Auxiliary Relays

All alarm and trip contacts and auxiliary relays shall comply with the relevant requirements of IEC 255.

Alarm and tripping contacts shall be provided with electrically independent and ungrounded circuits and shall be insensitive to vibration and earth tremors.

Alarm contacts shall be suitable for making and breaking up to 20 W DC, inductive load- at the specified alarm voltage. Trip contacts shall be suitable for making and carrying for 0.2 seconds a current corresponding to 150 W at the specified tripping voltage.

Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

Rating and Diagram Plate

Rating and diagram plates shall be to BS 171 and shall be engraved, stamped or embossed on brass or stainless steel.

The following information shall also be indicated on the rating and diagram plates:

a) Connection diagram;

b) insulation levels; and

c) full details of each current transformer's location, polarity, secondary terminal markings for each ratio, test winding terminal markings, test winding current rating and the maximum permissible test duration, also, all the information required IEC 185, as applicable, with the provision that no information need be duplicated.

The diagram plate shall be fixed to the transformer in such a position that it can be easily read by a person standing at ground level.

Designation

Each transformer shall be provided with two easily-legible brass or aluminium label with the following designation - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A	TRF-R

Earthing Terminal

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

e) from the high-voltage neutral to the earth point on the bottom of the transformer;

f) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

g) tow (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

h) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800deg.C or approved clamping to withstand the specified fault levels

Lifting Lugs

Lifting lugs shall be designed to lift the complete assembled transformer with oil.

Jacking Pads

Not less than four suitably and symmetrically placed jacking pads shall be provided in positions, which will not be impeded when the transformer is loaded onto the transport vehicle.

Each jacking pad shall be designed to support at least half of the total mass of the transformer complete with oil.

Unless otherwise approved, the heights of the jacking pads above the bottom of the transformer base and the unimpeded working surface of the jacking pads, shall be as follows:

a) Minimum/maximum height of jacking pad above base: 650/700 mm;

b) unimpeded working surface: 300 x 300 mm; and

c) the provisions made for transporting the transformer shall leave the lifting lugs and the jacking pads clear of obstructions so that their function may be fulfilled when the transformer is in position on the transporting vehicle.

Surge Arrestor/Divertor Brackets

Removable HV surge arrestor brackets shall be fitted at the HV side on top of the radiators and LV surge arrestor brackets shall be fitted on the LV side of the transformer.

9. AUTOMATIC VOLTAGE CONTROL

If specified in Schedules of particulars, each transformer shall be provided with an automatically operated "on-load" tap changer on the high voltage windings of the transformer.

General

The tap changer shall be capable of altering secondary the voltage in the steps specified in Schedules of particulars. This may be adjusted to fit the manufacturer's standard equipment. Such tap changers shall work on the "step-by-step" principle.

Tap changing equipment shall be oil immersed, readily accessible and capable of carrying the same currents due to external short-circuit as the transformer windings and shall withstand the impulse and di-electric tests of the associated winding. Mercury type switches shall not be used.

The tap-changer shall be easily removable and shall be installed in an oil-filled tank isolated from the oil in the main transformer tank, and will operate with a direct drive from the drive mechanism.

Should a single compartment tap changer be supplied, a separate oil conservator (or a separate compartment in the main oil conservator) shall be provided.

The tap changer conservator shall meet the requirements applicable to the main conservator.

Drop-down tanks, which necessitate the provision of pits in the foundations, are not acceptable.

A tap position indicator and non-resettable operation counter shall be provided on each tap change drive mechanism.

Tap positions shall be numbered such that, for any given applied voltage, an increase in tap number means an increase in controlled voltage and vice versa.

The terms "raise" and "lower" shall be deemed to mean, "raise voltage and tap position number" and "lower voltage and tap position number" respectively and all drawings and instructions shall clearly indicate this fact.

A diagram or chart shall be provided for the tap changer drive giving the relative timing of all contacts for a normal tap step operation and for a transition step.

The Contractor shall indicate, preferably on the OLTC drive schematic diagram, which requirements each device is intended to satisfy.

The equipment shall also be arranged to ensure that when a tap change has been commenced, it shall be completed independently of the operation of the control relays or switches. If a failure of the auxiliary supply during a tap change or any other contingency would result therein that the movement not be completed, approved means shall be provided to safeguard the transformer and its auxiliary equipment.

A contact, wired out to separate terminals, shall be provided for monitoring of the tripping of the HV circuit breaker controlling the transformer in the event of an over-current occurring simultaneously with the operation of the tap changer diverter switch. This monitoring contact shall be arranged to:

1.) Close not less than 0.12 seconds and not more than 2.0 seconds before the diverter switch contacts part and shall be arranged so that, if the diverter switch is going to operate, they will close within the specified period; and

2.) open as soon as possible but not less than 0.15 seconds after the diverter switch contacts have opened fully.

Where it is necessary to remove parts or the whole of the on-load tap changer for transport purposes, it shall be possible to complete erection on site with the transformer windings covered with oil.

Tap Transfer Equipment

The tap transfer equipment shall be so designed that it will not be possible for a portion of the main transformer windings to be short-circuited, except through a current limiting resistance or reactance, or for the main winding to be open-circuited.

Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.
b)	Make and Carry for 1 sec	10 Amp
c)	Continuous carry	5 Amp
d)	Breaking capacity for d.c. when the control	

	circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

Control and Protection Equipment Detail

Control and protection equipment shall be provided under another specification, but provision must be made for the following control and protection functions:

a) A voltage regulating relay according to specification 12;

b) tap position indicators;

c) supervisory tap position indication according to specification 12;

d) selector switch for manual/remote operation of the tap changer, i.e. “raise” and “lower” voltage; and

e) with alarms and trip contacts for each of the following:

ALARMS:

i) 110V AC tap-changer control supply fail alarm;

ii) tap changer fail alarm; (out of stop)

iii) voltage regulating relay fail alarm;

iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

Marshalling Kiosks

A sheet steel, vermin-proof, well ventilated and weather proof marshalling kiosk of approved construction shall be mounted on the transformer with suitable rubber mountings to ensure no vibration. The kiosk interior and exterior painting shall be as specified.

A lockable door with "lift-off" type hinges and adequate sealing to prevent the ingress of water in the kiosk, shall be provided in the kiosk.

To prevent internal condensation an approved type of metal-clad heater shall be provided controlled by a 5A circuit-breaker inside the kiosk. Ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. Door-operated switches shall control interior illumination.

All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

The kiosk shall be divided into separate compartments for the mounting of the following groups of equipment and shall be clearly labelled on the outside of the kiosk to identify the compartments:

a) Temperature indicators, test links and ammeter for the winding temperature indicator circuits as specified;

b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. (35mm^2 cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

10. SECONDARY WIRING AND TERMINAL BOXES

All secondary wiring used on the transformer or on auxiliary equipment attached to the transformer shall be stranded conductor (minimum 7 strands) to avoid fracture due to vibration. The wiring shall be PVC insulated and shall conform to SABS 150. Wiring from current transformers shall have a minimum cross-sectional area of $4mm^2$. All other wiring shall have a minimum cross-sectional area of 2,5 mm^2.

All wiring from alarm and tripping contacts or any other equipment on the transformer requiring connection to external circuits, shall be either armoured, in conduit, or in metal protective channel and brought onto a terminal box situated at a convenient height on the transformer.

To prevent entry of water into the terminal boxes, the secondary wiring from the Buchholz relay and current transformers shall be arranged for bottom entry or side entry with a down loop into these boxes.

All terminal boxes shall be provided with 25 mm dia gauze covered drain hole.

All cabling between the transformer and the instrument cubicle, local control equipment and the control panel in the substation, shall be the responsibility of the Contractor.

Provision shall be made on the transformer terminal boxes and control equipment cabinets for outgoing connections of PVC/PVC/SWA/PVC cable according to SABS 150. An undrilled removable gland plate to accommodate a compression type gland shall be provided for this purpose.

Terminal boards shall be made of moulded insulating material and suitable barriers shall be provided between adjacent terminals.

Terminals shall have "Klippon" connectors. Terminals of the type where clamping screws are in direct contact with the wire are not acceptable.

Each terminal board shall be provided with not less than 10 per cent spare terminals with a minimum number of 2, unless otherwise approved. Terminal boards shall not be covered by compound.

The arrangement of the terminal boards in the boxes or panels shall be such to facilitate the entry of the incoming control or other cables. An earthing stud shall be provided in each terminal box for the earthing of current and voltage transformer secondaries.

All wiring shall be marked at each terminal according to the schematic diagram by means of interlocking numbered ferrules. The type of ferrule and the numbering used shall be to the approval of the Engineer.

11. INSPECTION AND TESTS

Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

11.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

11.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) Corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

11.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

11.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

11.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

11.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification

12. MISCELLANEOUS

Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

Instruction Manuals

Four (4) copies of Instruction Manuals in English shall be supplied the acceptance certificate will be issued. The manuals shall be complete with all relevant drawings to enable the equipment to be assembled, checked and overhauled.

Information shall be included on the following:

a) Mechanical operation of tap changers for parallel operation;

b) electrical operation of the "master follower" scheme of ap changers for parallel operation of transformers; and

c) setting and testing of winding temperature and oil temperature indicators and Buchholz relay.

Spares

The following spares shall be supplied if required in the schedule of Particulars and Guarantees:

a) One 3-phase set of tap changer current breaking transfer switch contacts per unit;

b) one set of contacts and coils for each type and size of relay and Contractor; and

c) spares shall be packed in separate cases and clearly labelled "SPARES". Each item of spares in a case shall be suitably identified by means of a metal label. The Client's order or contract number shall appear on all cases containing spares and each case shall be provided with a detailed packing list.

Oil

The transformers and tap changers shall be provided complete with oil. The oil shall comply with IEC 60296, 60296A and 156 and shall be clean and free of any trace of moisture and corrosive sulphur. Nynas 10XN is recommended

Transport

All shafts, bearings and other machined surfaces exposed for transport to site shall be given a temporary protective coating to prevent corrosion. If it is necessary to remove bushings, radiators, pipe work or any other items involving flanged joints, for transport, suitable blank flanges or covers shall be provided for both mating flanges, and these shall be gasketted and bolted in position for transport. Spare gaskets shall be provided for each such joint. All metal blanking plates shall be handed over to the Client upon completion of erection.

Where transport weight limitations permit, the transformer shall be transported with sufficient oil to cover the core and windings. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not practical, the transformer shall be maintained continuously during transport under slight positive pressure of inert gas. The pressure and the temperature at the time of filling shall be communicated to the Client and unless otherwise approved, a pressure gauge suitably protected is to be fitted to the transformer to facilitate inspection of the gas pressure on arrival at site. Every precaution shall be taken to ensure that the transformers arrive at site in a satisfactory condition without the necessity for further drying out. Transformers exceeding a transport mass of 50 000 kg must be fitted with an impact recorder.

PART 10.5 : 40 MVA 132/11KV OR 132/33KV TRANSFORMER

SPECIFICATION No. : PT.61.6/1-2007(Previous No: PT.61/0-2005)

CONTENTS

1. SCOPE

This section of the specification provides for the manufacture, supply, testing before shipment, delivery, off-loading and positioning on a concrete base, erection, site testing, connection, handing over in a working condition and maintenance of 40 MVA 132/11 kV or 132/33KV step-down transformers with on-load tap changing and associated control and auxiliary equipment.

This specification only makes provision for transformers of which the design drawings and spares are available, on request, to local manufacturers or local recognised repair utilities for backup service and repair work after the maintenance period. Addition to this, a twelve month maintenance period is required where by the contractor will be responsible for a 24 hour response on call out.

All transformer spares must be stock in South Africa and available from the manufacturer with in 48 hours.

The manufacturer must be available with in 24 hours notice for any advice, recommendations, inspections and clarifications on the site during the maintenance period and there after.

The manufacturer must be committed for any repair, modifications and refurbishment to the transformer at any time.

2. STANDARDS

The transformer shall comply with the current editions of specification **NRS 054 The transformer shall also comply with the following items other wise specified as in the NRS 054**

3. CAPITALIZATION OF LOSSES

The following loss capitalization formula will be used but the lowest capitalized will not necessarily be accepted:

Cc = X + **33 500** Fe + **6 500** Cu
Cc = Capital cost
X = Transformer cost
Fe = Iron losses in kW
Cu = Copper losses in kW at maximum rating

If the actual losses of the transformer exceed the guaranteed losses quoted by more than the tolerances specified in NRS 054 the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer.

If, however, the actual losses are lower than the guaranteed figures, no increase in price will be allowed.

4. TAPCHANGER DETAIL

The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type. The OLTC operation principle should use vacuum cells instead of copper tungsten arcing contacts and this OLTC should be maintenance free up to 300.000 switching operations. No time or condition based maintenance intervals are applicable, no additional equipment shall be necessary to achieve this limit.

The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

The OLTC(s) shall be mounted into the transformer. The diverter switches with vacuum cells or selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

Tapchanger Driving Mechanism

The supply for the driving mechanism will be available from a 400/231 Volt ±5% 3-phase 50 Hz supply switchboard.

Thermal overload and single-phasing protection shall be provided for the drive motor. Mechanical stops are to be provided to prevent the mechanism from overrunning its end position.

For manual operation of the tap changing equipment a readily detachable handle shall be provided for manual operation. Provision shall be made to prevent the tap changer contacts from being left in an intermediate position when operated manually. A mechanical tap position indicator and operation counter shall be provided on the driving mechanism both of which shall be externally visible. Such operation counter shall have at least five digits and shall have NO provision for resetting.

The driving mechanism shall be enclosed in a dust-proof and vermin-proof cabinet provided with a separately fused heater and switch. The cabinet must be able to lock with a padlock.

A local/remote switch with raise and lower hand controls must be provided in the drive-mechanism. The tap-changer must be controlled from an 110V AC Transformer fitted in the marshalling kiosk.

A tap position encoder must be provided.

The tap position encoder must convert the tap position into a Binary Coded decimal (BCD) signal for indication purpose. The Tap position Encoder must be rail-mounted in the Tap Changer Drive Mechanism box or transformer-marshalling kiosk. Two separate potential free contacts must provide an output BCD with the following technical requirements:

a)	Rated voltage, make and break	300 V d.c./250 V a.c.	
b)	Make and Carry for 1 sec	10 Amp	
c)	Continuous carry	5 Amp	
d)	Breaking capacity for d.c. when the control circuit time constant is L/R<msec at the control voltage levels:	50V d.c.	1.0 A
		110V d.c	0.6 A
		220V d.c	0.5A
e)	Contact material	Silver, gold flashed	

The encoder must operate under the following environmental conditions:

a) Specified ambient service temperature range -10 to +55 C

b) Transport and storage temperature range -40 to +70 C

5 Transformer earthing and connections

No internal core earthing connections shall be smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations, which may be reduced to a cross-sectional area of 20 mm^2 where they are clamped between the laminations

A suitable rated and marked earthing terminal or clamp shall be provided on four sides of the tank base Two sides must continue to the top cover to accommodate the neutral earth and the surge arrester earth.

External earthing must be 16mm copper plated diameter steel rods manufacture in accordance with SABS 1063 The earth must withstand specified fault levels for three seconds and shall be installed as follows:

a) from the high-voltage neutral to the earth point on the bottom of the transformer;

b) from the tertiary or neutral bushing (if specified) and core earth to the earth point on the cover must be flat copper;

c) tow (2) separate conductors from the Surge arrestor bracket to the earthing terminals on the cooler header or tank cover.

d) earth rods running down the side of the transformer must be insulated from the earth clamp.

Copper plated rods must be connected to the tank cover exothermic according to IEEE Std 80-1986 Connection rated at 800deg.C or approved clamping to withstand the specified fault levels

6 Main Terminals

The transformers shall be provided with outdoor type bushing insulators on the HV and LV terminals mounted on the top main cover.

7 Bushings

All bushings for 44kV voltages and higher including the neutral bushing/s shall be supplied with a capacitor cap.

8 Cable Boxes

If specified in particulars and guaranties the LV cable boxes for PILC 650mm single core cables three per phase shall be provided with suitable armour clamps.

Suitable I0mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

Cable boxes shall be air ventilated, as specified in Schedules of particulars Cable boxes shall have inspection covers to remove and disconnect the cables and links when required

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables to a flexible clamp.

9 Gaskets

Gasketed joints shall be of the groove an 'O'-ring type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the o-ring manufacturer to ensure leak free seals. The material of the 'O'- ring shall be Viton rubber.

The 'O'-rings shall be moulded or pre-joined by vulcanising to the correct diameters. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

10 Conservator Tank

An air bag has to be provided in the main conservator with a dehydrating breather fitted to the bag. High and low oil level alarm contacts shall be provided together with the oil level indication. The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range and when the transformer is not loaded. The bag or system shall not prevent or restrict the draining of the conservator or the flow of oil to the transformer. The diagram and rating plate shall bear a statement that the conservator is fitted with a bag. To prevent oil filling into the bag, the oil-filling aperture shall be clearly marked. The system shall be airtight. The manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

Two approved oil gauges shall be provided to indicate the full operating range from minus 10°C to 60°C, and with the oil level at 20°C clearly marked on both gauges. One gauge shall be of the direct reading type visibly showing the oil level. The other gauge shall be fitted with a low oil level contact. This contact shall be cabled to the control panel to operate a drop flag relay. One contact on the flag relay shall be connected (in parallel with other alarm contacts) to the general transformer alarm relay.

11 Drain, filter and sampling valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

Oil sampling valves shall be 50mm NB with blanking off plate fitted with a ½" B BSP plug

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) a valve at the top and bottom of each separately mounted cooler bank;

c) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

d) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

12 Designation

Each transformer shall be provided with two easily-legible Stainless steel or aluminium label with the designation specified in Schedules of particulars - "A" and "R" with 110 mm character size and 150x300 mm label size.

TRF-A	**TRF-R**

13 Surge Arrestor/Divertor Brackets

Removable HV surge arrestor brackets shall be fitted at the HV side on top of the radiators. LV surge arrestor brackets shall be fitted on the LV side of the transformer if specified in Schedules of particulars. The surge arrestor bracket must be fitted with two earth conductors down to the base of the transformer tank.

14 Control and Protection

Control and protection equipment shall be provided under another specification, but provision must be made for the following control and protection functions:

a) A voltage regulating relay according to specification 12;

b) tap position indicators;

c) supervisory tap position indication according to specification 12;

d) selector switch for manual/remote operation of the tap changer, i.e. "raise" and "lower" voltage; and

e) with alarms and trip contacts for each of the following:

ALARMS:

i) 110V AC tap-changer control supply fail alarm;

ii) tap changer fail alarm; (out of stop)

iii) voltage regulating relay fail alarm;

iv) transformer Buchholz alarm;

v) NEC Buchholz alarm; (only if NEC is required)

vi) transformer winding temp alarm;

vii) transformer oil temp alarm;

viii) NEC oil temp alarm; (only if NEC is required)

ix) transformer oil level alarm;

x) NEC oil level alarm;

xi) cooler supply fail alarm; (only if fans are required)

xii) cooler fail alarm; (only if fans are required)

xiii) oil supply fail alarm; and (only if a pump is required)

xiv) oil pump fail alarm. (only if a pump is required)

TRIP:

i) Transformer Buchholz trip;

ii) NEC Buchholz trip; (only if NEC is required);

iii) transformer winding temp trip;

iv) transformer oil temp trip;

v) NEC oil temp trip; (only if NEC is required)

vi) tap-changer pressure trip;

vii) transformer pressure trip;

15 Marshalling Kiosks

A sheet steel, vermin-proof, well ventilated and weather proof marshalling kiosk of approved construction shall be mounted on the transformer with suitable rubber mountings to ensure no vibration. The kiosk interior and exterior painting shall be as specified.

A lockable door with "lift-off" type hinges and adequate sealing to prevent the ingress of water in the kiosk, shall be provided in the kiosk.

To prevent internal condensation an approved type of metal-clad heater shall be provided controlled by a 5A circuit-breaker inside the kiosk. Ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. Door-operated switches shall control interior illumination.

All incoming cables shall enter the kiosk from the bottom. The gland plate and associated compartment shall be sealed in an approved manner to prevent the ingress of moisture.

The kiosk shall be divided into separate compartments for the mounting of the following groups of equipment and shall be clearly labelled on the outside of the kiosk to identify the compartments:

a) Temperature indicators, test links and ammeter for the winding temperature indicator circuits as specified;

b) the control and protection equipment for the tap changer gear including an isolating switch in the incoming circuit must be capable of carrying and breaking the full load current of the motor. Provision shall be made for a 3-phase 380V ring supply. ($35mm^2$ cable);

c) terminal boards and gland plates for incoming and outgoing cables except for the 415V supply cables for tap change motors which shall terminate at the base of the compartment in which the supply is required; and

d) a miniature circuit breaker switch board with a 30A earth leakage unit and CB shall be supplied to control the plug, heater and light circuits as indicated on the schematic diagram attached. The earth leakage unit and circuit breaker shall comply with SABS 156 with a minimum fault rating of 5kA. Incoming isolators shall have a through-fault rating of at least 10kA.

A group of 30 terminals shall be provided for marshalling the 132kV isolator multicore cables in the kiosk. The trunking used for multicores shall be 80 x 100mm deep.

All CT terminals shall be fitted with SAK10 or equivalent slide links.

Glaze windows of adequate size shall be provided in the door of the kiosk opposite the temperature indicators to enable visual inspection thereof without opening the door.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

The kiosk shall be fitted with an internally mounted standard 15 amp industrial plug, switch for 250V AC supply.

Both doors shall be provided with weatherproof door-hooks in the open position.

The kiosks shall comply with the specified requirements regarding cabling and wiring, ferruling, terminal boards and links and fuses.

The kiosks shall be provided with a 240V E.S. lamp at each door on the inside of the cubicle controlled by means of door switches.

16 Labels

Cubicles shall be provided complete with labelling. Labels shall be made of durable materials and shall be engraved or etched. Dymotype labels or similar types of labels shall not be used. All labels shall be fixed mechanically without dependence on adhesives.

All labelling shall be to the approval of the Engineer.

17 INSPECTION AND TESTS

17.1 Witnessing of Tests

The Client reserves the right to appoint a representative to inspect any of the transformer manufacturing stages or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Engineer shall inspect the transformer in the following manufacturing stages:

- Transformer windings and core before assembling the transformer
- After the transformer core and windings are assembled. (applicable on transformers lager than 40MVA)
- Pretank, The manufacturer shall make an "out of tank" inspection after the oil impregnation and vacuum treatment to check the tightness of the windings, spacers, clamping arrangement and lead supports. If this "out of tank" inspection after impregnation has not been witnessed by the Client's representative, the Contractor may, at the discretion of the Client's representative, be called upon to arrange for an "out of tank" inspection after the completion of the works tests.
- Routine and type testing.
- Tank over pressure and/or dispatched from the Contractor's Works

17.2 Tests and inspections in General

The Contractor shall give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnessed tests requested. Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying

For each factory inspection tests be done outside the Gauteng area, the Contractor shall allow for travelling, subsistence and training cost of 2 Engineers or Technicians to attend the tests. If tests are done overseas, the costs shall also allow for air fares and hotel accommodation..

17.3 Routine Tests

The following additional routine tests shall be performed on each unit:

a) All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute;

b) each transformer, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without a pressure leakage for 36 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level. Detachable radiators and conservator may be tested as separate units;

c) on-load tap changing equipment shall be subjected to the manufacturers' routine operating and voltage tests; and

d) a test shall performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

e) Impulse tests (full waves and 110% chopped waves) shall be performed on all windings of all phases in accordance with IEC 60076-3

f) short-duration induced AC withstand voltage test in accordance with IEC 60076-3

g) corrosive sulphur tests on a sample of copper winding to IEC60296

h) DP test on insulation after the process cycle of the active part.

17.4 Type Tests

The following, additional tests shall be performed on the unit; the cost of which shall be included in the tender price:

a) A temperature rise test shall be performed in accordance with NRS 052 and shall clearly demonstrate that the transformer, with its own cooling equipment will not exceed the specified oil and winding temperature rises when on continuous full-load and on the principal tapping. This test shall, where possible, immediately precede the di-electric tests

b) zero sequence impedance tests and third harmonic voltage test. The Contractor shall provide a diagram showing the test results circuit, the voltages and current measured during the tests and the exact points at which the test measurements were made.

The test results shall be analysed and the equivalent star three-terminal network zero-sequence values stated in ohms referred to the higher voltage.

17.5 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the transformers from the Contractor's Works.

17.6 Impact recorder.

The Contractor will attach one impact recorder to the transformer before dispatch This will form part of the final inspection before dispatch

17.7 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the transformer is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the transformer.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification

18 MISCELLANEOUS

18.1 Contract Drawings

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title, contract number and CCP drawing number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;

b) rating and diagram plates;

c) on-load tap changer assembly drawings;

d) schematic and wiring drawings for on-load tap changer circuits, including a diagram of a complete timing cycle for the tap changer, giving:

   i) time in seconds for normal tap changer operation:

      - raise direction after previous raise; and
      - lower direction after previous raise

   ii) Time in seconds for tap changer operation where a transition step is involved:

      - raise direction after previous raise; and
      - lower direction after previous raise.

e) schematic drawings for the on-load tap changer circuits shall include the following:

   i) tap position indicator circuit.

   ii) location of each item of equipment either by means of a suitable terminal marking or legend.

f) on-load tap changer drawings shall be accompanied by a fully detailed description giving step-by-step sequence of operations including a description of the voltage regulating lockout scheme. The same references shall be used on schematic, wiring and cabling drawings;

g) wiring diagram outline and drilling details of each item of loose control equipment;

h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and

i) details of under base and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or Commission on the Contractor's behalf.

PART 10.6 : 250 MVA 400/132/22 kV and 275/132/22 KV AUTOTRANSFORMERS WITH ACCESSORIES

SPECIFICATION No : PT80.1-0-08 REV-4

GENERAL

G.1 NATURE OF WORKS

This Specification provides for the supply, delivery and off-loading on Site, erection, painting, completion, setting to work and maintenance of the 400/132/22kV-, 250MVA Autotransformer and accessories, which will operate in parallel with the future transformers.

G.2 DEFINITIONS

The following terms, where used in this Specification, shall have the following meanings respectively:

The words "approved" and "approval" shall mean approved by and approval of the Engineers.

The word "specified" shall mean specified herein or in the attached schedules.

The expression "Commencement Date" hereafter used in connection with the time from which various periods are to run, shall mean the date specified.

The expression "Ton" shall mean 1 000kg, i.e. Metric Ton".

G.3 GENERAL PARTICULARS OF SYSTEM

The following are the general particulars governing the design and working of the complete system of which the Contract Works will eventually form a part:

(a) Electrical energy will be generated at inter-connected power stations as three-phase current at a frequency specified in the Schedules, Part I, and transmitted there from by means of overhead lines and underground cables.

(b) The system will be in continuous operation during the varying atmospheric and climatic conditions occurring at all seasons.

(c) The system highest voltage will be as stated in the Schedules.

(d) The method of earthing the system neutral shall be as specified in the Schedules.

Note: "*" Revised section compared to old specification.

G.4 EXTENT OF WORK

The Contract Works shall include all work incidental thereto whether specified in detail or not, and shall comprise the following:

DEFINITE WORK

The manufacture, supply, testing, delivery to Site, described in Schedule "A:, erection, testing on Site, completion, setting to work and maintenance in accordance with the Conditions of the Contract at the prices stated in the price Schedules.

G.5 VARIANCE WITH CONDITIONS OF CONTRACT

G.5.1 In the event of there being any inconsistency between the provisions of this Specification and the Conditions of Contract, the provisions of this Specification shall prevail and shall be considered as incorporate in the Contract.

G.6 DATED FOR COMPLETION, ETC

G.6.1 The dates of readiness for inspection and testing, access to Site, delivery and completion of the various Sections of the Contract Works shall be as stated in the Schedules.

G.7 PLACES OF MANUFACTURE, ETC

G.7.1 The manufactures and the places of manufacture, testing and inspection of the various portions of the Contracts Works shall be as stated in the Schedules.

G.8 GENERAL PARTICULARS AND GUARANTEES

G.8.1 The Contract Works shall comply with the general particulars and guarantees stated in the Schedules.

G.8.2 All plant and apparatus supplied under this Contract shall be to approval.

G.8.3 The Contractor shall be responsible for any discrepancies, errors or omissions in the particulars and guarantees, whether or not such particulars and guarantees have been approved by the Engineers.

G.9 LANGUAGE, WEIGHTS AND MEASURES

G.9.1 The English language shall be used in all written communications between Tshwane, the Engineers and the Contractor with respect to the services to be rendered and with respect to all documents and drawings procured or prepared by the Contractor pertaining to the work, unless otherwise agreed by the Engineers. Labels and plates shall be inscribed in English. All weights and measures shall be expressed in SI units.

G.10 STANDARDS

G.10.1 The transformer shall comply with the latest IEC Standard, IEC 60076, IEC 60354 and ANSI/IEEE C57.

G.11 DRAWINGS, MODELS AND SAMPLES

G.11.1 A list of drawings attached to the Specification.

G.11.2 Detail outline drawings are to be submitted by the Contractor with his Tender. The Contractor shall also provide free of charge any additional drawings required by the Engineers.

G.11.3 The Contractor shall submit samples of materials as required from time to time by the Engineers.

G.11.4 The Contractor shall submit all drawings or samples of material for approval in sufficient time to permit of modifications to be made and the drawings or samples resubmitted without delaying the initial deliveries or completion of the Contract Works.

G.11.5 All dimensions marked on the drawings shall be considered correct even though measurements by scale may differ there from. Detailed drawings shall be worked to where they differ from general arrangement drawings.

G.11.6 All detail drawings submitted for approval shall be to scale. All important dimensions shall be given and the material of which each part is to be constructed shall be indicated.

G.11.7 Drawings, samples and models already submitted by the Contractor and approved by the Engineers (and such drawings, samples and models as shall be thereafter submitted by the Contractor and approved by the Engineers) shall not be departed from without the instructions in writing of the Engineers.

G.11.8 The Contractor shall be responsible for any discrepancies or errors or any omissions from the drawings, except as provided for under the Conditions of Contract whether such drawings have been approved or not by the Engineers, and no approval given by the Engineers to any drawings or samples shall relieve the Contractor from his liability to complete the Contract Works in accordance with this Specification and the Conditions of Contract or exonerate him from any of guarantees.

G.11.9 If the Contractor shall require approval of any drawings within fourteen days of its submission in order to avoid delay in the completion of the Contract Works he shall advise the Engineers to such effect when submitting the drawing.

G.11.10 All drawings, samples and models shall be submitted in accordance with the provisions of Schedules and shall become the property of Tshwane.

G.12 COMPLIANCE WITH REGULATIONS

G.12.1 All apparatus and material supplied, and all work carried out shall comply in all respects with such of the requirements of the Regulations and Acts in force in the Republic of South Africa as are applicable to the Contract Works and with any other applicable regulations to which the Tshwane is subject.

G.12.2 The Contractor and his representative shall in all ways comply with the

Tshwane's Safety Rules regarding electrical apparatus and the safety of men working thereon. No testing or other work on apparatus which has been delivered to Site and which is liable to be electrically charged from any source shall be permitted except under a written "Permit to Work" which will be issued for the purpose of the work by the Tshwane Operating Engineers.

G.13 ACCESS TO MANUFACTURER'S WORKS

G.13.1 Access to the Contractor's and Sub-contractor's works shall be granted to the representative of the Engineers for the purpose of inspection, testing and ascertaining progress.

G.14 PROGRESS REPORTS

G.14.1 The Contractor shall submit to the Engineers at such intervals and in such form as may be required by them detailed progress reports of the manufacture and erection of all Plant and materials included in the Contract.

G.15 TESTING AND INSPECTION

G.15.1 The Contractor shall carry out the tests stated in the Schedules in accordance with the conditions thereof and such additional tests as in the opinion of the Engineers are necessary to determine that the Contract Works comply with the conditions of this Specification either under test conditions (in the Manufacturer's Works, on the Site or elsewhere), or in ordinary working conditions. Type tests may be omitted at the discretion of the Engineers if satisfactory evidence is given of such tests already made on identical equipment.

G.15.2 All materials used shall also be subjected to and shall withstand satisfactorily such routine tests as are customary in the manufacture of the types of plant included in the Contract Works.

G.15.3 All tests shall be carried out to the satisfaction of the Engineers, and if required, in their presence, at such reasonable times as they may require.

G.15.4 Not less than seven days notice of all tests shall be given to the Engineers in order that they may be represented if they so desire.

G.15.5 As many test as in the opinion of the Engineers are possible shall be arranged together. Six copies of the Contractor's records of all tests shall be supplied to the Engineers.

G.15.6 Measuring apparatus shall be provided by the Engineers and if required shall be calibrated at the expense of the Contractor at an approved laboratory.

G.15.7 The Contractor shall be responsible for the proper testing of work completed or plant or materials supplied by a sub-contractor to the same extent as if the work, plant or materials were completed or supplied by the Contractor himself.

G.15.8 All apparatus, instruments and connections required for the above tests shall be provided by the Contractor, but the Tshwane will permit the Contractor to use for the tests on the Site any instruments and apparatus which may be provided permanently on the Site under this or other contracts and conditional upon the Contractor accepting liability for any damage which may be sustained by the Tshwane's equipment during the tests.

G.15.9 The Tshwane will also provide, free of charge, on the Site , electrical energy, if available, for the purpose of approved preliminary tests and for the official tests. If further preliminary tests are necessary or if further official tests are required due to the Contract Works not complying with the Conditions of this Specification, the Tshwane may call upon the Contractor to pay the costs of providing the additional electrical energy required.

G.15.10 The Contractor shall supply suitable test pieces of all materials as required by the Engineers. If required by the Engineers, test specimens shall be prepared for check testing and forwarded at the expense of the Contractor to and independent testing authority selected by the Engineers.

G.15.11 The costs of all tests and/or analyses shall (except so far as otherwise provided by the Specification) be borne by the Contractor, but the cost of check tests and/or analyses effected elsewhere than at the manufacturer's works or on the Site and the results of which are approved, will be refunded to the Contractor by Tshwane.

G.15.12 No inspection or passing by the Engineers of work, plant or materials, whether carried out by the Contractor or sub-contractor, shall relieve the Contractor from his liability to complete the Contract Works in accordance with the Contract or exonerate him from any of his guarantees.

G.16 SITE WORKS

G.16.1 The foundations, buildings, approaches and Site works will be provided under other contracts and will include all leveling, excavation, trenching, reinstatement, fencing, external rails, tracks and roadways.

G.17 FOUNDATIONS AND BUILDING WORKS

G.17.1 No foundation and building works shall be provided on this contract.

G.18 TRANSPORT AND ERECTION

G.18.1 The Contractor shall provide at his own cost and expense all plant and equipment necessary for off-loading materials and plant from railway or other vehicles, for transporting the same to its final position and for erection on Site and will be held to have satisfied himself fully as to he work involved In such off-loading, handling and transportation and erection.

G.18.2 The Contractor shall inform himself fully of the South African maximum permissible weights carried.

G.18.3 The Contractor will also be responsible for verifying the access facilities given in the Schedules.

G.19 SUPPLY OF ELECTRICAL ENERGY TO THE CONTRACTOR

G.19.1 If a suitable supply is available the Tshwane will provide, free of charge, from a fixed point or points on the Site, a supply of electrical energy of the stated kVA, for supplying power for erection tackle, drills and other tools and for lighting. The Contractor shall provide all wiring for such tackle and for lighting from the point of supply. Wiring shall be of the best quality tough rubber sheathed or other approved type, suitable fixed, protected and maintained. All necessary precautions shall be taken to ensure the safety of every person employed or working on the premises, and this shall include routine inspection of all temporary installations and portable equipment.

G.19.2 The Tshwane will give reasonable notice of discontinuation of supply, but the right is reserved in cases of emergency or where it is not reasonably practicable to give notice, to cut off the supply without previous warning. Tshwane can accept no responsibility for the consequences, which may result from the cessation of the supply.

G.20 SUPERVISION AND CHECKING OF WORK ON SITE

G.20.1 The carrying out of all work on the Site included in this Contract shall be supervised throughout by a sufficient number of qualified representatives of the Contractor who have had thorough experience of the erection and commissioning of similar Contract Works.

G.20.2 The Contractor shall ascertain from time to time what portions of the work on the Site the Engineers desire to check, but such checking shall not relieve the Contractor from his liability to complete the Contract Works in accordance with the Contract or exonerate him from any of his guarantees.

G.20.3 If at any time it appears to the Engineers that the contractor will be unable to complete any section of the Contract Works in the time stipulated, then the Contractor shall, if required by the Engineers, carry on such work outside normal working hours and shall not make any claims for any extra expense thereby incurred unless in the opinion of the Engineers the delay is due to causes for which the Contractor would be entitled to an extension of time under the Conditions of Contract.

G.20.4 The Contractor shall satisfy himself as to the correctness of all connections made between apparatus supplied under the Contract Works and apparatus supplied under any other contract before any of the former is put into operation.

G.21 RESPONSIBILITY OF CONTRACTOR

G.21.1 Until each Section of the Contract Works have been taken over or deemed to have been taken over under the Conditions of Contract, the Contractors shall be entirely responsible for the Contract Works, whether under construction, during tests or in use for the Tshwane's service.

G.21.2 The obligations of the Contractor under of the Conditions of Contract with regard to keeping a competent representative on the Site shall not cease on the erection of the plant being completed, but shall continue until the expiration of three months from the plant having been taken over or deemed to have been taken over or deemed to have been taken over under of the Conditions of Contract, or until any renewals, replacements or adjustments required before the end of such three months haven been completed to the satisfaction of the Engineers, without affection the fulfilment of the Contractor's guarantees, whichever shall be the later.

G.21.3 The said representative shall be the Contractor's supervising engineer or one of the contractor's supervising engineers approved by the Engineers and shall supervise and be responsible for the proper carrying out of such renewals, replacements or adjustments.

G.21.4 On the Contractor ceasing to be obliged to keep a supervising engineer on the Site under the foregoing provisions of this Clause, the Contractor shall, until the expiration of the period of maintenance, make such arrangements as to ensure that attendance on Site within twenty-four hours of being called upon by the Engineers of a competent supervising engineer for the purpose of carrying out any work of maintenance for which the Contractor shall be liable and during such part or parts of the said period as the Engineers shall deem it necessary, the said representative shall be continuously available on the Site.

G.21.5 Any work, which it may be necessary for the Contractor to carry out in pursuance of his obligations under the Conditions of Contract, shall be carried out so as to interfere as little as practicable with the normal operation of the Generating Station or Substation. Work on the Site shall be carried out at such time and during such hours as the Engineers may require.

G.22 OPERATING AND MAINTENANCE INSTRUCTIONS

G.22.1 The Contractor shall submit Operating and Maintenance Instructions in accordance with the Schedules.

G.23 SPARES

G.23.1 All spares apparatus shall comply with the requirements of this Specification, and in particular with those of Clause 1 of Part II with regard to interchangeability. Spares ordered within three months of placing of the Contract shall be available at the time of commissioning of the Plant.

G.23.2 All spares apparatus or materials containing electrical insulation shall be delivered in approved cases suitable for storing such parts or material over a period of years, without deterioration. The cases will remain the property of Tshwane. Each case shall have affixed to the underside of the lid a list detailing its contents.

G.24 CAPITALISATION OF LOSSES

*G.24.1 The assumed life of the transformer will be 30 years over which period the losses evaluated at 35% of the CMR will be capitalized. Tshwane does not allow any plus tolerance on individual loss figures without applying penalties. Where the losses exceed the guaranteed values in the schedules the Employer reserves the right to adjust the tender price based on an assumed transformer life of thirty (30) years, or reserve the right to reject the transformer accordingly.
The formula to be used in evaluating the transformer losses shall be as follows:
R33 500.00 Fe + R6 500.00 Cu per transformer

where Fe is the fixed loss in kilowatts at 35% CMR and Cu is the variable loss in kilowatts at CMR.

POWER TRANSFORMERS

1. GENERAL DESIGN OF APPARATUS

1.1 Any departures from the requirements of this Specification which are either proposed by the Bidder or are agreed between the Engineer, and the Bidder will be as stated in the Schedules. **Any departures which the Bidder wishes to include in his offer must be clearly state; any departures contained in letters or explanatory notes accompanying Bids will not be accepted unless entered in the Schedule**.

1.2 Except where otherwise specified or implied herein the Contract Works shall comply with the latest applicable International Standards (hereinafter referred to as "IEC"), to the latest South African Standards (hereinafter referred to as "SABS"), unless otherwise specified.

1.3 The Contract Works shall be designed to facilitate inspection, cleaning and repairs, and for operation where continuity of service is the first consideration. All apparatus shall also be designed to ensure satisfactory operation under such sudden variations of load and voltage as may be met with under working conditions on the System, including those due to faulty synchronizing and short circuits. The design shall incorporate every reasonable precaution and provision for the safety of the Contract Works and of the associated work supplied under other contracts.

1.4 The Contract Works shall be designed to operate in service with the minimum emission of noise and vibration consistent with economical use of material.

1.5 All materials used shall be of the best quality and of the class most suitable for the working under the conditions specified and shall withstand the variations of temperatures and atmospheric conditions arising under working conditions without undue stresses in any part, and also without affecting the strength and suitability of the various parts for the work which they have to perform. No welding, filling or plugging of defective parts will be permitted without the sanction in writing of the Engineer.

1.6 Corresponding parts liable to renewal shall be interchangeable. When required by the Engineers, the Contractor shall demonstrate this quality.

1.7 Cast iron shall not be used for chambers of oil-filled apparatus or for any part of the equipment, which is in tension or subject to impact stresses. This clause is not intended to prohibit the use of suitable grades of cast iron for parts where service experience has shown it to be satisfactory.

1.8 All outdoor apparatus, including bushing insulators and fittings, shall be designed so as to avoid pockets in which water can collect.

1.9 All taper pins used in any mechanism shall be of the split type complying with SABS.

1.9 All connections and contacts shall be of ample section and surface for carrying continuously the specified currents without undue heating and fixed connections shall be secured by bolts or set screws of ample size, adequately locked. Lock nuts shall be used on stud connections carrying current.

1.10 All apparatus shall be designed to minimize the risk of accidental short circuit due to animals, birds or vermin.

1.11 Galvanising shall be applied by the hot dipped process and for all parts other than steel wires shall consist of a thickness of zinc equivalent to not less than 0.6kg/m². The zinc coating shall be smooth, clean and of uniform thickness and free from defects. The preparation for galvanising and the galvanising it shall not adversely affect the mechanical properties of the coated material.of the coasted material.

1.12 All drilling, punching, cutting, bending and welding of parts shall be completed and all burrs shall be removed before the galvanising process is applied.

1.13 Galvanising of wires shall be applied by the hot process and shall meet the requirements or SABS 935. The zinc coating shall be smooth, clean and of uniform thickness and free from defects. The preparation for galvanising and the galvanising itself shall not adversely affect the mechanical properties of the wire.

1.14 Alternative processes shall not be used without the Engineer's approval. Where a metal spraying process is approved, the sprayed surface shall be painted.

1.15 Surfaces, which are in contact with oil, shall not be galvanised or cadmium plated.

1.16 Aluminum shall be of the highest purity commercially obtainable. The composition shall be stated in the Schedules, and the Contractor shall submit certificates of analyses giving the percentage and nature of any impurities.

1.17 All aluminum alloys shall be of approved compositions as stated in the Schedules.

1.18 Labels shall be provided for all apparatus such as relays, switches, fuses, contained in any cubicle or marshalling kiosk.

1.19 Descriptive labels for mounting indoors or inside cubicles and kiosks shall be of an approved material that will ensure permanence of the lettering. A matt of satin finish shall be provided to avoid dazzle from reflected light. Labels mounted on dark surfaces shall have white lettering on a black background.

1.20 All plates shall be of in corrodible material. If vitreous enameled iron plates are used the whole surface of each plate, including the back and edges, shall be properly covered and resistant to corrosion. On all plates the colours shall be permanent and free from fading. With vitreous enameled plates protective washers of suitable material shall be provided, front and back, on the securing bolts or screws.

1.21 Labeling shall be clear, concise and adequate and shall be to the approval of the Engineer, in English.

1.22 Labels shall, as far as possible, conform to the following four standard sizes:

(a) Labels for fuses and links shall measure approximately 28 – 45mm x 12 – 20mm and lettering of 3 – 7mm shall be used according to the amount of inscription required. The lettering shall have a width of stroke of approximately 1mm.

(b) Labels for relays, contractors, thermal devices and similar apparatus shall measure 65mm x 20mm and shall have lettering as specified in (a) above.

(c) Labels for controllers and change-over switches shall measure 70mm x 30mm and, where practicable, have 20mm lettering with 2mm stroke.

(d) Labels for the doors of junction boxes, marshalling kiosks and similar equipment shall measure 125mm x 50mm and have 12mm lettering with 2mm stroke.

1.23 Labels shall be attached to panels with brass screws or a aluminum rail.

1.24 The threads and hexagons of all nuts, bolts and studs of 6mm nominal diameter and above shall be an accepted International Standard. Terminal bolts or studs used for carrying current of more than 100 amperes shall not be less than 16mm in diameter. Brass terminal bolts or studs of less than 6mm in diameter shall not be used for electrical connections. Where a lesser size is necessary, stainless steel or phosphor bronze may be used down to and including 4mm diameter, provided the current carrying capacity is adequate.

1.25 All nuts and pins shall be locked in position, with the exception of those external to the transformer where, with the agreement of the Engineer, locking may be omitted. Nuts having a thread diameter not exceeding 24mm shall be locked by means of an approved design of lock washer or locking plates or special locking nuts. Above this size lock washers shall not be used. Wherever possible, bolts shall be fitted in such a manner that in the event of the nuts working loose and falling off; the bolt will remain in position.

1.26 On outdoor equipment, all bolts, nuts and washers in contact with non-ferrous parts, which carry current, shall be of phosphor bronze.

1.27 Each bolt or stud shall project at least one thread through its nut(s) but not more than 6mm or four threads, except when otherwise approved for terminal board studs or relay stems.

1.28 If bolts and nuts are placed so that they are inaccessible by means of ordinary spanners, suitable special spanners shall be provided.

1.29 Before painting or filling with oil or compound, all ungalvanised parts shall be completely clean and free from rust, scale and grease, and all external rough surfaces on castings shall be filled.

1.30 The interior of all transformer tanks and other oil filled chambers and internal structural steelwork shall be cleaned of all scale and rust by sandblasting or other approved method. These surfaces shall be painted with an oil resisting varnish or paint.

1.31 Except for nuts, bolts and washers, which may have to be removed for maintenance purposes, all external surfaces shall receive a minimum of three coats of paint.

1.32 The primary coat of approved etching primer shall be applied immediately after cleaning. The second coat shall be of an oil and weather resisting nature and of a shade or colour easily distinguishable from the primary and final coat and shall be applied after the primary coat has been touched up where necessary. The final coat shall be of a glossy, oil and weather resisting non-fading paint of approximately Shade No 632 of BS 381C. The period between the application of the second and final coats shall not exceed three months unless otherwise directed by the Engineer.

1.33 The metal surfaces of mechanism chambers and kiosks and cabinets shall be cleaned to bright metal by sandblasting or acid pickling. Immediately after cleaning a rust inhibiting phosphate coating shall be applied to provide a metal phosphate film overall strictly in accordance with the manufacturer's instructions. After 24 hours and not more than 7 days, a red lead base primer to SABS 312/1951, Type 2, Grad 2, shall be applied by brush. Finally, three coats of paint shall be applied.

1.34 Nuts, bolts and washers, which may have to be removed for maintenance purposes, shall receive a minimum of one coat of paint after erection.

1.35 All interior surfaces of mechanism chambers and kiosks except those, which have received anti-corrosion treatment, shall receive three coats of paint applied to the thoroughly cleaned metal surface. The final cost shall be of a light coloured anti-condensation mixture.

1.36 Damage to paintwork incurred during transport and erection shall be made good by thoroughly cleaning the damaged portion and applying the full number of coats of paint that had been applied before the damage was caused.

1.37 If the Contractor is delayed through no fault of his own in erecting the equipment and because of such delay is required to apply the final coat before the stage at which this would normally be done, the Purchaser will refund any additional expenditure thereby incurred in any subsequent painting.

1.38 The design and materials and processes used in the construction of the transformers shall be such as to reduce to a minimum the risk of the development of acidity in the oil. Special measures, such as nitrogen sealing or the use of inhibited oils, are not required unless specified by the Engineer.

2. ELECTRICAL CHARACTERISTICS AND PERFORMANCE

*2.1 All transformers, unless otherwise specified, shall be oil immersed, core type. They shall be suitable for indoor or outdoor installation as specified, and shall be in accordance with and IEC 60076 unless otherwise specified. All oil-immersed transformers shall be provided with conservator vessels. The type of cooling shall be as specified in the Schedules.

2.2 Where a combination of two methods of cooling is applied to one transformer as for ONAN/ONAF, ONAN/OFAF or ONAN/OFAN units, the transformer shall be capable of operating under the ONAN condition up to full load 70% after which the cooling equipment shall come into operation and the transformer will operate as an ONAF.

2.3 Transformers shall be capable of remaining in operation at full load for 10 minutes after failure of the oil and/or water circulating pumps or blowers without the calculated winging hot-spot temperature exceeding 140ºC. Transformers fitted with two coolers each capable of dissipating 50% of the losses at CMR shall be capable of remaining in operation for 20 minutes in the event of failure of the oil and/or water circulating pumps or blowers associated with one cooler without the calculated winding hot-spot temperature exceeding 115ºC.

2.4 Where transformers are designed for forced-oil or air-blast cooling, but are initially supplied only with natural oil cooling, provision shall be made for adding the cooling plant at a later date, if required, to increase the output of the transformers.

2.5 Transformers provided with ONAN/ONAF, cooling shall comply as regards rating, temperature rise and overload with the appropriate requirements of IEC 60076-7 when operating with ONAN cooling and with ONAF cooling.

2.6 All transformers except where stated in Clauses 2.7 and 2.8, shall be capable of operation, continuously without injurious heating at their CMR and at any ratio, with the specified direction of flow of power and the voltage of the untapped winding maintained at the voltage stated in the Schedules.

The average winding rise above ambient at nameplate MVA rating shall not exceed 55°C for oil natural flow through the windings, and shall not exceed 60°C for oil forced directed flow through the winding.

The winding hot spot temperature rises above ambient at nameplate MVA rating shall not exceed 68°C.

The top oil temperature rise above ambient shall not exceed 50°C. If forced oil flow through the winding is applied (ODAF/ODWF) the oil flow through the core must also be forced so that the oil at top of the core does not exceed a 50°C temperature rise above ambient.

The hot spot temperature rise above ambient of metallic parts in contact with cellulose material outside the winding block shall not exceed 68°C. The rise above ambient of other metallic parts in contact with oil including core and tank shall not exceed 75°C for the surface in contact with the oil.

2.7 Transformers with tapping ranges extending not more than 10½% below the nominal voltage shall operate on the principal tapping without exceeding the limits laid down in IEC60076 for oil temperature rise and winding temperature rise as measured by resistance. On other tapings they shall operate continuously without injurious heating.

2.8 Transformers with tapping ranges extending more than 10½% below the nominal voltage shall meet the temperature rise limits specified in IEC60076 over the range of 0 to –5% tapings. On other tapings they shall operate without injurious heating.

2.9 The Contractor may submit details of temperature rise tests carried out on transformers similar to those to be provided under the Contract. If the tests are considered satisfactory, the Engineer may waive the temperature-rise type test, in which event the Contractor shall credit the Purchaser with the cost of the test as stated in the Schedules.

2.10 The voltages between phases on the higher and lower voltage windings of each transformer measured at no load and corresponding to the normal ratio of transformation shall be those stated in the Schedules, and shall be subject to tolerance permitted in IEC60076 (1970).

2.11 Means shall be provided in accordance with Clause 7.1 for varying the normal ration of transformation.

2.12 Transformers shall be connected in accordance with the group symbol specified in the Schedules.

2.13 Except where modified below, it is to be assumed that the amount of generating plant simultaneously connected is such that normal voltage will be maintained on one side of any transformer when there is a short circuit between phases or to earth on the other side. Any transformer may be directly connected to an underground or overhead transmission line and switched into and out of service together with its associated transmission line.

2.14 All transformers shall be capable of withstanding for five seconds without damage and external short-circuit between phases. Transformers without tertiary windings shall be capable of withstanding for five seconds without damage a short-circuit between one phase and earth. The electromagnetic forces upon which the design is based shall be state in the Schedules.

2.15 Transformers with tertiary windings shall be capable of withstanding for three seconds without damage any external short-circuit to earth with the short-circuit MVA available at either the HV or LV terminals not exceeding the values given in the Schedules, and with the neutral points on both HV and MV windings directly connected to earth.

2.16 The product of the number of turns of the tertiary windings and the cross sectional area of one such turn shall not be less than 35% of the corresponding product for the untapped main winding.

2.17 If stated in the Schedules, the transformers shall be provided with tertiary windings for reduction of zero phase sequence impedance and for the provision of station auxiliary supplies. Where the tertiary winding serves both these purposes the terms “tertiary” and “LV’ shall be synonymous. The method of bringing out the tertiary winding, the rating of the winding and the method of earthing shall be as stated in the Schedules.

2.18 The tertiary winding shall be capable of carrying continuously the load specified therein.

*2.19 The losses of each transformer shall be as stated in the Schedules. The tolerance on the losses of each transformer shall not be in accordance with IEC 60076. The no load and load losses shall have no plus tolerances if the losses exceed the guaranteed losses given in the bid by an amount in clause 2.23 the Tshwane reserves the right, at its discretion, to:

(a) Reject the transformer.

(b) Accept the transformer after alterations approved by the Tshwane are made to the transformer at the cost of the bidder.

(c) Accept the transformer at an adjusted price, the bided price being reduced by an amount equal to the capitalised value of the excess losses as calculated in accordance with the capitalisation formula.

For the purpose of adjusting the bid price, the stated excess losses will be taken as the amount by which the actual losses exceed the losses quoted In the bid.

In calculating the tender price adjustment the core and copper losses will be considered independently, that, is, no credit will be given for low copper losses to offset high core losses and vice versa, and no increase in the bid price will be allowed if either or both the actual core or copper losses are less than those quoted in the bid.

2.20 The voltage regulation from no load to continuous rated output at unity power factor and at 0.8 lagging power factor with constant voltage across the higher voltage windings shall be as stated in the Schedules.

2.21 The minimum ohmic impedance measured on the high voltage side shall not be less than the value stated in the Schedules. This shall correspond to minimum "percentage ohmic impedance" stated in the Schedules. Percentage ohmic impedance is and shall be, for purposes of this Specification, expressed in terms of nominal system voltage, irrespective of the voltage tapping under consideration.

2.22 The value of ohmic impedance measured on the high voltage side and on any tapping shall not exceed the value specified i.e. the highest ratio of maximum to minimum impedance over the tapping range shall not exceed 1.30.

2.23 The permitted maximum variation is not subject to any tolerance.

*2.24 The transformer core shall be designed to withstand a continuous over fluxing of 1.10pu for all other transformers covered by this specification. The type and thickness of the core material shall be stated in the Schedules. For three phase cores the interleaving of the middle leg should be such that no local hot spots occur.

The maximum flux density in any part of the core and yokes, at normal ratio and at normal voltage and frequency, of each transformer shall be as stated in the Schedules.

2.25 VIBRATION AND NOISE

The design and manufacture of the transformers and auxiliary plant shall be such that the level of vibration does not adversely affect any clamping or excessively stress any material.

If required by the Engineer, this shall be demonstrated by measurement and the acceptable magnitude of vibration shall be to approval.

The transformers shall be designed so that the average sound level will not exceed the values given in NEMA, when measured at the factory in accordance with the conditions outlined in NEMA.

As the latter does not state how the average sound level shall be determined in the case of natural cooling with separate cooling banks, such coolers shall not be regarded as part of the major sound producing surface, thus the average surface sound level of the transformer tank and fittings shall be not greater than the appropriate value in TR1-0.06.

The average sound level of the coolers shall also be measured, and recorded separately.

2.26 Where specified in the Schedules, a properly designed system of vibration isolation is required for the installation, which shall be subject to the approval of the Engineer.

The transformer may be isolated from the ground by means of one of the proprietary vibration isolators, such as cross ribbed neoprene or other flexible pads, the material of which is oil and UV resistant. The material shall be used according to the maker's recommendations, and the loading shall be uniform.

The degree of base vibration isolation may be required to be complementary to the air borne noise attenuation provided by a transformer enclosure made from a 280mm thick brick-and-cavity wall, thus the predicted 100Hz vibration attenuation at the transformer base should be in excess of 30db.

Where separate coolers are specified, they shall be similarly mounted, and shall be flexibly connected to the transformer tank by connections having a lower stiffness than the under-base mounts.

2.27 If required by the Engineer, any transformer shall be subject to noise measurements in accordance with NEMA Standard IEC 60076 or other approved national standard.

2.28 The transformers shall be designed with particular attention to the suppression of harmonic voltages. The third harmonic shall not exceed two percent.

2.29 The transformer tap change and primary connection shall be rated as stated in the Schedules.

2.30 The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the earthed clamping structure and the production of flux components at right angles to the plane of the laminations, which may cause local heating.

2.31 Every care shall be exercised in the selection, treatment and handling of core steel to ensure that, as far as is practicable, the laminations are flat and the finally assembled core is free from distortion.

2.32 Each lamination shall be insulated with a material that will not deteriorate due to pressure and the action of hot oil.

2.33 Oil ducts shall be provided where necessary to ensure adequate cooling. The winding structure and major insulation shall not obstruct the free flow of oil through such ducts. Where the magnetic circuit is divided into packets by cooling ducts parallel to the plane of the laminations or by insulating material above 0.25mm thick, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between packets.

2.34 The magnetic circuit shall be earthed through the link specified in Clause 4. With the link removed the magnetic circuit shall be insulated from all structural parts so as to withstand the tests specified and shall subsequently be earthed.

2.35 The framework and clamping arrangements shall be earthed in accordance with Clause 4.

2.36 The class and type of insulation used on the core bolts where used and under the nuts and side plates shall be stated in the Schedules.

2.37 All parts of the cores shall be of robust design capable of withstanding any shocks to which they may be subjected during lifting, transport, installation and service.

2.38 All structural members of the assembled cores shall be of steel. All castings shall be fettled and structural steel adequately cleaned and painted before being built into the structure. Any non-magnetic or high resistance alloy used shall be subject to approval.

2.39 Adequate fitments shall be provided to enable the core and windings to be lifted.

2.40 Suitable accommodation, attached to the transformer shall be provided for the storage of any removable portions of the lifting arrangements.

2.41 Adequate provision shall be made to prevent movement of the transformer relative to the tank during transport and installation or while in service.

2.42 The supporting framework of the cores shall be so designed as to avoid the presence of pockets which would prevent complete emptying of the tank through the drain valve, or cause trapping of air during filling.

3. WINDINGS

3.1 All star connected windings for systems of 88kV and above shall have graded insulation as defined in IEC 60076. All windings for system voltages of 66kV and below shall be fully insulated as defined in IEC 60076. All neutral points shall be insulated for the voltages specified in the Schedules.

3.2 Auto-connected transformers when required shall have the individual winding neutral ends of the three phases brought out to separate bushing insulators for connection to the primaries of external neutral current transformers associated with each individual phase end. The neutral connection between phases and to earth will be made on the side of the current transformers remote from the neutral terminals of the main transformer.

3.3 Power transformers shall be designed to withstand under Site conditions, the impulse test voltages specified in IEC 60076. If required by the Engineer, any transformer shall be subjected to the impulse test specified in the Schedule. Where necessary air terminations shall be modified for test purposes.

3.4 The transformer shall withstand the power frequency voltage tests specified.

3.5 The windings shall be designed to reduce to a minimum the out-of-balance forces in the transformer at all voltage ratios.

3.6 The insulation of transformer windings and connections shall be free from insulating composition liable to soften, ooze out, shrink or collapse during service.

3.7 The stacks of windings shall receive adequate shrinkage treatment before final assembly.

3.8 The coil clamping arrangement and the finished dimensions of any oil ducts shall be such as will not impede the free circulation of oil through the ducts.

3.9 No strip conductor wound on edge shall have a width exceeding six times its thickness.

3.10 The windings and connections of all transformers shall be braced to withstand shocks, which may occur during transport, or due to switching and other transient conditions during service.

3.11 Coil clamping rings, if provided, shall be off steel or of suitable insulating material built up from flat laminations.

3.12 Any metal pieces in contact with laminated rings shall be so designed and secured that they do not weaken the electrical or the mechanical properties of the rings.

3.13 If the transformer winding is built up of sections or disc coils, separated by spacers, the clamping arrangements shall be such that equal pressures are applied to all columns of spacers. All such spacers shall be securely located, shall be of suitable material, as specified, and shall receive adequate shrinkage treatment before assembly.

3.14 For windings exposed to radial inward stresses (compressive stress), self-supporting coil design (free buckling) is required but windings must still be fully supported back to the core. Regardless of the direction of short circuit forces (inward/outward), the copper yield strength shall be at least 25%

higher than the calculated average radial stress for the highest stressed winding package.

Special attention has to be paid to the effects of axial short circuit forces as result of:

- Shifted ampere-turn gravity along the circumference of pitched windings, which are extremely exposed, to the radial component of the stray flux.
- End thrust of winding due to unbalanced ampere-turn gravity.
- Axial bending stress on the conductors at the axial end of the windings.

Preferred Winding Designs:

- Where radial inward compressed windings are constructed with epoxy bounded conductors when applicable.
- Where main windings consist of parallel blocks (i.e. centre fed winding).
- Where extreme pitched windings can be avoided or arranged in an area of low radial stray flux components.
- Where the overall winding layout demonstrates a mechanical robust design.
- The free bucking should be limited to a maximum of 60% of the yield and bending stresses to 80% of the yield.

3.15 Each winding shall be well dried and sized using a minimum pressure of 7.5N/mm² for helical and disc windings. It is expected that the windings will be dried with the pressure maintained. All windings shall be sized using a maximum tolerance of -0 + 2mm, or -2, +0mm the pressure after final vapour phase drying shall not be less than 5N/mm².

The manufacture will be responsible for proposing methods for checking the pressure on the windings after the assembly is completed.

3.16 When determining the equivalent power frequency for impulse voltages for analysis of insulation stresses, the ratio of full wave impulse voltage to the power frequency shall not exceed 2.5. The minimum acceptable margin in oil spaces shall be 20% based on the Weideman oil strength data.

3.17 All windings shall be constructed with copper conductors only. Continuously transposed cable (CTC) shall be free from inter-strand shorts and tested after the winding has been completed. Where a copper conductor is jointed in the winding, a certificate of an x-ray test must be issued for proof of a solid connection.

4. INTERNAL EARTHING ARRANGEMENTS

4.1 All metal parts of the transformer with the exception of the individual core laminations, core bolts and associated individual clamping plates shall be maintained at some fixed potential.

4.2 The top main core clamping structure shall be connected to the tank body by a copper strap. The bottom clamping structure shall be earthed by one or more of the following methods:

(a) By connection through vertical tie-rods to the top structure.

(b) By direct metal-to-metal contact with the tank base, maintained by the weight of the core and windings.

(c) By a connection to the top structure on the same side of the core as the main earth connection to the tank.

4.3 The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link placed in an accessible position beneath an inspection opening in the tank cover. The connection to the link shall be on the same side of the core as the main earth connection, and taken from the extreme edge of the top yoke in close proximity to the bridging pieces referred to in Clause 2.37.

4.4 Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section and the arrangement of the connections shall be subject to approval. Where oil ducts or insulating barriers parallel to the plane of the laminations divide the magnetic circuit into two or more electrically separate parts the ducts or barriers shall be bridged in accordance with Clause 2.37 and the magnetic circuit shall not be regarded as being of sectional construction.

4.5 Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of the transformer as the main earth connection.

4.6 Where a tertiary winding is provided and not connected to external terminals, one point of the winding shall be earthed to the core clamping structure through a removable and accessible link.

4.7 Clause omitted.

4.8 All the earthing connections with the exception of those from the individual coil clamping rings shall have a cross-sectional area of not less than $70mm^2$ where in close thermal contact with the core.

5. TANKS

5.1 The tanks of all transformers shall be complete with all accessories and shall be designed so as to allow the complete transformer in the tank and filled with oil, to be lifted by crane or jacks, transported by road, rail or water without over-straining any joints and without causing subsequent leakage of oil.

5.2 The main tank body including tap-changing compartments, radiators and coolers shall be capable of withstanding a vacuum of 760mm of mercury at sea level when empty of oil.

5.3 Tanks shall be constructed of mild steel plate, the minimum thickness of which shall be 6mm for the sides and 10mm for the bottom where the longer sides have a horizontal length in excess of 1 800mm. For a horizontal length in excess of 1 800mm, the minimum side plate thickness shall be 8mm and the minimum bottom plate thickness 12mm.

5.4 Where the design of the tank is such that the bottom plate will be in direct contact with the surface of the foundations, the above minimum bottom plate thickness shall be increased to 20mm and 25mm respectively.

5.5 The base of each tank shall be so designed that it shall be possible to move the complete transformer unit in any direction without injury when using rollers, plates or rails. A design, which necessitates slide rails being placed in a particular position shall not be used.

5.6 Unless specifically approved detachable under bases shall not be used.

5.7 Where the base is of a channel iron contraction it shall be designed to prevent retention of water.

5.8 Tank stiffeners shall be continuously welded to the tank and designed to prevent retention of water.

5.9 Wherever possible the transformer tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided pipes shall be provided to vent the gas into the main expansion pipes. The vent pipes shall have a minimum inside diameter of 20mm except for short branch pipes, which may be 6mm minimum inside diameter.

5.10 All joints other than those, which may have to be broken, shall be welded. Defective joints may be re-welded subject to the written approval of the Engineer.

All welders engaged on fabrication either in the manufacturer's works or on Site and on any weld repairs subsequently found necessary, shall, before undertaking welding, satisfactorily complete procedure and qualification tests in the presence of the Engineer.

The minimum requirements for the testing of welders on structural steel would be as follows:

(a) Butt Welds (manual)

Test plates to be of average thickness for the Contract.

Two tests required:

Horizontal/vertical and vertical.

From each test weld are to be prepared one forward and one reverse bend test and one macro specimen. The bend tests are to be taken through 180º over a former of diameter equal to three times the thickness of the plate.

(b) Fillet Welds

The size of fillet weld to be an average of those called for on the Contract.
Two tests are required:
Horizontal/vertical and vertical.
From each test weld, nick break and macro specimens are to be prepared.

(c) Butt Welds (machine welding)

On full penetration butt welds the first two seams welded are to be witnessed with “run-on” and “run-off” plates. From these plates are to be prepared a forward bend, reverse bend and a macro. The bend requirements are as for the manual test.

On partial penetration butt welds, the first two seams are to be witnessed and macro specimens are to be prepared from the “run-on” and “run-off” plates in addition to the ends of the actual weld. The extent of penetration is to comply with the approved drawing.

5.11 Each tank shall be provide with:

(a) Lifting lugs suitable for lifting the transformer complete with oil.

(b) A minimum of four jacking lugs, in accessible positions to enable the transformer complete with oil to be raised or lowered using hydraulic or screw jacks. The minimum height of the lugs above the base shall be:

(i) Transformers up to and including 1×10^4 kg mass – 300mm

(ii) Transformers above 1×10^4 kg mass – 500mm

(c) Horizontal plates with 50mm diameter draw holes drilled therein shall be fitted adjacent to each corner of rectangular tanks at not more than 750mm from the base to permit the tank to be hauled in any direction or slewed. On round-ended tanks the draw holes shall be located approximately on the diagonals of the rectangle formed by the overall boundaries of the tank. At least 100mm free working space shall be provided above and below each draw hole.

5.12 As an alternative to draw holes rope fairings may be provided at each corner at not more than 750mm above the base to enable the hawser to be placed round the tank for haulage purposes.

5.13 Each tank cover shall be of adequate strength, and shall not distort when lifted. Inspection openings shall be provided as necessary to give easy access to bushings, for changing ratio or winding connections, or testing the earth connections at the link board. Each inspection opening shall be of ample size for its purpose and there shall be at least two openings, one at each end of the tank, of not less than 450mm x 350mm.

5.14 The tank cover and inspection covers shall be provided with suitable lifting arrangements. Unless otherwise approved inspection covers shall not weight more than 25kg each.

5.15 The tank cover shall be fitted with pockets for a thermometer and for the bulbs of the winding temperature indicators specified in Clause 9.1 – 9.16. Protection shall be provided where necessary for each capillary tube.

5.16 The thermometer pocket shall be fitted with a captive screwed cap to prevent the ingress of water.

5.17 The pocket shall be located in the position of maximum oil temperature at CMR and it shall be possible to remove the instrument bulbs without lowering the oil in the tank.

5.18 Accommodation for current transformers shall be provided over all bushings of 132kV and above. Below 132kV provision may be made for fitting the CT over the internal connection of the transformer. Provision shall be made for the connection to current transformer to be readily accessible without removing oil from the transformer tank.

5.19 TANK COVER

To allow for the effect of induced loop currents and capacitive surge currents the tank cover shall be fixed to the transformer such that good electrical contact is maintained around the perimeter of the tank. Special care should be taken in the vicinity of HV and LV bushings.

5.20 JOINTS

Joints, other than those, which may have to be separated during transport or for maintenance in service, shall be welded.
The main tank/cover joint shall be welded. A fireproof gasket shall be included to prevent foreign matter entering the transformer during welding or dewelding. The joint shall be designed to permit removal of the weld with minimum damage to the mating flanges, and to leave them adequate for rewelding.

5.21 A conservator complete with sump and drain valve shall be provided in such a position as not to obstruct the electrical connections to the transformer and having a capacity between highest and lowest visible levels of not less than 7½ percent of the total cold oil volume in the transformer and cooling equipment. The volume shall be stated in Schedule “D” Part IIA, Item 34. The minimum indicate oil level shall be with the feed sump to the main tank covered with not less than 12mm depth of oil and the indicated range of oil levels shall correspond to average oil temperatures of from minus 10°C to plus 80°C. The height of the conservator shall be such that, without the previous approval of the Engineers, the oil level throughout the working temperature range shall not be lower than the top of the highest transformer bushing.

The conservator shall be fitted with a rubber bag.

5.22 If extending the feed pipe inside the conservator vessel forms the sump, this extension shall be for at least 75mm. The conservator shall be designed so that it can be completely drained by means of the drain valve provided, when mounted as in service.

5.23 One end of the conservator shall be bolted into position so that it can be removed for cleaning purposes.

5.24 Two oil gauges of approved type shall be provided preferably one at each end of the conservator. At least one gauge shall be of the direct reading prismatic or reflex type. Float operated oil gauges shall be of the magnetic type.

5.25 Where it is necessary to fit two or more gauges of the prismatic type at one end in order to cover the full expansion range, they shall be so disposed that the oil level is in view at all parts of the range.

5.26 The oil level at 20°C shall be marked on the gauges.

5.27 Taps or valves shall not be fitted to oil gauges.

5.28 The oil pipe connection from the transformer tank to the conservator vessels shall be arranged to provide a straight run of pipe, rising at an angle of from 3 – 7 degrees to the horizontal, to comply with the conditions of Clause 9.22, and shall consist of:

(a) For transformers up to and including 1 000kVA 25mm inside diameter pipes.

(b) For transformers from 1 001 tot 10 000kVA: 50mm inside diameter pipes.

(c) For transformers of over 10 000kVA: 75mm inside diameter pipes.

5.29 The pipe work between the conservator and the transformer shall comply with the requirements of Clauses 9.18 – 9.25. A valve shall be provided at the conservator to cut off the oil supply to the transformer.

5.30 Unless otherwise specified, each rubber bag in the conservator vessel shall be fitted with a breather in which silica gel is the dehydrating agent and designed so that:

(a) The passage of the air is through the silica gel.

(b) The external atmosphere is not continually in contact with the silica gel.

(c) The moisture absorption indicated by a change in colour of the tinted crystals can be easily observed. At least 25 percent of the total quantity of silica gel crystals shall be tinted.

(d) All breathers shall be mounted at approximately 1.4m above ground level.

5.31 Each transformer shall be fitted with the following:

(a) One 50mm valve at the top and one 50mm valve at the bottom of the tank mounted diagonally opposite to each other for connection to oil circulating equipment.

(b) A drain valve of adequate size together with such arrangement as may be necessary within the tank to ensure that the tank can be drained of oil as far as practicable.

(c) A drain valve fitted to each conservator, as specified in Clause 5.

(d) A robust sampling device at top and bottom of the main tank. The sampling devices shall not be fitted on the filter valves specified under (a) above.

(e) Flange type air release plugs.

5.32 Filter valves shall be fitted with blank flanges, or if specified in the Schedule with adaptors for connection to oil circulating equipment.

5.33 All other valves opening to atmosphere shall be fitted with blanked flanges.

5.34 Valves and valve mountings shall be provided as specified under “Cooling Plant”.

5.35 Drain, filter and sampling valves up to and including 75mm are to be of gunmetal or brass, the Glove type being satisfactory, provided that the fixed valve seat end is arranged to be on the pressure side of all installations. Valves in the conservator pipe work and header systems are to be of the Full way type, with internal screw cast iron bodies will be acceptable over 75mm.

Butterfly type valves with gunmetal or other approved flaps are acceptable for radiator isolation duties, and cast iron bodies may be used if suitably proportioned.

5.36 Means shall be provided for padlocking the valves in the open and closed positions. Locks shall be provided for all valves, they shall be fine pin “Yale” type or equivalent. All locks shall be of the same type and three keys to pass all locks shall be provided. Provision is not required for locking individual radiator valves.

5.37 Every valve shall be provided with an indicator to show clearly the position of the valve.

5.38 All valves shall be provided with flanges having machined faces.

5.39 The drilling of valve flanges shall be metric and in accordance with the requirements of BS 4504.

5.40 Where specified a pressure relief device shall be provided of sufficient size for rapid release of any pressure that may be generated within the tank, and which might result in damage to the equipment. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tanks specified in the Schedule. Means shall be provided to prevent the ingress of rain.

5.41 Unless otherwise approved the relief device shall be mounted on the main tank and if on the cover shall be fitted with a skirt projecting 25mm inside the tank to prevent gas accumulation.

5.42 If a diaphragm is used, it shall be of approved design and material and situated above maximum oil level.

5.43 For relieving or equalising the pressures in the pressure relief device an equaliser pipe connecting the pressure relief device to the conservator shall be fitted.

5.44 Facilities shall be provided for the mounting of external neutral current transformer(s) and also, where applicable, an external tank leakage current transformer.

5.45 An earthing terminal capable of carrying for 30 seconds the full lower voltage current of the transformer shall be provided. Provision shall be made at positions close to each of the bottom four corners of the tank for bolting the earth terminals to the tank structure to suit local conditions. Terminal bolts or studs shall not be less than 16mm in diameter.

5.46 The following plates shall be fixed to the transformer tank at an average height, where possible, of 1.75, above the ground level:

(a) A rating plate bearing the data specified in the appropriate Clauses of IEC 60076.

(b) A diagram plate showing in an approved manner the internal connections and also the voltage vector relationship of the several windings in accordance with IEC 60076, and in additions a plan view of the transformer, giving the correct physical relationship of the terminals. When links are provided in accordance with Clause 2.12, changing the transformer IEC Vector group symbol and/or ratio, then approved means shall be provided for clearly indicating which vector group or ratio the transformer is connected. The transformer ratio shall be indicated for each tap.

(c) A property plate of approved design and wording.

(d) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also warn operators to refer to the Maintenance Instructions before applying the vacuum treatment specified in Clause 12.2.

(e) A number plate showing the Purchaser’s transformer serial number as stated in the Schedules in 75mm characters.

5.47 All the above plates shall be of stainless steel or of other approved material capable of withstanding continuous outdoor service.

5.48 GASKETS:

All gasket joints shall be of the groove and O-rings type. Grooves shall be dimensioned and the mating surfaces machined to the specification of the O-ring manufacturer to ensure leak-free seals. The O-rings shall be moulded or pre-joined by vulcanizing to the correct diameter. Butt or chamfered joints that rely on overfill of the groove to seal are not acceptable. Gaskets shall be replaced each time a seal is broken.

Metal shall not bear directly on porcelain, and resilient material interposed between clamps and porcelain shall comply with the requirements of BS 2815. A test certificate for this material, and a test report in the form given in Appendix C of BS 2815 shall be included with documents accompanying any application for approval.

5.49 Oil resisting synthetic rubber gaskets shall not be used, except where the synthetic rubber is used as a bonding medium for cork or similar material.

5.50 The clearance between oil pipe work and live metal shall comply with the requirements of Clause 6.

6. COOLING PLANT

6.1 Radiators and coolers shall be designed so that all painted surfaces can be thoroughly cleaned by hand and subsequently painted in site by suitable brushes or sprays.

6.2 Radiators and coolers shall be so designed as to avoid pockets in which moisture may collect and shall withstand the pressure tests for the tanks to which they are connected.

6.3 The cooler and pipe work are subject to vibration and noise restricting requirements as stated in Clause 2.

6.4 Unless the pipe work is shielded by adequate earthed metal the clearance between all pipe work and live parts shall be not less than that specified.

6.5 The cooling arrangements of all transformers, other than water cooled units, having rating of 30MVA and above shall be such that failure of one part of the cooling plant will not result in the loss of more than 50 percent of the total forced cooling capacity.

6.6 If required water-cooled oil coolers shall be provided as specified in the Schedules.

6.7 Radiators connected directly to the tank or to headers mounted on the tank, shall be detachable and shall be provided with machined or ground flanged inlet and outlet branches. Plugs shall be provided at the top and bottom of each radiator for draining and filling.

6.8 Valves shall be provided on the tank or header at each point of connection to the tank or header, and provision made for locking. Keys and locks shall be provided.

6.9 Where separate radiator tanks are provided the conservator vessels specified shall be mounted thereon.

6.10 All coolers shall be suitable for mounting on a flat concrete base.

6.11 Valves mountings shall be provided on the tanks of all transformers other than water cooled units to enable all the cooling equipment to be located at either end of the tanks. The mountings not in use shall be blanked off without valves.

6.12 The oil circuit of all coolers shall be provided with the following:

(a) A valve at each point of connection to the transformer tank.

(b) A valve in the main oil connection to the bottom and top of each cooler or radiator.

(c) Removable blanking plates to permit the blanking off of the main oil connection to the top of each cooler. The blanking plates, when not in use, shall be bolted to some suitable structure on the transformer.

(d) A drain valve at the lowest point of each cooler.

(e) A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.

(f) Machined flanges on all items.

(g) A 50mm filter valve, as specified in Clause 5.34 at the top and bottom of each cooler. Where specified in Scheduled “D”, Part IA, Item 37, shall be fitted to these valves.

(h) On all air cooled coolers which have no ONAN rating, a differential pressure gauge across the oil inlet and outlet of the cooler, marked to indicate correct oil circulation is to be fitted. Where ONAN coolers are not provided in addition to such coolers, an oil flow indicator with electrical contacts, is to be fitted. Unless otherwise specified these contacts shall comprise one pair normally open, rated in accordance with Clause 9.8.

6.13 In addition, the following are to be provided only with water cooled coolers:

(a) Pressure gauges on oil and water inlet and outlet branches.

(b) A differential pressure gauge, or equivalent approved device, fitted with electrical contacts, to give an alarm when cooler outlet oil pressure does not exceed inlet water pressure.

(c) Visual oil and water flow indicators, fitted with electrical contacts, in the pipe work adjacent to the coolers.

(d) Brass cased and guarded thermometers screwed into pockets in the inlet and outlet oil and water branches of the coolers.

6.14 The disposition of flow indicators is to approval.

6.15 The necessary oil piping shall be provided for connecting each transformer or transformer group to the coolers and oil pumps and for an equalising connection when more than one transformer is connected to any oil cooling equipment. The oil piping shall be of approved material with machined flanged joints. Cast iron shall not be used.

6.16 The blowers for use with oil coolers or for air blast cooling shall be motor driven. They shall be of approved make and design and shall be suitable for continuous operation out of doors and capable of dealing with the maximum output and head required in service.

6.17 The blowers shall be capable of withstanding the stresses imposed when brought up to speed by the direct application of full line voltage to the motor.

6.18 The blowers shall be complete with all necessary air ducting. The blowers, air ducting and coolers shall be designed so that they operate with a minimum of noise or drumming. In order to reduce the transmission of noise and vibration the blowers shall be either mounted independently from the coolers, or, alternatively, an approved form or anti-vibration mounting shall be adopted. It shall be possible to remove the blower complete with motor without disturbing or dismantling the cooler structure framework.

6.19 Blades or runners fabricated to form hollow sections shall not be used.

6.20 Blades shall be of aluminium unless otherwise approved.

6.21 The ducts and casings shall be made of galvanized steel not less than 2mm thickness suitably stiffened by angles or tees.

6.22 Galvanised wire-mesh guards with a mesh not greater than 25mm shall be provided to prevent accidental contact with the blades. Guards shall be provided over all moving shafts and couplings.

6.23 Motors shall be of the squirrel cage totally enclosed weatherproof type and shall comply with IEC as applicable for continuously rated machines. The motors shall be capable operating at all loads without undue vibration and for continuous running form a 415 volt three-phase 4 wire 50 cycle supply.

6.24 All motors shall be capable of continuous operation in the service conditions at any frequency between 18 and 51 cycles, together with any voltage within ±5 percent of the nominal value. Motors upon which the primary equipment depends for its continued operation at full load shall also be capable of continuous operation at 85 percent of the nominal voltage at normal frequency without injurious overheating.

6.25 The rotor and stator slots shall be skewed relatively to each other.

6.26 All motors shall have ball or roller bearings.

6.27 Vertical spindle motors shall have approved bearings capable of withstanding the thrust due to the weight of the moving parts and the action of the impeller.

6.28 The stator windings shall be adequately braced and suitably impregnated to render them non-hygroscopic and oil resistant. Weatherproof motors shall be provided with suitable means of breathing and of drainage to prevent accumulation of water.

6.29 Each terminal box shall be fitted with an approved means of terminating the external wiring.

6.30 Varnished cambric or glass insulation shall be used for connections from the windings to the terminals. All motor terminals shall be of the stud type and totally enclosed and shall be to approval.

6.31 Each water pump, or blower, and its motor shall be mounted on a common base plate and the drive shall be direct.

6.32 Where multiple fan cooling is employed, using small single-phase motors, the motors in each cooling bank shall be grouped so as to form approximately a balanced three-phase load.

6.33 Each motor or group of motors shall be provided with a three-pole electrically operated contactor and with control gear of approved design both for starting and stopping the motor by hand and automatically from the contacts on the winding temperature indicating device specified in Clause 9. Overload and single-phasing protection shall be provided but no-volt releases shall not be fitted. This equipment shall be accommodated in the marshalling kiosk specified in Clause 10.1.

6.34 Where small motors are connected in groups, the group protection shall be arranged so that it operates satisfactorily in the event of a fault occurring on a single motor.

6.35 The control arrangements shall be such that motors totaling more than 15kW shall not be started simultaneously when the cooling plant motors are started automatically, or by hand by means of a single switch operation.

6.36 Where blowers and oil pumps are provided, the connections shall be so arranged as to allow the motors or groups to be started up and shut down either collectively or individually.

6.37 All motor contractors and their associated apparatus shall be capable of holding in and operating satisfactorily and without overheating for a period of ten minutes if the supply voltage falls for that period to 75 percent of normal at normal frequency. The motor contractors and associated apparatus shall be capable of normal operation, with a supply voltage of 85 percent of the normal value and at normal frequency.

6.38 All contacts and other parts, which may require renewal, adjustment or inspection, shall be readily accessible.

6.39 All wiring for the control gear accommodated in the marshalling kiosk together with all necessary cable boxes and all wiring between the marshalling kiosk and the motors shall form part of the Contract Works.

7. VOLTAGE CONTROL

7.1 Where specified in the Schedules each transformer shall be provided with voltage control equipment of the tap-changing type or other approved apparatus for varying its effective ratio whilst the transformers are on-load and without producing phase displacement. The variation shall take place in steps specified in the Schedules. Except for auto-connected transformers, where tapping may be brought out from either the series or common part of the windings, tapings shall be arranged on the high voltage windings. The voltage control equipment shall be designed so that it may be easily adapted to operate by automatic control as specified in Clause 7.26.

7.2 Equipment for local and remote electrical and local hand operation shall be provided and shall comply with the following conditions:

(a) It shall not be possible to operate the electric drive when the hand-operating gear is in use.

(b) It shall not be possible for any two electric control points to be in operation at the same time.

(c) The equipment shall be equipped for supervisory control and indication. A multi-way switch, make-before-break, having one fixed contact for each tap position, shall be provided and wired to the marshalling kiosk. This switch shall be provided in addition to any, which may be required for remote tap position indication. Supervisory indication shall also be provided in the form of contacts to close on “Tap Change Incomplete”. All other components of the supervisory gear will be supplied under a separate contract.

(d) Operation from the local or remote control switch shall cause one tap movement only unless the control switch is returned to the off position between successive operations. Initiation of “Voltage reduction”, Clause 7.30, shall cause a fast continuous tap movement to the required tap number.

(e) All electrical control switches and the local operating gear shall be clearly labeled in an approved manner to indicate the direction of tap changing.

(f) The local control switches shall be mounted in the Marshalling Kiosk.

7.3 The equipment shall be so arranged as to ensure that when a tap change has been commenced it shall be completed independently of the operation of the control relays or switches. If a failure of the auxiliary supply during a tap change or any other contingency would result in that movement not being completed, approved means shall be provided to safeguard the transformer and its auxiliary equipment.

7.4 Apparatus of approved type shall be provided for each transformer:

(a) To give indication mechanically at the transformer and electrically at the remote control point, of the number of tapping in use on the transformer. The numbers shall range from 1 upwards. For transformers other than auto-connected transformers, the lowest number shall represent the tapping position corresponding to the maximum number of high voltage winding, turns, i.e. the plus percent position, and the highest number shall represent the tapping position corresponding to the minimum number of high voltage winding turns, i.e. the minus percent position. In the case of the exception detailed above (auto-connected transformers) the lowest number shall represent the tapping position corresponding to the lowest turns ratio, i.e. equivalent to the highest number shall represent the tapping position corresponding to the highest turns ratio, i.e. equivalent to the lowest number of turns in the common winding.

(b) To give an indication at the remote control point that a tap change is incomplete by means of an illuminated lamp, alarm buzzer and a potential free N/O contract shall be provided for supervisory purposes.

7.5 The lamps and alarm buzzer will be supplied on a separate contract unless a remote control panel is specified in the Schedules.

7.6 The remote control switches and remote tap position indicator shall be supplied as loose apparatus. They will be mounted and wired under a separate contract, unless a remote control panel is specified in the Schedules.

7.7 All indicating devices shall operate correctly at any voltage between the limits of 85 percent and 115 percent of nominal value.

7.8 Any enclosed compartment not oil filled shall be adequately ventilated. A metal clad heater shall be provided in the driving mechanism chamber and connected in parallel with the heater in the marshalling kiosk. All contractors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation.

7.9 The OLTC design shall be according to the tap-selector switch principle or shall consist of a tap-selector and rotary type diverter switch of high speed transition resistor type. The OLTC operation principle should use vacuum cells instead of copper tungsten arcing contacts and this OLTC should be maintenance free up to 300.000 switching operations. No time or condition based maintenance intervals are applicable, no additional equipment shall be necessary to achieve this limit.

7.10 The OLTC shall be in conformity with IEC 60214. OLTC shall have been type tested by a qualified testing department or the manufacturer. Only designs, which have been type, tested in accordance with the relevant IEC standards will be accepted. All equipment related to the OLTC shall be supplied by the original OLTC manufacturer. This is also applicable for tie-in resistors, if provided. License products etc. are not acceptable.

7.11 The OLTC(s) shall be mounted into the transformer. The diverter switches with vacuum cells or selector switches shall have an own oil compartment separate from the transformer oil as well as their own closed sub-section in the oil conservator.

7.12 If possible no piping or other equipment shall be arranged beyond the tap changer head to allow lifting of the diverter switch with vacuum cells without any restriction and without removing (dismantling) of any other equipment.

7.13 An oil-flow operated protection relay shall be provided for internal failure protection. This oil-flow relay shall be provided on elbow pipe on tap changer head and shall have slide valve on side piping to OLTC conservator.

7.14 The motor drive, plus all auxiliary equipment for operation of the tap changer, shall be incorporated in a rigid control of min 4mm thick aluminum alloy, protection class IP66 and shall be mounted onto the transformer tank in a convenient floor height. The driving gear shall be of the belt-type or equivalent dry-type gear. Oil filled driving gears are not acceptable.

7.15 The voltage of supply for electrical operation of the control and indicating gear shall be as specified in the Schedules.

7.16 Limit switches shall be provided to prevent over-running of the mechanism and except where modified in Clause 7.18, shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition.

7.17 The control circuits shall operate at 110V AC single-phase to be supplied from a transformer having a ratio of 240/55-0-55V with the center point earthed through a removable link mounted in the marshalling kiosk and supplied under this contract.

7.18 Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150VA between the limits of 30 volts and 250 volts AC and DC and for making 500VA between the limits of 110 volts and 250 volts DC.

7.19 A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

7.20 The terminals of the operating motor shall be clearly and permanently marked with numbers corresponding to those on the leads attached thereto.

7.21 Where specified in the Schedules, approved means shall be provided for automatically maintaining within adjustable limits a pre-determined voltage at the lower voltage busbars to which the transformer is connected.

7.22 Automatic parallel voltage control equipment shall be provided when specified in the Schedules.

7.23 In addition to the requirements of 8.3 of IEC 60214 for on-load tap changers, tap changing equipment shall be capable of carrying the same currents, due to external short-circuit, as the transformer windings with which they are associated, as specified in this document.

8. BUSHING INSULATORS AND TERMINALS

8.1 Transformers shall be fitted either with bushing insulators or with cable boxes as stated in the Schedules.

8.2 The electrical characteristics of bushing insulators shall be as specified in the Schedules. On multi-ratio transformers, bushings shall be designed to carry the greatest current obtainable from any winding to which they may be connected. The bushing insulators shall comply with the requirements of IEC, and shall satisfy the partial discharge test specified in the Schedules.

8.3 Stresses due to expansion and contraction in any part of the bushing insulator shall not lead to the development of defects.

8.4 Any stress shield shall be considered an integral part of the bushing assembly.

8.5 On all condenser bushings rated at 66kV and above a tapping shall be brought out to a separate terminal for testing purposes on site, and the terminal shall normally be connected to earth.

8.6 Bushings shall be so arranged that they can be removed without disturbing either the current transformers, secondary terminals an connections or pipe work.

8.7 Bushings insulators of 66kV and above shall be the draw-through type. A flexible pull-through lead suitable sweated to the end of the winding copper shall be provided and it shall be continuous to the connector, which is housed in the helmet of the bushings. When bushings with an under-oil end of the re-entrant form are used, the associated flexible pull-through lead shall be fitted with a suitably designed gas-bubble deflector.

8.8 An oil gauge, preferable of the prismatic type, shall be provided to indicate that the correct level is maintained. Where lower voltage bushing insulators are not oil-filled the type of filling shall be approved.

8.9 All porcelain shall be sound, free from defects and thoroughly vitrified. The glaze shall not be depended upon for insulation. The glaze shall be smooth, hard, of an uniform shade of brown and shall cover completely all exposed parts of the insulator. Outdoor insulators and fittings shall be unaffected by atmospheric conditions due to weather, proximity to the coast, fumes, ozone, acids, between minis 2°C and plus 50°C under working conditions.

8.10 The porcelain shall not engage directly with hard metal and where necessary gaskets complying with Clause 5.51 shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

8.11 All fixing material used shall be suitable quality and properly applied and shall not enter into chemical action with the metal parts or cause fracture by expansion in service. Cement thicknesses shall be as small and even as possible and proper care shall be taken to center and locate the individual parts correctly during cementing.

8.12 All porcelain insulators shall be designed to facilitate cleaning.

8.13 Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surfaces of all paper insulators shall be finished with approved non-hygroscopic varnish, which cannot be easily damaged.

8.14 Each porcelain bushing or insulator and paper bushing shall have marked upon it the manufacturer's identification mark, and such other mark as may be required to assist in the representative selection of batches for the purposes of the sample tests stated in the Schedules. These marks shall be clearly legible and visible after assembly of fittings and shall be imprinted and not impressed.

8.15 Bushing insulators shall be mounted on the tank so that the connections can be taken away clear of all obstacles. For transformers other than auto-connected transformers the HV terminals shall be arranged so that the connections can be taken away horizontally on the HV or MV sides, and, in the latter case, with the following clearances above the MV terminals:

(a) For transformers with HV windings of 275kV……………….. 2.5m

(b) For transformers with HV windings of 132kV……………….. 1.4m

(c) For transformers with HV windings of 66kV……………..….. 0.95m

(d) For transformers with HV windings of 33kV…………………..0.75m

For auto-connected transformers, where it is desired to take the HV connections away horizontally on the MV side, the clearances above the MV terminals shall be to the Engineer's approval.

8.16 Internal connections to bushings insulators shall be flexible.

8.17 Clamps and fittings made of steel or malleable iron shall be galvanised in accordance with Clause 1.13. All bolt threads shall be greased before erection.

8.18 The bushing flanges shall not be of re-entrant shape which may trap air.

8.19 Cable boxes shall be suitable for terminating the cables directly or alternatively shall be in the form of sealing end chambers for accommodating sealing ends into which the cables will be terminated, as instructed by the Engineer.

8.20 Cable boxes shall be designed to accommodate all cable joint fittings or sealing ends required by the manufacturer of the cables, including stress cones or other approved means for grading the voltage stress on the terminal insulation of cables operating at voltages of 22kV and above between phases. They shall also be provided with expansion chambers for the filling medium and means of preventing the formation of air spaces when filling. Drain plugs of ample size shall be provided to enable the filling medium to be quickly removed. The filling medium shall be as stated in the Schedules.

8.21 The faces of flanges provided to accommodate sealing ends for terminating oil duct or gas pressure cables operating at voltage of 66kV and above between phases shall be machined or ground.

8.22 The cable boxes shall be fitted with universal tapered brass glands, with combined armour and earthing clamps. The ends of all wiping glands shall be tinned before dispatch to site. Glands for single core cables shall be insulated from the box in an approved manner including an island layer and removable earthing connectors shall be provided. The design of the island layer shall be such as to prevent the cable sheath fouling the cable box shell and thus invalidating the island layer. Gland insulation shall be capable of withstanding a dry high voltage test of 2 000 volts AC for one minute on each side of the island layer. Sufficient glands shall be provided for the termination of the main power cables and also for the supplementary cable for any auxiliary transformer if specified.

8.23 Provision shall be made for earthing the body of each cable box.

8.24 Where cable boxes are provided for three-core cables the sweating sockets on the two outer phases shall be inclined towards the center to minimize bending of the cable cores. Where there is more than one core per phase, the socket block shall be so designed as to minimise bending of the cable cores.

8.25 Where cable for 11kV and above are terminated in the cable box, an oil-filled disconnecting chamber with removable links shall be provided for testing purposes. A barrier shall be provided on both sides of the disconnecting chamber to prevent ingress of the oil used for filling the chamber into the cable box or the transformer. It shall only be necessary to remove part of the oil in the chamber itself when making the necessary testing connections.

8.26 Where sealing end chambers are provided the disconnecting chamber may be omitted and the facilities for testing shall be provided in the sealing end chamber itself. A barrier shall then be provided between the sealing end chamber and the main tank subject to the provisions of Clause 8.29.

8.27 The barrier between the main tank and the disconnecting or cable sealing end chamber may be omitted, subject to the Engineer's approval, where the design is such that the cover of the disconnecting or cable sealing end chamber can be removed without lowering any oil level other than in the chamber itself in order to make the necessary testing connections.

8.28 The disconnecting or sealing end chamber shall have a removable cover and the design of the chamber shall be such that ample clearances are provided to enable either the transformer or each cable to be subjected separately to high voltage tests.

8.29 The oil level in disconnecting or sealing end chamber shall be maintained from the main conservator tank by means of a connection to the highest point of the chamber and this connection shall be controlled by suitable valves. The connection to the conservator shall be made by means of a pipe of not less than 25mm inside diameter so that any gas leaving the chamber shall pass through the gas and oil actuated relay.

8.30 The characteristics of insulators used in cable boxes and disconnecting or sealing end chambers shall be as stated in the Schedules and shall be tested.

8.31 The cable boxes and disconnecting or sealing end chambers shall also be capable of withstanding for 15 minutes both at the time of the first tests on the cables and at any subsequent time as may be required, between phases and to earth, a DC test equal to:

2E kV or and AC test equal to $\frac{4E}{3}$kV, where E is the rated system phase to phase voltage in kV.

8.32 During these tests the links in the disconnecting or sealing end chamber or cable box will be withdrawn and the transformer windings with connections thereto will be earthed.

8.33 Unless otherwise approved the creepage distance and clearances to earth and between phases shall not be less than those specified in the Schedules.

8.34 Cable boxes and disconnecting or sealing end chambers shall be of approved design and, unless otherwise specified, shall be suitable for oil filling. Oil-filled boxes shall not be constructed of cast iron and shall be capable of withstanding the pressure test specified in the Schedules.

8.35 The spacing of bolts for joints on oil filled cable boxes shall not exceed 100mm centers.

8.36 Terminals shall be marked in a clear and permanent manner.

8.37 Unless otherwise specified, main cabling and jointing and filling of cable boxes will be carried out under another contract.

9. TEMPERATURE INDICATING DEVICES, ALARMS AND GAS AND OIL OPERATED RELAYS

9.1 All transformers other than unit auxiliary and earthing transformers shall be provided with approved devices for indicating the hottest spot winding and the maximum oil temperature. Each device shall have a dial type indicator, and, in addition, a pointer to register the highest temperature reached. Except where modified below, two separate sets of contacts shall be fitted, one of which shall be used to give an alarm and the other to trip the associate circuit breakers.

9.2 On transformers with mixed cooling, one set of contacts controlled by the winding temperature device shall be used to control the cooling plant motors, a second set shall be used to give an alarm and a third to trip the associated circuit breakers.

9.3 On auto-connected transformers, when the voltage ratio and tapping range specified results in a current distribution such that for different operating conditions the hottest spot winding temperature may be associated with either the series or common part of the windings, the device shall indicate the hottest spot winding temperature in any part of the winding irrespective of the load and tapping position.

9.4 The temperature indicators shall be housed in the marshalling kiosk. If specified in Schedule “D” Part I, remote repeater indicators electrically operated from the above indicators are to be provided for mounting on the control panels. Unless otherwise specified, the remote repeater indicators shall be of the round, flush mounting type, with a nominal diameter of about 100mm and a scale length of approximately 300 angular degrees.

9.5 On transformers without mixed cooling, subject to the agreement of the Engineers, remote indication of temperature may be provided by an electrical distance temperature indicator, without contacts, mounted on the control panel. One indicator with alarm and trip contacts will be mounted in the marshalling kiosk.

9.6 The tripping contacts of the temperature indicators shall be adjustable to close between 60°C and 120°C and alarm contacts to close between 50 and

100°C and both shall re-open when temperature has fallen by an desired amount between 15°C and 30°C.

9.7 The contacts used to control the cooling plant motors on the above devices shall be adjustable to close between 50°C and re-open when the temperature has fallen by any desired amount between 15°C and 30°C.

9.8 All contacts shall be adjustable to a scale and shall be accessible on removal of the cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150VA between the limits of 30 volts and 250 volts AC or DC and of making 500VA between the limits of 110 and 250 volts DC. Cooler motor control contacts shall be suitable for operating the cooling motor contractors direct or, if necessary, through an interposing relay.

9.9 The temperature indicators in the marshalling kiosk shall be so designed that it shall be possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.

9.10 The working parts of the instrument shall be made visible by the provision of cut-away dials and glass fronted covers.

9.11 Connections shall be brought from the device to terminal boards placed inside the marshalling kiosk.

9.12 Terminals, links and a moving iron ammeter of about 60mm diameter, shall be provided in the marshalling kiosk for each WTI for:

(a) Checking the output of the current transformer.

(b) Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator.

9.13 A diagram and instruction plate shall be provided in each marshalling kiosk.

9.14 Information shall be included in the maintenance instructions in the form of either a graph or table, showing the relationship between current injected into the heater coil and the corresponding indicator reading for:

(a) The transformer operating at CMR and an oil temperature of 60°C.

(b) The transformer unenergised and an oil temperature of 20°C.

9.15 Cooler failure or oil and water flow alarm initiating devices shall be provided as specified in Clause 6.12 and 6.13.

9.16 If stated in the Schedules, the following equipment shall be supplied:

(a) An electrical drop flag indicating device for connection in series with each set of alarm contacts provided on the temperature indicating devices and the gas and oil-actuated relays.

(b) An alarm relay, illuminated signal and audible warning device for use in connection with the alarm contacts on the temperature indicating device, gas and oil-actuated relays and flow meters. These shall be arranged so that the audible warning device may be switched out of circuit leaving the illuminated signal in operation as long as the contacts of the initiating devices remain closed. The audible alarm circuit shall be restored automatically when the contacts of the indicating device open.

9.17 When specified in the Schedules, a low oil level alarm device shall be fitted, this device shall be arranged to actuate an alarm when the oil level drops below the level of the prismatic indicating gauges.

9.18 Each main transformer and each earthing and auxiliary transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts which close on collection of gas and tripping contacts, which close following oil surge or low oil level conditions. The operational limits of the relay shall be as state in the Schedules.

9.19 Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay, or with the approval of the Engineer, external devices for operating the floats.

9.20 The allow gas to be collected at ground level, a pipe approximately 5mm inside diameter shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point approximately 1.4m above ground level, where it shall be terminated by a cock.

9.21 A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay. See Clause 5.31.

9.22 A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the tank side of the gas and oil-actuated relay and three times the internal diameter of the pipe on the conservator side of the gas and oil-actuated relay.

9.23 The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relays shall not take place under normal service conditions.

9.24 The pipe work shall be so arranged that all gas arising from the transformer shall pass into the gas and oil-actuated relay. The oil circuit through the relay shall not form a delivery path in parallel with any circulating oil pipe, nor shall it be teed into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided.

9.25 When a transformer is provided with two conservators the gas and oil-actuated relays shall be arranged as follows:

(a) If two conservators are connected to the transformer by a common oil pipe one relay shall be installed in the common pipe.

(b) If the two conservators are pipe separately to the transformer two relays shall be installed, one in each pipes connection.

9.26 The clearance between oil pipe work and live metal shall comply with the requirements of Clause 6.4 and the Schedules.

10. MARSHALLING KIOSKS

10.1 A sheet steel, vermin-proof, well-ventilated and weatherproof marshalling kiosk of approved construction shall be provided for the transformer ancillary apparatus. The kiosks interior and exterior painting shall be in accordance with Clause 1.35. Where specified in the Schedules, the marshalling kiosk shall be omitted and the transformer ancillary apparatus shall be mounted in approved heated and ventilated chamber(s), in accordance with he requirements of the Engineers. The chamber(s) shall comply with the following requirements relating to Marshalling Kiosks, where these are applicable.

10.2 The kiosk shall be arranged so that the equipment is grouped as below:

(a) Temperature indicators, cooler control “autohand” changeover switch and test links and ammeter for the winding temperature indicator circuits, as specified in Clause 9.

(b) Control and protection equipment for the tap change gear including an isolating switch in the incoming circuit capable of carrying and breaking the full load current of the motor and of being locked in the open position, and interposing relays for supervisory control equipment if required. An LV single phase transformer in accordance with Clause 7.19 and controlled and protected by a moulded case circuit breaker.

(c) Control and protection equipment for the cooling plant including an isolating switch in the incoming circuit capable of carrying and breaking the full load current of all cooling plant motors and of being locked in the open position, together with means of isolating each motor circuit or group of motor circuits when a multifan arrangement is adopted.

(d) Terminal boards and gland plates for incoming and outgoing cables except for the 415 volts supply cables for tap change and cooler motors which shall terminate at the base of compartment in which the supply is required.

(e) One set of 4 bolted links suitable for the termination of a 70mm², 4 core cable bringing supplies from the LVAC board to the transformer-marshalling kiosk. The studs associated with these links shall be long enough to permit the connection of a temporary cable for oil filtration plant supply without disturbing any other connections.

(f) One master-isolating switch of the lockable pattern interposes between the bolted links of (e) above and the TMK auxiliary supply busbars.

The arrangement of the TMK auxiliary supplies shall be to the approval of the Engineers.

10.3 All the above equipment except (d) shall be mounted on panels within the respective compartments and back of panel wiring shall be used for interconnection.

10.4 Each compartment shall be provided with access doors at front and rear.

10.5 All doors shall have "lift-off" type hinges and be fastened by integral handles. Nuts, bolts or carriage keys shall not be used. The doors must be sealed, and frames onto which the doors close must have a projecting channel to prevent further ingress of water, which may pass the seal. Provision shall be made for locking each door. Locks and duplicate sets of keys shall be provided.

10.6 The temperature indicators shall be so mounted that the dials are not more than 1.7m from ground level, and the door(s) of the compartment shall be provided with glazed windows of adequate size.

10.7 Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessary of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp beans avoided where the capillary tubes enter the kiosk.

10.8 To prevent internal condensation an approved type of metal clad heater shall be provided controlled by a water-tight single pole ironclad rotary switch mounted on the outside of the kiosk and a 5amp fuse and neutral link inside the kiosk. The heater shall be fed from the kiosk 240 volt general supply circuit ventilation louvers shall be provided and any divisions between compartments inside the kiosk shall be perforated to permit natural air circulation. The heater switch may, with special permission, be internally mounted.

10.9 All internal wiring between compartments shall be in conduits cleated near the side of the kiosk and so placed as not to obstruct access.

10.10 All incoming cables shall enter the kiosk from the bottom and the gland shall be not less than 450mm from the base of the kiosk. The gland plate and associated compartment shall be sealed in an approved manner to prevent ingress of moisture from the cable trench.

10.11 On marshalling kiosks provided with auto-connected transformers, all glands of multicore cables for circuits other than those from the transformer to the kiosk shall be insulated from the kiosk by either insulating each individual cable gland or the complete gland plate.

10.12 Separate cable sealing boxes shall be provided for each incoming cable. They shall project at least 20mm above the gland plate to prevent any moisture draining into the cable crutches from the gland plate. Each cable-sealing box shall be easily removable without disturbing other sealing boxes fixed to the gland plate. The ends of all wiping glands shall be tinned prior to dispatch to site.

10.13 All wiring, connections, terminal boards, fuses and links shall be in accordance with Clause 10.17 to 10.55.

10.14 Labels shall be provided on the outside of the kiosk doors to identify the compartments.

10.15 All three-phase relays, contactors, isolating switches and thermal devices shall be marked with the appropriate phase colour. Apparatus in which the phase elements are mounted horizontally shall be coloured red, yellow, blue from left to right when viewed from the front of the panel, and when mounted vertically they shall be coloured red, yellow, blue from top to bottom.

10.16 Unless otherwise specified in the Schedules, the kiosk shall be fitted with the following switches sockets mounted internally to provide auxiliary supply points:

1 - Industrial 15 ampere plug-socket for 240 volts AC supply. This switch-socket is to be connected through a 20 ampere CB and earth leakage.

10.17 All cables and wiring shall be of approved types and sizes. Any wiring liable to be in contact with oil shall have oil-resisting insulating and the bared ends of stranded wire shall be sweated together to prevent creepage of oil along the wire.

10.18 There shall be no possibility of oil entering connection boxes used for cables or wiring.

10.19 Panel connections shall be insulated, and shall be neatly and securely fixed to the panel. All instruments and panel wiring shall be of an approved self-extinguishing type and shall be run in porcelain or non-rusting metal cleats of the limited compression type or in non-rusting flexible tubes or galvanised steel tubes. All wiring to a panel shall be taken from approved terminal boards.

10.20 Where the cable contract is separate from the contract, the cable contractors will be responsible for leaving sufficient lengths of tails at each end of the multicore cables to connect up to the terminal boards. They will also strip, insulate, ring through and tag the tails and will also seal the cable boxes. The transformer contractor shall be responsible for re-checking the individual cores and for the final connecting up and fitting of numbered ferrules.

10.21 Unless otherwise approved no insulated wire shall have less than seven strands and shall not be less than $2.5mm^2$ in section. If single conductor is approved for instrument wiring annealed copper of circular cross section shall be used and the section of the copper shall be not less than $2.5mm^2$.

10.22 The external cabling on the transformer and between the transformer and the marshalling kiosk and circuits connected to current transformers associated with protective equipment must be PVC insulated. The wiring shall enter the bottom compartment of the kiosk through the gland plate in such a manner that the rear is kept clear for access. External cabling for all circuits connected shall, unless otherwise approved, consist of wire armoured PVC cable in accordance with SABS 150 – 1957.

10.23 Where the use of conduit is approved, the runs shall be laid with suitable falls, and the lowest parts of the run shall be external to the kiosks or boxes. All conduit-runs shall be adequately drained and ventilated. Conduits shall not be run at or below ground level.

10.24 415 Volt AC circuits shall not be brought into indoor relay or control cubicles.

10.25 When 415 volt connections are taken through junction boxes or marshalling kiosks, they shall be adequately screened and "415 VOLT DANGER" notices must be affixed to the outsides of the junction boxes or marshalling kiosks.

10.26 All cubicle wiring shall be tested according to the Schedules, and unless otherwise approved, conform to the following standard colour code:

Colour of Wire	Circuit Particulars
Red	Red-phase connections in current and voltage transformer circuits only.
Yellow	Yellow-phase connections in current and voltage transformer circuits only.
Blue	Blue-phase connections in current and voltage circuits only.
Green	Neutral connections in current and voltage transformer circuits only, whether earthed or unearthed. Insulated earth wires.
Black	A connection in AC circuits other than current and voltage transformer circuits. Connections in AC/DC circuits.
Grey	Connections in DC circuits.

10.27 All wires on panels and all multicore cables shall have ferrules, which bear the same number at both ends.

10.28 Ferrule numbering shall be to approval of the Engineer.

10.29 At those points of interconnection between the wiring carried out by separate contractors where a change of number cannot be avoided, double ferrules shall be provided on each wire. The change of numbering shall be shown on the appropriate diagram of the equipment.

10.30 Ferrules shall be of white insulating material and shall be provided with glossy finish to prevent adhesion of dirt. They shall be clearly and durably marked in black and shall be not be affected by damp or oil. Standard ferrule numbering shall be used in accordance with the proposed schematic supplied with this bid. Approval shall be obtained for any alterations or additions required.

10.31 All wire associated with the tripping circuits shall be provided with red ferrules marked "Trip" or "T" alternatively where telescopic ferrules are supplied the function letter ferrule shall be coloured red.

10.32 Stranded wires shall be terminated with tinned approved claw washers, or approved crimped lugs, separate terminations being used for each wire. The size of the terminations shall be suited to the size of the wire terminated. Wiring shall, in general, be accommodated on the sides of the cubicles and the wires for each circuit shall be separately grouped. Back-of-panel wiring shall be arranged so that access to the connecting stems of relays and other apparatus is not impeded.

10.33 Wires shall not be jointed to teed between terminal points.

10.34 Bus wires shall be fully insulated and run separately along the top or bottom of the cubicles. Fuses and links shall be provided to enable all circuits in a cubicle, except a lighting circuit, to be isolated from the bus wires.

10.35 Wherever practicable, all circuits in which the voltage exceeds 125 volts, shall be kept physically separated from the remaining wiring. The function of each circuit shall be marked on the associated terminal boards.

10.36 Where apparatus is mounted on panels all metal cases shall be separately earthed by means of copper wire or strip having a cross section of not less than 1.5mm². Where strip is used, the joints shall be sweated.

10.37 Where practicable, the clearances between relay stems or connecting studs shall not be less than 30mm and in no case less than 25mm.

10.38 Resistances shall be provided with stud terminals. Setscrews shall not be used.

10.39 All wiring diagrams for control and relay panel shall preferably be drawn as viewed from the back and shall show the terminal boards arranged as in service. All diagrams shall show which view is employed.

10.40 Multicore cable tails shall be so bound that each wire may be traced without difficulty to its cable.

10.41 The spare cores of all multicore cables shall be numbered and terminated at a terminal block in the cubicle. Where cables are terminated in a junction box and the connections to a relay or control cubicle are continued in conduit an approved number of spares cores shall be taken through the conduit and terminated in the cubicle.

10.42 The screens of screened pairs of multicore cables shall be earthed at one end of the cable only. The position of the earthing connections shall be shown clearly on the diagrams.

10.43 All terminal boards shall be mounted obliquely towards the rear doors to give easy access to terminations and to enable ferrule numbers to be read without difficulty.

10.44 Terminal board rows shall be spaced adequately not less than 100mm apart to permit convenient access to wires and terminations.

10.45 Terminal boards shall be so placed with respect to the cable crutch (at a minimum distance of 20mm) as to permit satisfactory arrangement of multicore cable tails.

10.46 Terminal boards shall be provided with 6mm stud terminals or other terminals approved by the Engineers. Terminal board studs shall not be numbered. Where setscrew terminations are specifically approved in special instances the screws shall have hexagonal 6mm heads with slot for the use of a screwdriver. Holes for setscrews shall be slightly recessed to facilitate entry of the screws.

10.47 All connections shall be made to the front of the terminal boards. Current shall not be carried through the boards by the studs.

10.48 Terminal boards shall have pairs of terminals for incoming and outgoing wires and not more than two wires shall be connected to any one terminal. Insulating barriers shall be provided between adjacent connections. The height of the barriers and the spacing between terminals shall be such as to give adequate protection while allowing easy access to terminals.

10.49 Insulating covers of non-flammable material, preferably transparent, shall be provided on terminal boards on which connections for circuit with a voltage greater than 125 volts are terminated.

10.50 Labels shall be provided on the fixed portion of the terminal boards.

10.51 No live metal shall be exposed at the back of the terminal boards.

10.52 The use of terminal boards as junction points for wires, which are not required in the associated cubicle, shall be avoided wherever practicable. Provision shall be made, however, so that up to 40 terminals can be accommodated for this purpose.

10.53 Fuse and link carriers and bases shall be of good quality moulded insulating material and shall be coloured No 17 sea green (BS 381C) for 15 ampere fuses, black for 5 ampere fuses and white for links.

10.54 Fuses for other than auxiliary plant or cooler motor supplies shall be of an approved rewireable type.

10.55 Fuses and links shall be labeled in accordance with the diagram.

11. CONTROL PANELS

11.1 A remote control panel per transformer shall be provided by others in the Schedules. The arrangement of the panel shall be to approval. Panels shall be designed such that similar additional panels may be added in the future to form a panel suite. Cubicles shall be vermin-proof and termite-proof.

12. DRYING OUT, TRANSPORT AND ERECTION

12.1 All transformers shall be dried out by an approved method at the manufacturer's works and so arranged that unless otherwise approved they may be put into service without further drying out on site. Any subsequent drying out which may be necessary after taking over will generally be carried out by moving the transformers to a manufacturer's works or other place where suitable facilities exist for applying the same methods as those first employed; but the Contractor shall submit to the Engineer for his approval details of the method which they recommend should be adopted for drying out the transformers on site should it prove necessary to do so.

12.2 The completely assembled transformer shall be designed to withstand vacuum treatment at 760mm of mercury, at sea level.

12.3 Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures, e.g. strutting of tap changers barrier or tank cover, which must be taken before the specified vacuum treatments can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment is to be provided with each transformer. The maximum vacuum, which the complete transformer, filled with oil, can safely withstand without any special precautionary measures being taken, shall also be stated in the Maintenance Instructions.

12.4 After the transformer has been erected and completely filled with oil on site, adequate steps shall be taken in order to exhaust, as far as possible, all air, which may be trapped within the tank and pipe work.

12.5 The Contractor shall be responsible for ascertaining the method of transport to site and designs affected by restrictions in transport are to be subject to approval.

12.6 The Contractor shall be responsible for verifying the access facilities given in Schedule “K” and for making all arrangements for transport and erection.

12.7 All transformers, unless otherwise approved, are to be transported in oil, but bushings, cable boxes, conservator vessels and breathers, radiators, wheels, or other external parts may be removed providing that they can be replaced on site without necessitating further drying out of the transformer.

12.8 The Contractor shall erect and connect up the apparatus provided under the contract as far as the approved terminal positions on the parts concerned and he shall co-operate with the other Contractors concerned in the completion and testing of this connection work, including the fitting of engraved numbered ferrules and making the transforming plant ready for service.

12.9 Special care shall be taken not to injure the skin of galvanised or specially treated surfaces during erection and also to prevent or remove any rust streaks or foreign matter deposited on galvanised surfaces during storage or transport or after erection.

12.10 After erection on site all damaged paintwork shall be carefully cleaned down and restored. Where the final coat of paint is applied on site the surface shall be thoroughly cleaned and rendered free from oil before painting is commenced.

13. MULTICORE CABLES

13.1 The Contractor shall be responsible for providing information regarding the connection of multicore cables to the terminals in the marshalling kiosk and tap change control panels to the contractors who will be responsible for the laying and connecting up of multicore cables between these two items and any other associated equipment.

The Contractor shall also be responsible for the preparation of cabling schedules and diagrams for the multicore connections between the transformer marshalling kiosk and the tap change control panel for incorporation into the similar schedule and diagrams for the substation installation as a whole.

13.2 Multicore cable work included in this contract shall cover the supply, laying, erection, making off, testing and connecting up of cables between the transformer and the transformer marshalling kiosk only.

14. CURRENT TRANSFORMERS

Where specified in the Schedules, current transformers shall be provided.

14.1 Current transformers provided for protective purposes shall comply with the requirements of Schedule "D" and shall be to the requirements of the Contractor supplying the switchgear who will also be responsible for the overall protective scheme of the power transformers.

14.2 Current transformers shall be installed in the positions stated in the Schedules and the secondary wiring of such current transformers between current transformer terminals and power transformer marshalling kiosk shall form part of this Contract. The secondary wiring of current transformers shall comply with the relevant sections of Clauses 10.17 to 10.55. All current transformers shall comply with the requirements of BS 3938 except where otherwise stated. The design, characteristics and construction of current transformers for protection gear and circuits shall be to approval. All current transformers shall be capable of withstanding the conditions, which would be imposed during all the type tests prescribed in IEC 60076, and the tests specified in the Schedules.

14.3 Each current transformer shall be of approved ratio and shall be capable of providing the necessary energy to operate the associated protective devices and instruments. The full load current rating of the windings shall be as stated in the Schedules. The primary windings shall be of the bar type. Unless otherwise approved all current transformers shall be capable of being left open circuited in the secondary with the primary circuit under full load without overheating or damage.

14.4 The method of securing the current transformers in position shall be such that undue pressure cannot be exerted on the transformer windings. The positioning of current transformer bushings shall be to the approval of the Engineers.

14.5 Estimated magnetization curves shall be provided for all designs of current transformers.

14.6 Where current transformers provided under other contracts have to be mounted on or in the power transformer the Contractor shall be responsible for the supply of all mounting brackets and fittings, etc., and shall be responsible for obtaining all necessary dimensions and details of the current transformers from the contractor supplying the latter. The primary connection between the power transformers and externally mounted current transformers will be provided on other contracts.

14.7 Where external neutral current transformers are specified for directly earthed power transformers they shall be enclosed in a metal case fitted with an external bushing on the side of the current transformer connected to the power transformer neutral point. This bushing shall provide a level of insulation not less than that corresponding to a system voltage of 22kV. The earth end of the current transformer primary conductor shall be bonded to the case and threaded to accept the earth conductor. The insulating medium in the case shall be appropriate to the required insulation level of the unit.

14.8 Where external current transformers are specified for indirectly or resistance earthed power transformers, they shall be enclosed in a metal case fitted with external bushings on both the transformer neutral and earth connection side. These bushings shall provide a level of insulation equal to that of the neutral end of the associated power transformer winding. The bushings shall be provided with threaded studs to accept earth conductor and power transformer neutral connections. The case shall not be bonded to the primary conductor and shall be filled with an insulating medium appropriate to the required insulation level of the unit.

14.9 The physical positions, ratios, class, terminal details, etc., of all current transformers contained within the tank of the power transformer shall be shown on the transformer rating plate as laid down in IEC 60076.

14.10 Where current transformers supplied under this Contract have to be mounted on apparatus provided under other contracts, the Contractor shall be responsible for making all the necessary arrangements direct with the other contractors and for keeping the Engineers informed.

14.11 Where specified in the Schedules spare current transformers shall be provided under the Contract.

14.12 Current transformers provided for use with winding or oil temperature monitoring schemes and for use with circulating current schemes for controlling transformers operating in parallel shall be suitable for the purpose for which they are intended. Such current transformers shall be deemed to form part of the transformer for which they are required, and shall be supplied whether specified separately or not in the Schedules.

15. AUXILIARY TRANSFORMER

No auxiliary transformers are required on this contract.

16. TRANSFORMER PROTECTION

16.1 All transformer protection relays and controls will be supplied and mounted on panels provided on other contracts.

17. SUPERVISORY REQUIREMENTS

17.1 Provision shall be made on other contracts for the supervisory controls, indications, analogues and alarms.

18. TESTS

18.1 GENERAL:

The following tests shall be carried out in order to determine whether the materials and apparatus comply with the Specification and to provide the necessary operating data.

Not less than seven days notice of all tests shall be given to the Engineer in order that they may be represented if they so desire. As many tests as in the opinion of the Engineer are possible shall be arranged together. Six copies of the Contractor's records of all tests shall be supplied to the Engineer.

All material, which is specified for tests at the Manufacturers Works, must satisfactorily pass such tests before being painted. All instruments shall be approved by the Engineer and if required shall be calibrated at the expense of the Contractor by the Bureau of Standards or such other body as may be agreed.

Certain type tests may be waived on the production of satisfactory certificates showing that these tests have been carried out.

A. Test to be carried out at the Manufacturer's Works unless an alternative place of testing is specified or agreed:

1. Transformers. Routine an Type Tests.
2. Bushings – Routine, Sample and Type Tests.
3. Tanks – Routine and Type Tests.
4. Cooling Plant – Routine and Type Tests.
5. Pipe work and Valves – Routine Tests.
6. Motors – Routine and Type Tests.
7. Oil – Sample Tests.
8. Gas and Oil Actuated Relays – Routine and Sample Tests.
9. Secondary Wiring – Routine Tests.
10. Galvanising – Sample Tests.
11. Cubicles – Routine Tests.
12. Current Transformers – Routine Tests.

B. Site inspection and tests to be carried out on Site:

- all voltage ratios on all phases;
- vector group;
- three-phase 380V magnetizing currents on all windings;
- winding and core megger test (minimum 1.5kV);
- functional test for all alarm and trip contacts;
- CT polarities;
- fan and oil pump directions and operation of starting and overload protection relays;
- control/power cabling insulation (minimum 1kV);
- correct operation and indication of tap changers;
- correct position of all valves in the oil circuits.

18.2 DESCRIPTIONOF TESTS TO BE CARRIED OUT AT THE MANUFACTURER'S WORKS

18.2.1 TRANSFORMERS

The following routine and type tests shall be carried out. The tests shall be in accordance with IEC 60076 except where otherwise specified. Where a transformer is to be subjected to a temperature rise type test, routine tests (j) and (k) shall be carried out as soon as practicable after this test, that is, whilst the transformer is still hot.

Routine Tests

(a) Resistance of windings, carried out in accordance with IEC 60076.

(b) Ratio on all tapings and Vector Group, in accordance with IEC 60076.

(c) Impedance at rated current and normal frequency on the principal tapping, which corresponds to the rated voltage, and also the maximum and minimum tapings measured in accordance with IEC 60076, and at any tapings required by the Engineer.

(d) Load losses ate rated current and normal frequency on the principal tapping, according IEC 60076.

(e) Insulation resistance using a meggar of not less than 2 volts or by other approved method before and after high voltage tests. The temperature at which these resistance measurements are taken shall be recorded.

(f) Magnetic circuit insulation

(i) A power frequency voltage of 2kV for one minute applied as follows:

Core bolts: to core, yoke clamps, and core leg side plates

Core to yoke clamps and to core leg side plates

(ii) Immediately prior to dispatch 2kV for one minute applied between core and earth. The insulation resistance must also be measured.

(g) No load current at rated voltage and normal frequency. In addition, the magnetising current shall be recorded at voltages of 50, 70, 90, 95, 100, 105, 110% an 120% of nominal.

(h) No-load losses at normal frequency with rated voltage applied to the principal tapping, measured in accordance with IEC 60076.

(i) Induced voltage withstand tests:

These tests shall be applied to each transformer winding as indicated below, but otherwise as specified in IEC Publications 52 and 60076-3.

Induce voltage tests according to ACLD of IEC 60076-3 will be accepted for this transformer.

The prestress voltage (U_1) shall be 1.8 √3 of maximum voltage Um applied for the test time.

The partial discharge levels measured at 1.6pu maximum phase voltage (U_2) shall not exceed 300pC at the end of the 30 minute tests period and shall show no rising tendency.

If values in excess of 300pC are measured, this will be regarded as a test failure.

(j) Applied voltage. Note: Transformers with graded insulation and having the earth connection brought out through insulating bushing shall be subjected to a test of one minute duration and of the magnitude specified in IEC 60076.

(k) The regulation shall be determined (by calculation) at power factors of unity and 0.8lag.

(l) Switching impulse test (SI). Switching impulse shall be according to IEC 60076-3.

The voltage impulse shall have a virtual front time of at least 100 μs, a time above 90% of the specified amplitude of at least 200 μs, and a total duration from the virtual origin to the first zero passage at least 500 μs but preferably 1 000 μs.

(m) Impulse voltage:

These tests shall include 110% chopped wave tests and shall be carried out in accordance with
IEC 60076 and 60.

The chopped wave tests shall be carried out at a level at the instant of chopping equal to at least that applicable for full wave tests and with a chopping time as stated in IEC. The sequence of voltage application shall be stated in the schedules. Transferred surge tests on the tertiary winding shall be associated with direct impulse tests on the HV winding.

Type Tests

(n) Temperature rise: Temperature rise tests shall be carried out to demonstrate both the forced cooled rating and natural cooled rating in accordance with IEC 60076. During these tests the accuracy of the oil and/or winding temperature devices shall be determined. The efficiency of the coolers shall also be confirmed during and after this test.

Where tests are made at altitudes lower than 1 800m, the limits of temperature rise specified in (i) (i.e. 55°C for oil and 60°C for windings) shall be reduced by the following amount for each 50m by which the test altitude is below 1 800m:

Naturally air-cooled – Oil immersed type 0.2% transformers

Forced air-cooled – Oil-immersed 0.3% transformers

(i) Transformers are used under conditions at the following ambient air temperatures:

- maximum	40°C
- daily average	35°C
- yearly average	25°C
- minimum	-10°C

Note – Due to higher prevailing ambient temperatures winding temperature and top oil temperature rises shall not exceed 60°C and 55°C respectively.

In this respect the above temperature limits differ from those specified in IEC 60076.

(o) Capacitance: The capacitance between windings and between each winding and earth shall be measured.

(p) Zero phase – sequence impedance shall be measured in accordance with IEC 60076.

(q) Noise level – The level of noise shall be measured to NEMA or other approved National Standards.

(r) Vibration: The level of vibration of the tank and auxiliaries shall be shown to be non-damaging. This shall be demonstrated by measurement, if necessary. The method of measurement, and the magnitude of the vibration shall be to approval.

(s) Bushing Partial Discharge Tests as Specified.

PART 10.7 : Neutral Earthing Compensators (NEC's) Combined with Neutral Earthing Resistors (NER's) and Auxiliary Power Transformers

SPECIFICATION No. : NE.20/0-97

CONTENTS

1. STANDARDS

The combined neutral earthing compensators, oil-immersed metallic resistors and auxiliary transformers shall comply with this specification and with the current editions of the following standards, except where otherwise specified:

	IEC	BS	SABS
Power transformers	76	171	780
Bushings	137	223	1035, 1037
Oil	296		555
Current transformers	185	3938	
Cable sealing boxes		2562	
Corrosion prevention and paint protection systems		381C	679
Fuses		88	
Insulation		2757	
High voltage testing	52, 60, 270		
Relays and contacts		142	
Pipe flanges		4504	
Reactors	289	4944	
Moulded case circuit breakers			156

1.1 Scope of Specification

Combined oil-immersed 3-phase neutral earthing compensators with metallic neutral earthing resistors and auxiliary power transformers are covered by this specification. They are intended for service in conjunction with the delta connected secondary windings of the power transformers specified in Schedules of particulars to provide earthing points for the LV systems and to limit the currents during line to earth faults on these systems. The auxiliary windings are to provide low voltage power supplies to the local substation and switchgear auxiliaries. Each NEC/NER and auxiliary transformer shall be combined in one complete unit and shall be referred to as such in the following discussions.

1.2 Erection

The tender price shall include for off-loading and erecting of the units. The tender price shall include for first filling the complete NEC/NER units and associated oil filled equipment, with oil to the correct temperature level and it shall include for the undertaking of drying-out process which may be necessary to ensure that the transformers are ready for operation before handing over.

Erection shall include off-loading, lifting, handling, positioning, oil filling and installation of the transformers together with all materials and ancillary equipment supplied for the contract works for a complete installation, including levelling, grouting and any provision deemed necessary to prevent movement of a transformer on its base in service, and also the provision of all necessary staging, sleepers and lifting tackle and appliances.

Erection shall further include filtering of oil and drying out and testing and checking processes which may be necessary to ensure that the units are ready for operation before handing over, together with the provision of the necessary materials, apparatus and instruments for these processes. All items provided for erection shall be removed from site when erection is completed. All site installation, testing and commissioning work shall be subject to the approval of the Engineer in all respects and shall be carried out strictly in accordance with the Conditions of Contract.

2. DESIGN DETAILS

2.1 Rating

The NEC/NER combinations shall limit the earth fault currents in each particular system to the levels specified in Schedules of particulars, taking into account the manufacturing tolerances and system parameters.

The units shall be capable of operating continuously without injury under the stated service conditions and without exceeding the temperature rises specified in BS 171 and Clause 2.2 of this document.

2.2 Ability to Withstand Short-Time Current and Temperature Rise

Each combined NEC/NER shall be capable of withstanding the rated short-time current for the specified duration as stated in Schedules of particulars.

The NEC alone shall be capable of withstanding the short-time current that will flow in the windings if the NER is short-circuited. In such event the rated short-time of the NEC shall be 50% of the time specified in Schedules of particulars for the combined unit.

The combined NEC/NER shall be capable of withstanding the dynamic mechanical forces arising under short circuit conditions without damage, even in the case when the NER is short-circuited.

The temperature rise values for the metallic resistor, both under full load operating conditions and short-time conditions, shall be stated by the tenderer in Schedule of Particulars and Guarantees (Section IV) and shall not exceed those limits specified in clauses 8.3.1 and 8.3.2.

2.3 Resistance/Temperature Co-efficient

The resistance, temperature co-efficient of the metallic resistor shall be such that the value of the resistor between 100 °C and 435 °C (i.e. 35 °C ambient plus 400 °C short-time temperature rise specified in clause 8.3.2) shall not exceed the value of the resistor at 100 °C by more than 5%.

2.4 Insulation Levels

The insulation of all windings for system voltages of 66 kV and below shall not be graded and shall be fully insulated as specified in BS 171. This includes the neutral point of the NEC notwithstanding the requirement specified in BS 4944 Clause 6.4.

The insulation of all star connected windings for system voltages of 132 kV and above shall be graded as specified in BS 171.

The NER shall be insulated to withstand the voltage test specified in Clause 8.2.

2.5 Noise and Vibration

The NEC/NER and auxiliary transformer units and supplementary cooling equipment, shall operate without undue noise and vibration and every care shall be taken in the design and manufacture to reduce noise and vibration to the level of that obtained by good modern practice.

The units shall be designed so that the average sound level will not exceed the values given in NEMA TRI-0.06, 1971 when measured at the factory in accordance with the conditions outlined in NEMA TRI-9.04, 1971, and Schedule "F" A1(r).

In the case that the average sound level exceeds the values given in NEMA TRI-0.06, the Employer reserves the right to:

a) Reject the units;

b) require the Contractor to take remedial measures; and

c) require the Contractor to bear the cost of any remedial measures the Employer may decide to take.

The level of vibration shall not adversely affect any connections or clamps on the unit or cause excessive stress on any portion of the unit.

2.6 Radio and Television Interference

The design of the units shall be such that they will not cause any objectionable interference with radio and television reception in the vicinity of the units either by direct radiation or by transmission through the power lines and system to which the units may be connected, when energised at full rated voltage and when delivering any load up to the continuous maximum rating.

2.7 Internal Connections

All internal connections shall be so supported to maintain clearances to each other and to earthed metal during transport and under short-circuit conditions, and to be free from vibration in normal service.

2.8 Electrical Clearances

Adequate electrical clearances shall be provided and care shall be taken to ensure that no fittings are located so as to interfere with the external connection to the bushings.

The clearances between live metal and oil pipe-work, including the conservator and oil pressure relief valve, shall be adequate to withstand the assigned impulse withstand test voltage. In all cases the NEC bushings shall be tank top mounted and the above clearances shall be maintained under all operating conditions.

2.9 Cross-sectional Area of Earthing Connections

No internal core earthing connections shall be of smaller cross-sectional area than 80 mm^2, with the exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 mm^2, where they are clamped between the laminations.

3. CURRENT TRANSFORMERS

3.1 General

Current transformers shall be of the multi-ratio type and fitted in the neutral connection at the earthed end of the NER with adjacent hand-holes in the tank for access purposes.

All current transformer secondary and tapping leads shall be brought out to the secondary wiring terminal box and marked for identification. A minimum of 7 strands shall be used for these leads both internally and externally to the tank.

Current transformers shall be provided with 10 A windings for injection testing purposes.

3.2 Rating and Performance of Current Transformers

Current transformers shall comply with BS 3938 - 1973. The rating and performance shall be as specified in Schedules of particulars.

The following information on current transformers shall be submitted for approval before manufacturing commences:

a) Magnetisation curve for one ratio;

b) exact turn ratio on each tapping;

c) secondary resistance on each ratio at:

    i) 20 °C and

    ii) 70 °C.

d) secondary leakage reactance for each ratio.

Current transformers shall also have an impulse strength equal to that of the section of the winding in which they are located.

4. CONSTRUCTIONAL DETAILS

4.1 General Arrangement

The units shall consist of a NEC combined with an auxiliary transformer and a metallic NER, either situated in the same tank or in a separate tank attached to the NEC tank, but in any case using only one common set of external HV terminals and a common oil conservator with associated auxiliaries and fittings.

The metallic neutral earthing resistor shall be oil immersed and securely mounted in the tank in each plane.

The auxiliary transformer shall be designed and constructed in accordance with SABS 780 as a low loss transformer.

4.2 Cores

All core steel shall be selected, treated and handled with great care to ensure that the finally assembled core is free from distortion and each lamination shall be insulated with a material that will not deteriorate due to pressure and the action of hot oil.

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned-copper bridging strips shall be inserted to maintain electrical continuity between sections.

The magnetic circuit shall be earthed to the core clamping structure at one point only through a removable link placed in an accessible position beneath an inspection cover on the same side of the core as the main earth connection between the core structure and tank.

Core bolt insulation shall withstand a test voltage of 2 kV at 50 Hz for one minute.

The core and core clamping structure shall be of adequate strength to withstand, without damage, the stresses to which it may be subjected during handling, transportation, installation and service. All nuts shall be effectively locked by means of standard machined lock nuts. Peening of bolt ends and/or threads alone or the use of tempered pressed steel nuts, will not be acceptable.

Lifting lugs or other means shall be provided for conveniently lifting the core, and when lifting, no stress shall be imposed on any core bolt or its insulation.

Unless otherwise approved, vertical tie rods shall be provided between top and bottom clamping structures.

4.3 Windings

The NEC's and auxiliary transformers shall be capable of withstanding without damage:

a) A three-phase fault on any terminals assuming that the fault level on the remaining terminals is that specified in Schedules of particulars for a period of five seconds; and

b) a line to ground fault on any terminals assuming that the fault level on the remaining terminals, is that specified in Schedules of particulars and that the earthed neutral of the unit is the only earth point on the system, for a period of five seconds.

All winding insulation shall be treated to ensure that there will be not appreciable shrinkage after assembly.

4.4 Main Terminals

The units shall be provided with outdoor type bushing insulators or cable boxes as specified in Schedules of particulars.

4.5 Bushings

Unless otherwise specified, bushing terminals shall be copper or copper alloy cylinders capable of carrying the rated full load current and short circuit currents specified in clause 4.3.1, without any damage to the bushing or its components.

Bushings shall comply with the electrical characteristics specified in Schedules of particulars.

For systems voltages of 44 kV and above, only condenser bushings shall be supplied.

Rigid tubular conductors shall be used for the electrical connections to the HV and/or LV bushings. The bushings shall be furnished with suitable conductor clamps to support the tubular conductors and to allow for the expansion and contraction thereof.

The tubular conductors shall be connected to the bushing terminals by means of flexible copper or aluminium conductors.

4.6 Cable Boxes

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables specified in Schedules of particulars.

Cable boxes for armoured cables shall be provided with suitable armour clamps.

Suitable 10 mm earthing terminals fitted with washers, nuts, lock nuts and removable copper earthing links, shall be provided on the cable boxes and on the insulated cable glands required for single core cables, for the purpose of bridging the gland insulation.

Cable boxes shall be either oil or compound filled, or air ventilated, as specified in Schedules of particulars.

4.7 Disconnecting Chambers

Where disconnecting chambers are specified in Schedules of particulars, the cable box bushing shall be attached to the back-plate of the cable box (or a separate backing-plate) to permit removal of the disconnecting chamber from the cable box (and cables) without the necessity of draining oil or compound from the cable box.

The disconnecting chambers shall be fitted with easily removable bolted links to facilitate separate testing of the cable without disturbing its connections, and a suitable and easily accessible earthing terminal for connection of the NEC windings to earth during this process.

4.8 General

For identical units, the cable boxes and disconnecting chambers shall be jig-drilled and fabricated so as to permit interchangeability of the units.

The NEC neutral earthing connection shall be brought out of the tank via an adequately insulated bushing similar to those specified for the phase terminals but fitted with a flag terminal. When a cable box is specified for the main terminals, the neutral bushing shall be specified separately in Schedules of particulars.

4.9 Tanks and Radiators

Corrugated tanks are not acceptable.

Tanks and fittings shall be of such a shape at water cannot collect at any point on the outside surfaces. It must also not be possible for gas to collect inside the tank unless such voids are connected by means of pipes to the main explosion ventilator pipe.

Guides shall be provided inside each tank to locate the core and windings centrally.

The base and tank of each unit shall be so designed that it shall be possible to move the complete unit, filled with oil, in any direction or to jack it up without structural injury or impairment of the oil-tightness of the unit. A design which necessitates slide rails being placed in a particular position or special detachable under base, shall not be used unless specifically approved.

Suitably proportioned manhole covers shall be provided in the tank cover to afford easy access to the lower ends of bushings and upper portions of the core and winding assembly.

All oil pipe connections above 12 mm diameter, shall be fitted with flanges.

The unit tanks and conservators shall be capable of withstanding a full vacuum (i.e. 760 mm of mercury at sea level).

In addition to the requirements of the test prescribed in IEC Publication 137: Clause 25, "Test for the efficiency of the seal", which shall be met by all bushings to which it is applicable, the sealing of the bushings against the ingress of atmospheric air and moisture via the surface of the bushing stem, to the unit tank, shall be proved by a test on one bushing of each type used.

The bushing mounted on a tank as described in IEC Publication 137: Clause 25 A2, shall be tested by drawing a full vacuum on the (empty) tank and then sealing off the tank from the means used to evacuate it.

The stem or terminal shall be considered satisfactory, if, after a lapse of two hours, the vacuum has been fully maintained.

The tank and cooling equipment shall be so designed that the vacuum treatment can be done on site.

Tank stiffeners shall not be installed in position where welded seams can be covered up.

The tank and cover shall be designed so that local heating due to stray flux in any structural parts, shall not exceed the temperature limit specified for the unit, and shall not cause temperature indication errors in the thermometer pockets.

4.10 Gaskets

Oil resisting synthetic rubber gaskets are not acceptable, except where synthetic rubber is used as a bonding medium for cork or similar material, or alternatively, where steel stops are provided to prevent over compression of the gaskets.

The Contractor shall submit details of gaskets material for approval.

4.11 Main Terminal Markings

All terminals shall be marked to correspond with the markings on the diagram plate.

Characters shall be marked in relief adjacent to their appropriate terminals. The characters may be of brass, steel or other acceptable metal and shall be permanently fixed to the tank, by means of brazing or welding.

4.12 Painting and Galvanising

All interior and exterior metal surfaces subject to corrosion shall be thoroughly cleaned by sand-blasting, shot-blasting or other approved methods before painting. All exterior surfaces shall be given a priming coat of anti-corrosion and oil-resisting paint, followed by two coats of weather and oil-resisting paint of good quality to colour No 632 of BS 381C, having a minimum total dry film thickness of 0.127 mm. The interior surfaces of the conservators shall be finished with a coat of light-coloured oil-resisting paint.

All cabinet interior shall have at least one priming coat and one finishing coat of gloss-white paint or enamel.

Should any paint work be damaged during transit or erection, this shall be made good on site.

All interior and exterior surfaces subject to corrosion that cannot readily be painted, shall be heavily galvanised (0.1079 mm average thickness) by the hot-dip process.

Bolts and nuts associated with galvanised parts, shall be hot-dipped galvanised, electro-galvanised or sheradized and shall meet the test prescribed in BS 729, that is, four dips in copper sulphate solution.

5. FITTINGS

The units shall be supplied complete with all fittings required by BS 171 and BS 4944 including the following:

5.1 Conservator Tank

The conservator tank shall be fitted with a removable end on which the oil gauge shall be mounted. The conservator tank shall be mounted to slope slightly downwards towards the drain valve, which shall be adjacent to the removable end and shall contain no pocket which is not drained by the drain valve.

The pipe connecting the conservator to the tank, shall extend at least 50 mm into the conservator and shall be brought out from the highest point of the main tank cover. A valve shall be provided immediately adjacent to the conservator. All pockets and bushing turrets of the main NEC tank and auxiliary transformer/NER tank, where this is separate from the main tank, shall be connected into this pipe between the main tank and the Buchholz relay.

The capacity of the conservator shall be such that the oil will not overflow or fall below the Buchholz relay floats for oil temperatures from -10 °C to 100 °C.

Brackets attached to the tank for the purpose of supporting the oil conservator, shall be arranged to be independent of the tank cover bolts.

5.2 Dial Type Oil Gauges

Dial type oil gauges shall be of the magnetically operated type, in which breakage of the gauge glass will not release any oil. Such gauges shall clearly indicate the oil level when viewed from ground level through the temperature range of -10 °C to 90 °C. The gauge shall be fitted with a pair of circuit closing ungrounded low oil level alarm contacts.

5.3 Silica Gel Breathers

Silica gel breathers shall have a window for inspection of the condition of the silica gel and oil cup or other device to prevent continuous contact of the silica gel with the air outside the unit. The quantity of silica gel shall be equal to 0.3 kg per 1000 litres of total oil content, unless otherwise approved by the Engineer.

5.4 Pressure Relief Device (optional)

The pressure relief valve(s), if so specified in Schedules of particulars, shall be fitted to the main tank wall in the vertical plane and arranged to be self-resealing and provide with contacts to indicate the "normal" and "operated" conditions, and also a mechanically operated, manually reset operation indicator.

5.5 Buchholz Relays

Buchholz relays shall be of the double float or bucket type and shall be of approved manufacture.

The gas release cock for the relay shall be placed within easy reach from ground level and connected to the relay by small bore non-ferrous tubing. The sight window of the relays shall be readily visible from ground level. The relay shall be fitted with tripping and alarm contacts and shall be so designed that the relay can be mechanically operated for testing purposes.

The relays shall be mounted in a straight run of pipe at least 350 mm long on the unit side and 230 mm long on the conservator side, rising at an angle of 3 to 7 degrees to the horizontal.

5.6 Winding Temperature Indicators (optional)

Winding temperature indicators, if so specified in Schedules of Particulars, shall be of the dial type, preferably compensated for changes in ambient temperature, and shall have a load temperature characteristic approximately the same as the hottest part of the windings. The current transformer for operating the indicator shall be built into the main transformer tank and shall be located to reflect the maximum hot spot temperature of the unit.

The indicators are to be provided with a dial indicating the temperature in °C and fitted with a reset-able maximum temperature indicator. A pair of adjustable alarm contacts which can be set to close at a predetermined temperature, are to be provided and, in addition, a pair of contacts for tripping purposes.

The instruments shall be mounted on a non-vibrating mounting which shall be provided by the Contractor. Such cubicle shall be provided with windows for viewing the instruments without opening the cubicles.

5.7 Dial Type Oil Thermometers

Dial type oil thermometers shall be graduated in °C for registering "top oil" temperatures. The instrument shall be provided with a reset-able maximum temperature indicator and a pair of adjustable alarm contacts which can be set to close at a predetermined temperature. In addition, a set of adjustable contacts shall be provided for tripping purposes.

The thermometer for each unit shall be mounted adjacent to the winding temperature indicator, if supplied, in the same floor mounted cubicle.

5.8 Thermometer Pockets

Each thermometer pocket shall be fitted with a captive screw cap.

5.9 Alarm and Trip Contacts and Auxiliary Relays

All alarm and trip contacts and auxiliary relays shall comply with the relevant requirements of BS 142 and in particular with Section 16: "Contact Ratings".

Alarm contacts shall be suitably for "cyclic duty" and trip contacts for "make duty", both as defined in Clause 50.2.2 of the above mentioned BS specification and, together with auxiliary relays, shall be tested in accordance with that clause, the test circuit parameters being those of Table 13, which, for convenience, is given below:

TABLE 13: TEST CIRCUIT PARAMETERS

	AC	DC
Make ratings	Resistive	Resistive
Break ratings	Cos 0 = 0.4 ± 0.1	L/R = 40 ± 5 ms

Alarm and tripping contacts shall be provided with electrically independent and ungrounded circuits and shall be insensitive to vibration and earth tremors.

Alarm contacts shall be suitable for making and breaking up to 20 W DC, inductive - as defined above - at the specified alarm voltage.

Trip contacts shall be suitable for making and carrying for 0.2 seconds a current corresponding to 150 W at the specified tripping voltage.

5.10 Drain, Filter and Sampling Valves

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Valves of 50 mm ISO R7 and smaller shall be of gunmetal or similar material approved by the Engineer. Drain valves or isolating valves larger than 50 mm ISO R7 and of the double-flanged gate type construction may have bodies of cast iron or cast steel.

Drain valves shall be of suitable dimensions in relation to the volume of oil in the unit tank and coolers.

Oil sampling valves shall be 50 mm NB.

Filtration connections shall have flanges drilled to BS 10, Table D, for 50 mm valves, or screwed 50 mm ISO R7 threads and shall be as follows:

a) A valve at the top and bottom of the main tank fitted diagonally opposite each other. The drain valve of the main tank may be used for this purpose if it is of the size described above;

b) the oil conservator drain valve located within easy reach of the ground by means of a pipe extension, if necessary, shall be suitable for a filter connection; and

c) all valve entries shall be blanked off with gasketted bolted-on blank plates or plugs.

5.11 Rating and Diagram Plate

Rating and diagram plates shall be to BS 171 and BS 4944 for the auxiliary transformers and NEC's respectively, with the provision that no information need be duplicated.

The following information shall also be indicated on the rating and diagram plates:

a) Connection diagram;

b) insulation levels; and

c) full details of each current transformer's location, polarity, secondary terminal markings for each ratio, test winding terminal markings, test winding current rating and the maximum permissible test duration, also, all the information required by Clauses /2.7.2 and 4.5 of BS 3938, as applicable, with the provision that no information need be duplicated.

A separate nameplate for the neutral earthing resistor carrying the following information shall be supplied:

a) System nominal voltage, in kV;

b) resistor rated voltage, in kV;

c) rated short-time current, in Ampéres; and specific duration, in seconds;

d) maximum continuous current, in Ampéres;

e) resistance at 100 °C, in ohms;

f) rated frequency, in Hz; and

g) insulation levels, in kV.

The diagram plate shall be fixed to the unit in such a position that it can be easily read by a person standing at ground level.

5.12 Designation

Each unit shall be provided with an easily legible brass or aluminium label with the following designation, 110 mm character size and 150 x 300 mm label size.

5.13 Earthing Terminal

A suitable rated and marked earthing terminal or clamp shall be provided on the tank base to suit a 50 mm x 3 mm flat copper strap.

5.14 Lifting Lugs

Lifting lugs shall be designed to lift the complete assembled unit with oil.

5.15 Jacking Pads

Not less than four suitably and symmetrically placed jacking pads shall be provided in positions which will not be impeded when the unit is loaded onto the transport vehicle.

Each jacking pad shall be designed to support at least half of the total mass of the unit complete with oil.

Unless otherwise approved, the heights of the jacking pads above the bottom of the unit base and the unimpeded working surface of the jacking pads, shall be as follows:

a) Minimum/maximum height of jacking pad above base: 650/700 mm;

b) unimpeded working surface: 300 x 300 mm; and

c) the provisions made for transporting the unit shall leave the lifting lugs (refer to Clause 5.14) and the jacking pads clear of obstructions so that their function may be fulfilled when the unit is in position on the transporting vehicle.

6. AUXILIARY TRANSFORMER OUTPUT

A moulded case air-insulated circuit breaker (MCB) shall be supplied and connected to the LV terminals of the auxiliary transformer. The MCB shall provide for bolted connections on the transformer side and shall be suitable for connecting lugs of at least cable sizes up to 120 mm².

The MCB shall comply with SABS 156 and shall be mounted in a dust-proof, vermin-proof and weather-proof enclosure with a vertically hinged access door. The enclosure shall be fitted to the side of the unit and provide for cable entries from below through a removable undrilled cable gland plate situated at a distance not less than 50 mm below the MCB.

7. SECONDARY WIRING AND TERMINAL BOXES

All secondary wiring used on the transformer or on auxiliary equipment attached to the transformer shall be strictly in accordance with the general requirements in Part 1 of the Technical Specification. Wiring from current transformers shall however have a minimum cross-sectional area of 4 mm^2. All other wiring shall have a minimum cross-sectional area of 2,5 mm^2.

All wiring from alarm and tripping contacts or any other equipment on the transformer requiring connection to external circuits, shall be either armoured, in conduit, or in metal protective channel and brought onto a terminal box situated at a convenient height on the transformer.

To prevent entry of water into the terminal boxes, the secondary wiring from the Buchholz relay and current transformers shall be arranged for bottom entry or side entry with a down loop into these boxes.

All terminal boxes shall be provided with 25 mm dia gauze covered drain hole.

All cabling between the transformer and the instrument cubicle, local control equipment and the control panel in the substation, shall be the responsibility of the Contractor.

Provision shall be made on the transformer terminal boxes and control equipment cabinets for outgoing connections of PVC/PVC/SWA/PVC cable according to SABS 1574. An un-drilled removable gland plate to accommodate a compression type gland shall be provided for this purpose.

The arrangement of the terminal boards in the boxes or panels shall be such to facilitate the entry of the incoming control or other cables. An earthing stud shall be provided in each terminal box for the earthing of current and voltage transformer secondaries.

8. INSPECTION AND TESTS

8.1 Witnessing of Tests

The Client reserves the right to appoint a representative to inspect the units at any stage of manufacture or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The Contractor shall ascertain whether inspection or witnessed tests, or both, are required and the Contractor shall then give the Client not less than seven (7) days notice of when the equipment will be ready for the inspection or witnesses tests requested.

No NEC/NER/auxiliary transformer shall be tanked or despatched from the Contractor's Works without approval by the Client or his duly appointed representative.

8.2 Tests in General

All routine tests specified in the relevant standards shall be performed on the units and associated equipment. In addition, the following tests shall be performed on each unit:

All insulated core and yoke bolts shall be tested to the core at a voltage of 2 kV at 50 cycles per second for one minute.

Each unit, filled with oil, fitted with bushings, radiators and any attachments normally in contact with the oil, shall withstand a pressure test without leakage for 12 hours. The test pressure measured at the base of the tank shall be equivalent to the pressure of a head of oil of twice the normal coil-oil level.

A test shall be performed on one protection current transformer of each type and ratio to prove compliance with design characteristics.

A zero sequence impedance test shall be performed on each NEC to verify that it falls within the specified tolerances. The test shall be in accordance with BS 171 and the test voltage can be 15% of the nominal phase to earth voltage of the NEC.

The resistance test shall measure the combined values of both the winding and metallic resistor as follows:

a) Between each phase terminal and the earthed connection of the metallic resistor separately; and

b) between the phase terminals connected together and the earthed terminal of the metallic resistor.

The values shall be corrected to a reference temperature of 100 °C and shall be within 5% of design values. For the purpose of these tests, the auxiliary transformer shall be disconnected.

During the over-voltage withstand test and separate source withstand test, the metallic resistor shall be included with the NEC and auxiliary transformer.

8.3 Type and Special Tests

All type tests specified in the relevant standards shall be performed on the unit and associated equipment. In addition, the following tests shall be performed on the unit; the cost of which shall be included in the tender price:

A temperature rise test shall be performed on the complete unit in accordance with BS 4944 and shall clearly demonstrate that the unit, with its own cooling equipment, will not exceed the specified oil and winding temperature rises (either NEC or auxiliary transformer windings) when on continuous full-load condition.

By "full load conditions" is meant the full load current of the auxiliary transformer plus continuous rated current of the NEC and maximum continuous current of the NER. The temperature rise for the metallic resistor shall under these conditions not exceed 65 °C.

This test shall, where possible, immediately precede the di-electric tests.

A special temperature rise test to verify that the metallic resistor shall not exceed at temperature rise of 400 °C after passing the rated short-time current for the specified duration, starting from an initial temperature of 100 °C (i.e. 35 °C ambient + 65 °C normal temperature rise). In addition, high speed recordings of the voltage and current shall be made during the short-time conditions, as well as top oil temperature rise recordings immediately after above test.

Impulse tests (full waves and chopped waves) shall be performed on all windings of all phases in accordance with BS 171.

The unit tank and cooling equipment, filled with oil, shall be subjected to a vacuum test to prove compliance with Clause 4.4. Bushings need net be mounted in position during this test. The cooling radiators and conservator may be tested as separate units.

A short-circuit test on the auxiliary transformer shall be performed to prove its capability to withstand the conditions specified in Clause 4.3.1.

In the event of any of the units or components thereof being a standard design and certified records of previous tests on identical units are available, the applicable type or special test need not be performed again, provided that it is to the approval of the Engineer.

8.4 Test Certificates

Four (4) copies of test certificates showing the results of all routine and type tests performed shall be supplied to the Client or his duly appointed representative prior to the despatch of the units from the Contractor's Works.

All test certificates shall be in English or Afrikaans.

8.5 Tests on Site

On completion of erection at site, the Contractor shall perform such tests as may be required to ensure that the unit is ready for handing over and putting into regular commercial use.

It shall be the Contractor's responsibility to commission all control equipment when commissioning the unit.

The Client may also carry out any tests that are considered necessary to prove that the plant fulfils the requirements of the specification.

9. MISCELLANEOUS

9.1 Contract Drawings

Drawings for approval shall be submitted in duplicate as soon as possible, but not later than three (3) months after the contract has been placed. After these drawings have been approved, a black line linen transparency of each drawing shall be supplied.

Drawings shall be of a convenient size to permit clear interpretation and the minimum size of condensed drawings will be subject to individual approval. (Legends, notes and descriptions shall be incorporated on each drawing, diagram or plan. Separate loose legend sheets or description or other leaflets will not be acceptable.) No drawing shall, however, exceed A0 size.

Manufacturers' standard drawings shall also bear the title and order or contract number of the project.

The following drawings shall be supplied:

a) Outline and general arrangement;
b) internal arrangement of the cores and windings, showing lead supports and winding clamping arrangements;
c) detail of core and core clamping;
d) sectional arrangement drawing of the windings showing sufficient details of the conductors and insulation for local maintenance purposes;
e) rating and diagram plates;
f) general internal arrangement of the various components and sectional arrangement drawings showing sufficient details of the metallic resistor for local maintenance;
g) wiring diagram outline and drilling details of each item of loose control equipment;
h) wiring diagram and dimensioned outlined drawing of control panels or cubicles which shall show base fixing arrangements; and
i) details of underbase and jacking points to permit the design of the plinths.

All drawings shall have titles in English.

The approval of drawings by the Client shall not relieve the Contractor of responsibility for correctness thereof or from the consequences of error or omission on the Contractor's behalf.

9.2 Instruction Manuals

See Part 1.4. Information include the setting and testing of winding temperature and oil temperature indicators and Buchholz relays.

9.3 Labelling

All control panel labelling shall be inscribed with black lettering on a white background that will not discolour or distort in service.

9.4 Spares

The following spares are required:

One set of contacts and coils for each type and size of relay and contactor.

Spares shall be packed in separate cases and clearly labelled "SPARES". Each item of spares in a case shall be suitably identified by means of a metal label. The Client's order or contract number shall appear on all cases containing spares and each case shall be provided with a detailed packing list.

9.5 Oil

The unit shall be provided complete with oil. The oil shall comply with IEC 296 and shall be clean and free of any trace of moisture.

9.6 Transport

All shafts, bearings and other machined surfaces exposed for transport to site, shall be given a temporary protective coating to prevent corrosion. If it is necessary to remove bushings, radiators, pipe-work or any other items involving flanged joints, for transport, suitable blank flanges or covers shall be provided for both mating flanges, and these shall be gasketted and bolted in position for transport. Spare gaskets shall be provided for each such joint. All metal blanking plates shall be handed over to the Client upon completion of erection.

Where transport weight limitations permit, the unit shall be transported with sufficient oil to cover the core and windings. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not practicable, the units shall be maintained continuously during transport under slight positive pressure of inert gas. The pressure and the temperature at the time of filling, shall be communicated to the Client and unless otherwise approved, a pressure gauge suitably protected is to be fitted to the unit to facilitate inspection of the gas pressure on arrival at site. Every precaution shall be taken to ensure that the units arrive at site in a satisfactory condition without the necessity for further drying out.

PART 10.8 : 11kV NEUTRAL EARTHING RESISTOR

SPECIFICATION No: NR.20/0-2003 – Rev 1 (Previous No: NR.20/0-91)

CONTENTS

1 SCOPE

This specification provides for the supply, delivery, and erection and testing where applicable, in the Municipal area of Tshwane, of:

11kV Liquid Neutral Earthing Resistors, complete with first filling of electrolyte, Isolating Links and Support Structures, Safety Cages, and 11kV Cable Sealing Ends or Copper Tubes.

2 STANDARDS

The neutral earthing resistors and associated equipment covered by this specification shall comply with the requirements of this specification, the particulars and guarantees stated in the schedules attached and the relevant requirements of the latest revisions of the following standard specifications or publications:

2.1 BS 4360: Weld-able structural steels.

2.2 SABS 763: Hot-dip (galvanised zinc coatings (other than that on sheet and wire).

2.3 IEC 137: Bushings for alternating voltages above 1 000V.

2.4 BS 381 C: Colours for specific purposes.

3 OPERATING CONDITIONS

3.1 Equipment rating:

The neutral resistors and associated equipment shall be suitably rated to operate satisfactorily under the following conditions:

3.1.1	Altitude above sea level	1 530m
3.1.2	Maximum ambient air temperature	40°C
3.1.3	Average ambient air temperature	35°C
3.1.4	Minimum ambient temperature	- 5°C
3.1.5	Maximum relative humidity	94%
3.1.6	Minimum relative humidity	20%
3.1.7	Pollution conditions	Normal
3.1.8	Lightning conditions	Severe
3.1.9	Seismic conditions	Normal

4 SYSTEM PARTICULARS

4.1 Supply network:

Further Particulars of the supply network on which the equipment will be used are as follows:

4.1.1	Nominal system high-voltage Uo	132kV RMS
4.1.2	Highest system high-voltage Um	145kV RMS
4.1.3	System BIL at Pretoria altitude	550kV RMS
4.1.4	System frequency	50Hz
4.1.5	Maximum high-voltage symmetrical fault current capacity (3 second rating)	25kA RMS
4.1.6	Maximum high-voltage asymmetrical fault current capacity (3 second rating)	30kA RMS
4.1.7	Maximum low-voltage symmetrical fault current capacity (3 second rating)	13kA RMS
4.1.8	Maximum low-voltage asymmetrical fault current capacity (3 second rating)	2kA RMS
4.1.9	High-voltage neutral earth	Solid
4.1.10	Low-voltage neutral earth	Resistance
4.1.11	Phase sequence	RYB Anti-clockwise

5 QUALITY

5.1 Material:

The equipment shall be manufactured and constructed to the highest standards and all materials used under this Contract shall be new and of approved qualities and of the class most suitable for working under the conditions specified, and shall withstand the variations of temperature and atmospheric conditions arising under working conditions without distortion or deterioration or the settings up of undue stresses in any part, such as to effect the efficiency, suitability and reliability of the installation.

5.2 Workmanship:

Workmanship shall be of the highest standard and shall in all respects be subject to approval by the Engineer.

6 GENERAL

6.1 The neutral earthing resistors are intended for use as low voltage fault current limiting resistors on 132/11kV, 35MVA Yy0 power transformers.

6.2 Neutral earthing resistors with two types of neutral connections are called for:

6.1.1 A direct copper tube connection between the bushing and the low voltage current transformer through an isolating link.

6.1.2 A cable connection between the bushing and the low voltage current transformer through an isolating link.

6.3 The cable that will be used with a cable connection will be a 3-core 11kV PILCSWA cable having a cross-sectional area of 70mm² per core.

6.4 In the case of a cable connection to the neutral earthing resistor, a safety cage on top of the neutral earthing resistor and two cable sealing ends per neutral earthing resistor are required.

7 DESIGN

7.1 Neutral earthing resistors

7.1.1 The whole of the rolled steel sections, flats, plates, bolts, nuts and bars used shall consist of mild steel to the requirements of BS 4360.

7.1.2 Cast iron shall be close grained, tough and uniform in character and shall be cast from the best grey pig and scrap iron. It shall have a tensile strength of not less than 140MPa.

7.1.3 All nuts, bolts and other fittings used shall be hot dip galvanised. Bolts when installed shall project trough their respective nuts, but by not more than the diameter of the bolt.

7.1.4 All joints other than those, which have to be broken, shall be welded, and care shall be taken to ensure that the tanks are watertight. Defective welded joints shall not be caulked, but may be re-welded subject to the written approval of the Engineer.

7.1.5 All joints that have to be broken during normal maintenance shall be machine faced. Packing, if employed, shall be of an approved type and thickness. The spacing and size of bolts used in any of these joints shall be approved.

7.1.6 Neutral earthing resistors shall be of the liquid type and shall have current rating of 2 000A and resistance of 3.2ohms at 15°C. They shall be capable of carrying the earth fault current for 20 seconds without mechanical damage, internal flashover or movement and with a total temperature rise not exceeding the tenderer's stated value given in the "Schedule of Particulars" Schedule A.

7.1.7 The electrical characteristics of all bushings, and supporting insulators shall comply with IEC 137 and shall be as stated in the "Schedule of Particulars" Schedule A.

7.1.8 Liquid type neutral resistors shall be of approved design and shall be totally enclosed in a metal tank suitable for outdoor installation. All resistor tanks shall be ventilated in an approved manner. Approved means shall be provided to minimise evaporation of the electrolyte. Each tank shall be provided with an approved form of visual electrolyte level indicator that can be read by an observer standing at ground level. The correct level of the electrolyte shall be clearly and permanently indicated in an approved manner.

7.1.9 No live metal shall be exposed inside the resistor tank above the surface of the electrolyte.

7.1.10 The minimum operating clearance of 2 440mm shall be provided between the earthed flange of the resistor high-voltage bushing, mounted on the tank top and the base of the resistor.

7.1.11 Where a hinged manhole cover is provided it shall be so arranged that in no position does it reduce the clearance between any live metal and earth.

7.1.12 The resistor tanks shall be cylindrical in form. Top plates shall be provided with lifting eyes or lugs and so designed as to prevent the collection of moisture on any part. Top plates shall be securely bolted to the main tanks. Means shall be provided to allow easy access for inspection and repair, and this shall preferably be obtained by manholes, the minimum dimension of which shall be 300mm. The manhole covers shall not exceed a mass of 25kg unless of the hinged type. The base of the tank shall be so designed that it shall be possible to move the tank in any direction. Brackets shall be fitted to the tanks at an approved height to allow the unit, when filled with electrolyte, to be lifted by jacks or other approved means and such brackets shall unless otherwise approved be riveted or welded to the tanks. Lifting eyes or lugs shall be provided on each tank for lifting the resistance unit when filled with electrolyte. The underside of the tanks shall be ventilated to prevent corrosion. The resistor tanks and all parts made of steel or malleable iron shall be galvanized or treated in other approved manner to prevent corrosion.

7.1.13 The tank must be provided with a 50mm diameter outlet pipe and a 50mm brass gate valve.

7.1.14 Unless otherwise approved the electrolyte shall be a solution of sodium carbonate and shall be suitable in all respect for use in the resistor.

7.1.15 The overall base diameter or maximum linear base dimension of the neutral resistor shall not exceed 1 700mm.

7.2 Safety cage on neutral resistor: See clause 6.4

7.2.1 Safety cages shall be of light galvanized expanded metal and steel frame construction attached to the neutral resistor tank by a maximum of six 10mm diameter galvanized bolts and readily removable to give working access to connections.

7.2.2 The minimum clearance to internal live connections shall be 200mm.

7.3 11kV Cable sealing ends: See clause 6.4

7.3.1 Cable sealing ends shall be rated for a service voltage of 11kV.

7.3.2 Cable sealing ends shall be provided with a tapered brass-plumbing gland capable of accepting a lead sheathed paper-insulated and armoured cable having a maximum diameter over the lead sheath of 45mm and provided with an armour clamp.

7.3.3 Cable sealing ends shall be provided with an internal soldering type terminating ferrule to accommodate a maximum conductor area of $240mm^2$ and an external threaded copper stem with nuts and washers.

8 EARTHING ARRANGEMENTS

The earthing connection to the neutral earthing resistor shall be provided with a 15mm diameter stud mounted near the base.

9 GALVANIZING

Hot dipped galvanizing process shall be applied in accordance with the requirements of SABS 763. All manufacturing processes, including all holes shall be finished before commencing with the galvanizing process.

10 CLEANING AND PAINTING

10.1 All parts to be painted shall be cleaned completely from rust, scale, grease or other spoils by sandblasting and/or acid pickling prior to painting. Ferrous parts shall have an acid-phosphate treatment before applying priming coats.

10.2 At least three coats of pain shall be applied in the factory as follows:

10.2.1 Primary coat using a suitable primer that, in the case of ferrous parts, shall comprise a rust inhibiting paint.

10.2.2 Two coats of non-fading weather resistant oil paint.

10.3 Exterior surfaces shall be finished in a light shade of grey, shade number 632 of BS 381C.

10.4 All painting shall have an anti-corrosion finish.

11 TESTS, TEST CERTIFICATES AND INSPECTION

11.1 Test and test certificates

11.1.1 All materials and equipment supplied to this Specification shall be tested in accordance with the requirements of the relevant Standard Specifications referred to and in accordance with the requirements of the tests specified.

11.1.2 Factory tests shall be regarded as an integral par of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying.

11.1.3 Three copies of the Contractor's records of all factory tests shall be furnished to the Engineer, immediately after such tests and before any material is transported. No material shall be installed before the Engineer has officially approved these tests.

11.1.4 Existing type test certificates will be considered on their merits and tenderers are requested to submit copies of existing type test certificates with their tenders. Should reasonable doubt arise as to the validity of test certificates submitted after acceptance by the Engineer in relation to the equipment actually to be supplied, for example by virtue of modifications to the equipment, the Engineer may direct that a further certificate(s) be obtained on a sample unit(s) manufactured under the contract at the expense of the successful tenderer. An independent recognised testing institute shall carry out such further testing.

11.1.5 If type testing is to be done specifically for the purpose of this contract, testing shall be carried out in accordance with the specified requirements by an independent recognised testing institute approved by the Engineer at the prices inserted in the Form of Tender attached to this Specification.

11.2 Inspection

11.2.1 The City Electrical Engineer or his representative shall have access to the manufacturer's premises at all reasonable times, and shall have the power to inspect and examine the materials and workmanship of the equipment during its manufacture there.

11.2.2 If the manufacturing of the equipment or part thereof takes place on other premises, the successful tenderer shall obtain permission for inspection as per the foregoing paragraph.

11.2.3 The successful tenderer shall give at least seven (7) days notice to the City Electrical Engineer of any material being ready for testing in order that he may be present if he so desires.

11.2.4 No inspection or passing by the City Electrical Engineer or his representative shall relieve the contractor from his contractual obligations or exonerate him from any or his guarantees.

12 GUARANTEE

12.1 The tenderer shall guarantee the neutral resistors supplied against failure due to faulty design, materials or bad workmanship for a period of one year from the date of delivery.

12.2 Unless stated to the contrary in the tender, it will be assumed that the above guarantee is subscribed to.

13 DRAWINGS

13.1 The following detailed drawings shall be supplied with the tender:

13.1.1 General arrangement plan of neutral earthing resistor.

13.1.2 Sectional views showing internal construction details.

13.1.3 General arrangement plan of 11kV cable sealing end.

13.1.4 General arrangement plan of safety cage.

13.2 Final detailed drawings as in Clause 13.1 shall be submitted by the successful Tenderer(s) for approval within the period stated in the Form of Tender Part C.

The onus is on the Contractor to obtain approval early, as he will be responsible for any alterations or modifications necessary to comply with the specified requirements.

14 DELIVERY

Delivery shall be to the respective substation sites as stated in the Description of Definite Work-Section IV.

15 INSTALLATION

15.1 Where installation is specified, the following shall apply.

15.1.1 City of Tshwane will install foundations for the resistor and isolating link structure based on drawings supplied by the Contractor.

15.1.2 The Contractor shall supply the foundation bolt cage for the isolating link support structure.

15.1.3 The Contractor shall supply and install the isolating link with its support structure.

15.1.4 The contractor shall install the earthing resistor and its connections to the transformer (through the isolating link).

PART 11.1.1: 11KV METAL CLAD SWITCHGEAR

SPECIFICATION No: SANS 1885: 2004 – Edition 1.1

PART 12.1 : PROTECTION AND CONTROL EQUIPMENT

SPECIFICATION NO. : RP.62/1-97 – Infranet PS05-001SZ

CONTENTS

1. SCOPE

1.1 Overview

This specification part calls for the detailed design, supply, installation, testing and commissioning of an integrated system of hardware and software for control, protection, interlocking, measuring, data recording, event recording, disturbance recording, communication, and engineering and operator interfacing for the 132, 33 and 11 kV equipment, transformers and substation secondary equipment, and includes interfacing to enable the remote master control centre at Capital Park Control Centre to control and interrogate the substation by means of bi-directional communication.

1.2 Integrated Control and Protection (Substation Automation)

The protection equipment shall consist, except where expressly stated to the converse, of numerical devices capable of communicating with and being interrogated by the substation control system on a local area network. The control equipment shall be suitable for continuous, reliable operation in a substation, and shall be required to carry out such tasks as interlocking, monitoring and control at bay-wide and station-wide levels. The systems offered shall be of the state of the art, follow the latest engineering practice, and shall ensure long term compatibility, continuity of equipment supply and the safety of the operating staff. Tenderers are requested to present only their latest **proven** products. The Tenderer may be required to demonstrate the operation of these proven products in actual, similar applications in South Africa or abroad.

1.3 Cubicles

The control and protection equipment shall be housed in sheet steel panel suites in the different control rooms, normally with one cubicle for each of the 132 kV bays and separate cubicles for busbar protection, local control computers and other common functions. For construction of these cubicles, refer to the relevant part of this enquiry document. Actual quantities of panels and content thereof are indicated in the relevant price schedules.

1.4 Overall Design and Commissioning

The Contractor will be responsible for the overall detailed electrical design to integrate all the equipment and switchgear supplied under this contract to form a complete working system which meets the requirements of this specification as a whole. The Contractor will also be responsible for site testing, functional integration and overall commissioning of the complete substation.

1.5 Complete Installation and Service

The Contract will include the provision, installation and commissioning of all equipment required, including all matters and details to provide a complete installation, negotiations with other Municipal Departments or other Authorities where necessary, and the carrying out of all aspects of the Work necessary to complete the Contract commitments. The specified requirements shall be considered basic in that the necessary refinements and additions to provide equipment which will function reliably shall be included in the Tender. Minor items not specifically mentioned in the Addendums and Schedules will be taken as having been included in the Contract Price.

1.6 Compliance

Compliance or otherwise with each item of this specification shall be expressly stated. Any items which may require clarification shall be taken up with the Engineer during the Tender stage, and the presentation of a Tender document by a Tenderer shall imply that the requirements of the specification presented herein have been thoroughly understood and shall be complied with unless the Tenderer clearly indicates the contrary. The Tenderer shall state compliance or otherwise for each paragraph of the written specification.

The Municipality reserves the right to accept or reject Tenders based on the overall compliance to the specification and each part thereof.

1.7 Assistance

Assistance will be given by the Electricity Department of the Municipality as specifically provided for in the Contract and at the discretion of the Engineer.

2. DEFINITIONS, ABBREVIATIONS AND SYMBOLS

For the purposes of this specification part and the related Particulars and Guarantees, Input lists, Outputs lists, Logic definitions, Event lists, block diagrams and scheme philosophy diagrams, refer to drawings and the definitions listed below. The substation control system philosophy diagram may also be of assistance in understanding the concepts described in the following definitions.

2.1 11 kV Switchgear Controller (SGC)

This refers to one of two devices. In the case of switchgear panels which have a multi-function combined over-current and earth fault relay, this relay shall, in addition to the protection functions, serve as the 11 kV switchgear bay controller. In the case of the 11 kV bus coupler and bus section panels, which do not require protection functions, a dedicated I/O module shall be used as the SGC. The functions of this device are to obtain status inputs from the switchgear, provide control outputs to the switchgear and associated equipment and perform the necessary interlocking as is shown in the relevant diagrams and input/output lists.

2.2 33 kV Switchgear Controller (SGC)

The multi-function over-current relay shall, in addition to its protection functions, serve as the 33 kV switchgear bay controller. The functions of this device are to obtain status inputs from the switchgear, provide control outputs to the switchgear and associated equipment and perform the necessary interlocking as is shown in the relevant diagrams and input/output lists.

2.3 11 & 33 kV SGC Supervisor

Should the 11 or 33 kV SGC not be capable of performing the required communication, interlocking and control logic, an SGC Supervisor shall be provided to carry out these functions.

2.4 132 kV Bay Controller (BYC)

An Intelligent Electronic Device (IED) used on every 132 kV bay panel, which assimilates general primary plant status information, contains the interlocking logic and provides the control mimic by taking cognizance not only of the bay-specific equipment status but also the status of other relevant equipment in the substation.

2.5 Engineering Local Area Network (E-LAN)

The separate LAN terminal via which a laptop may access the SMMI, all BYCs and SGCs, all protection relays and any other IEDs which may be present on the S-LAN, in order to carry out programming, setting and data retrieval. This LAN terminal makes use of the S-LAN, and does not require a separate engineering-oriented S-LAN.

2.6 Integrated Control And Protection (ICAP)

A concept whereby protection and control device functionality is merged into single modules. Protection devices therefore offer data gathering functions and control of the protected plant, while control devices may offer supplementary or backup protection functions. The primary purpose of ICAP is to maximise the utilisation of equipment in terms of functionality and information resolution while minimising the duplication of functions and wiring by making use of data processing and communication facilities inherent in modern numerical devices.

2.7 Isolator

A generic term used to describe all primary disconnectors and switch disconnectors.

2.8 Numerical device

A device termed as numerical in this document shall be microprocessor-based, programmable in terms of settings and configuration and, where required communications facilities to allow remote setting and re-configuration of the device.

2.9 Remote Engineering Workstation (REW)

The computer which may reside at a remote location relative to the substation and, via a communications channel installed for this purpose (the extended E-LAN), provide functions such as retrieval of engineering information from the SMMI and the setting and configuration of protection relays. The REW shall access the SMMI and IEDs via an extension to the E-LAN.

2.10 SCADA Access Port (SAP)

The physical point of connection between the protocol translator and the SMMI.

2.11 Substation IED (SIED)

The device which facilitates the gathering of substation common information and provides control facilities for substation common devices.

2.12 Substation Local Area Network (S-LAN)

The network which allows the BYCs, SIED, other IEDs and the SMMI to communicate and exchange information regarding the substation primary plant status, analogue values and secondary device generated information. The S-LAN shall also serve as the substation local communication medium to the IEDs for the E-LAN.

2.13 Substation Man-Machine Interface (SMMI)

The computer, monitor, keyboard, mouse and basic interfaces as well as all necessary configured software which comprise the local control computer for the substation.

3. STANDARDS

Refer to Section III, Part 1 of this specification for requirements regarding standards of workmanship and materials.

4. INTEGRATED CONTROL AND PROTECTION EQUIPMENT SPECIFICATION COMPONENTS

The specification part concerning the control and protection equipment is composed of a number of documents, which are interrelated and require careful studying as a whole in order to understand the full implication of the Municipality's requirements for the ICAP system. In addition, all other parts of the overall specification should be read in conjunction with Section III, Part 12 in order to understand the interface requirements. Section III, Part 1 in particular contains general information and requirements which are directly applicable to Section III, Part 12, such as drawing and documentation, ferruling, steelwork, painting, permits, etc.

4.1 Written specification: Part 12

This document contains the general requirements for the ICAP equipment.

4.2 Particulars and Guarantees: Part 12

Specific requirements regarding the equipment described in the written specification are listed in this document.

4.3 Price Schedule: Part 12

The price schedule lists the major items required for the ICAP system as well as the grouping of functions in cubicles or relay chambers. Any items not specifically listed are taken as having been included in the overall price. Detailed price breakdowns have been allowed for in order to allow the Municipality to make informed decisions regarding the inclusion or otherwise of specific functions. Tenderers shall complete the price schedule in the detail allowed for. The price schedule also allows for a number of options described in the written portion of the specification be priced in order to allow for the implementation of the most viable system. Tenderers are required to comment on alternative offers with regard to the compliance of alternative offers to the specification.

4.4 Input, output and event lists

The Hardwired Inputs sheet contains a list of status contacts from primary and secondary devices, which are to be made available to the control system via hard wiring to the communicating protection and control devices. The inputs listed are also indicated on the included logic diagrams. For the purposes of these lists, primary devices shall mean primary switchgear and disconnectors, and secondary devices shall mean protection, control and auxiliary devices.

The Secondary Inputs sheet lists the status information which is to be made available to the SMMI from the communicating protection and control devices via the S-LAN, and should preferably not be hardwired. Should the system not be capable of communicating a specific item of status information to the SMMI, this item should then be communicated to the SMMI via hardwiring to the relevant BYC, and a specific note made thereof in the Tender.

The Derived Inputs sheet lists variables that are to be used for SMMI indication and interlocking, and are the result of the interlocking and general logic equations listed which reside in the relevant bay modules. Abbreviations used in this sheet are sourced from the Hardwired Inputs and Secondary Inputs sheets.

The Analogue Inputs sheet lists the requirements for analogue values and at the levels which these values should be displayed on the SMMI.

The Digital Outputs sheet lists the digital outputs that are to be wired to various equipment from the BYC, SIED or SGC.

The Event lists indicate the Municipality's requirements regarding the Input Zone code, the Event Description which is made up of a Source field and a Status field, the Logic required to trigger the event, and the destination of the Event, be it the SMMI Mimic (denoted "Mimic" in the event lists, the event page, the alarm page or the SCADA system. Note that, in order to facilitate ease of fault post-mortems, only the events which are ticked are to be provided. Any events not ticked or listed but which are to be provided or cannot be disabled must clearly be indicated by the Tenderer.

4.5 Substation single line diagram

A single line diagram of the primary substation configuration is provided for tender purposes. The Contractor shall be responsible for the provision of a single line diagram, similar in resolution to the one provided, which reflects the actual installation.

4.6 Protection and Control logic diagrams

The substation control system's required architecture, as well as specific requirements regarding the implementation of the protection schemes is indicated on these diagrams. For interpretation of the symbols and abbreviations, refer to the above-mentioned Input and Output lists as well as the legend sheet. Note that the contacts shown in these diagrams are only representative of the type of contacts required for the control system. Actual quantities and types of contacts should NOT be based solely on the quantities shown in these diagrams.

5. GENERAL SERVICE CONDITIONS

5.1 Climatic Conditions

Refer to Section III, Part 1 for details regarding the climatic conditions applicable.

5.2 Distribution Network

The relay equipment will be utilised on an electricity distribution network comprising high-voltage overhead transmission lines, underground cables, switchgear and transformers, all of which are energised from interconnected power stations and infeed stations.

5.3 Operation and Maintenance

The equipment is intended for installation in remote, unattended switching stations and substations. The protection equipment shall be designed for minimum attention and maintenance and Tenderers shall state the extent of maintenance required for each major item in the scheme offered.

6. POWER SYSTEM PARTICULARS

6.1 General Parameters

Refer to Section III, Part 1 for details regarding the applicable system parameters.

6.2 System Configuration

A Single line schematic diagram of the substation is issued with the Enquiry for tender purposes.

Control room panel arrangement: a proposed layout is shown on the general building layout drawing. This will be finalised after award of Tender.

Sufficient space shall be left for relay panels for future feeders and equipment indicated on the drawings. Where these future feeder bays are spatially interspersed with present feeders, correctly sized spaces shall be left in the suite of panels for future panels to image the orientation of the switchgear bays.

7. GENERAL DESCRIPTION OF INTEGRATED CONTROL AND PROTECTION SYSTEM

7.1 Overview of System Elements

An overview of the basic architecture of the integrated control and protection system required is given below and is also shown on drawing. It does not represent a complete list of functions required. Detailed descriptions of the functions are given in the rest of the specification and in the schedules and drawings, or are to be added by the Tenderer.

The basic requirements for the ICAP system are as follows:

a) Local substation operator station (SMMI), with control computer, software and printer, for supervision, local control and engineering functions.
b) SIED module for common interlocking, alarms and event recording.
c) An interface between the SMMI and the SCADA RTU (specified in Section III, Part 12) to allow complete substation interrogation and control from the Master Control Centre at Capital Park.
d) SGC Supervisors for communicating with, controlling and providing automatic sequences via the 33 & 11 kV multifunction over-current relays, should these relays not be capable of providing the required automatic sequences and communication facilities. These relays shall also provide the necessary measurands to the control system.
e) Bay controller (BYC) modules for network, relay and equipment interfacing, provision of local bay control mimics on 132 kV bays, local bay interlocking, supervision and local engineering.
f) SGCs for monitoring & controlling 33 and 11 kV switchgear.
g) Displays on relays may be used provided it is not too small and cumbersome to read. The relay shall also be setable to have current values as the default display.
h) No local alarm annunciator for local bay control is required, provided that the bay module status indications are labelled to provide annunciation should the SMMI fail.
i) Should the relays not be able to display clear English descriptions of events and alarms, a legend label shall be provided and installed on the panel to assist in the interpretation of the relay indications.
j) Data exchange between the different units via an optical fibre serial station bus.
k) Parallel, hard wired inputs from and outputs to 132 kV switchgear and yard equipment.
l) Local engineering network with a single point connection for a laptop computer and extended communication to a remote engineering workstation (E-LAN).
m) Global Positioning System (GPS) satellite receiver for accurate time synchronisation of all control devices and relays.
n) Remote engineering workstation software for a standard Intel 486/Pentium-based PC with Windows 95 or NT as the operating system.

7.2 Numerical Technology

The equipment offered shall be based on the latest generation of numerical technology, to allow a wide range of integrated protection and control functions, with comprehensive communication facilities. All internal relay events shall be logged separately in the SMMI. The system shall have forward compatibility with future equipment for a period of at least ten years.

Tenderers shall provide detailed descriptions as to how their equipment would improve the "Power System Management" aspects such as protection, control, monitoring, automation and analysis.

The degree of standardisation and compatibility with the equipment and communication with products from other leading suppliers must be stated clearly, giving a clear description of possible restrictions.

If non-numerical, solid state measuring relays are offered by the Tenderer, or requested as options in the Tender, Tenderers shall clearly state the limitations of these relays compared to the numerical equivalent. Tenderers shall give clear descriptions, aided by diagrams, if necessary, to illustrate how these relays will be incorporated in the integrated control and protection scheme.

7.3 Security

Every part of the system shall have continuous self-supervision and user-friendly diagnostic functions with clear alarm outputs to indicate malfunctions in the protection and control system.

Protection and control systems shall be based on distributed, intelligent multi-processor technology and fibre optic communications for increased reliability and security. This requires that event data be buffered and stored at distributed network points including the protection relays, the bay controllers and the SMMI.

Event data stored at any level in the network must immediately be retrieved on restoration of a failed network connection to any device.

The devices must be designed to operate in an electrically hostile environment, with stringent requirements on electromagnetic interference immunity. Restrictions on radiated emissivity shall be adhered to.

Although the protective relays are integrated into the control system, all protection functions shall work independently of the control system communications network.

Control system redundancy should be limited and reliance should instead be made on equipment with high reliability and proper monitoring of each system component.

7.4 General Control System Design

The system shall be designed so that personnel without any background in microcomputer based technology can operate the system easily after some basic training.

The substation automation system offered shall support control, monitoring and interrogating functions from SCADA centres (Master Control Centre) via the communications gateway to the SMMI.

Local control of bays shall be via the following mechanisms:

a) 132 kV bay : bay local mimic diagram incorporated in the BYC.

b) 33 kV bay : switchgear bay control pushbuttons or cord control pendant.

c) 11 kV bay : cord control pendant or plug control box. (see Section III, Part 11.1).

Maintenance, modification or extension of components or programs may not cause a shutdown of the whole substation automation system. Self-monitoring of single components, modules and communication equipment shall be incorporated to increase the availability and the reliability of the equipment and minimise maintenance.

Preference will be given to multi-user systems whereby maintenance, modification and extension of programs and databases can be performed via the E-LAN, either locally or remotely.

All the protection functions shall be enabled by downloaded settings from the SMMI or REW within their defined ranges, but inadmissible settings shall be prevented by the system.

The entire substation is controlled and supervised from the station level while individual bays are protected, supervised and controlled from the bay level equipment. It shall not be possible to control the substation from more than one operating level (SCADA, station or bay level) simultaneously. Clear indication of the "active" control level shall be given at every control level.

At each control level, the selection of a local control mode shall over-ride any higher level operating level's control. For example, the selection of a 132 kV ICAP bay panel to local shall over-ride any authority which the SMMI may have had, and disallow any commands to come from the SMMI, although full transparency must be maintained to higher control levels at all times.

The bay controllers (BYC) and other IEDs shall be independent of each other and of the network administrator and their operation shall not be affected by any fault occurring in the other BYC or other IED of this substation. The only exception to this shall be where a BYC receives interlocking information from another BYC, in which case the healthy BYC shall fail to safe. One BYC shall control and monitor only one bay at 132 kV level and, where applicable, not more than 6 bays at 11 kV level.

The main process information of the substation shall be stored in distributed databases. The system shall be based on a concept of bay oriented distributed intelligence for safety and availability reasons. Functions shall be decentralised and bay oriented as close as possible to the process whenever possible. In the event of a network administrator fault, the bay module should still be able to power up correctly and function independently.

It shall be possible to explicitly prescribe, by means of software configuration, which events will be recorded and reported, and duplicity and redundant information should be minimised. Many events (as indicated in the Events listings provided) are only required to be logged on the rising edge transition, and must be maskable for the falling edge transition.

In the event of the SMMI or the communications channel between the BYC and the SMMI being inoperative, the BYC shall store at least 50 discrete bay events in a FIFO buffer for later retrieval by the SMMI.

7.5 Substation Control and Monitoring Functions

All substation functions have to be designed for a safe and reliable operation. The following are the minimum functions required:

a) Acquisition of binary and analogue signals.
b) Control, interlocking and supervision of the bays and the substation.
c) Alarm handling in the BYC and in the SMMI.
d) Display of the bay and substation status.
e) Display of measured and processed analogue values.
f) Display of system status (BYCs, network connections, printer, etc.).
g) Station control via a mouse controlled SMMI.
h) Support of automatic control sequences for standard switching routines, e.g. busbar transfer, simultaneous closing of two or more circuit-breakers, 11 kV chop-over scheme.
i) Provisions for remote master control centre access via a gateway.
j) Provision for a Substation Remote Engineering Workstation.
k) Facilities to independently and remotely reset each bay's protection relays after a fault.
l) Transformer tap change and protection control and supervision.
m) Synchronising-check functions (where required).
n) Display of trend values.
o) Fault recording.
p) Event recording.
q) Evaluation of historical data.
r) Archiving facilities for trending data to enable complete storage and retrieval of trending data for later analysis. The data must also be made available in a format which can be transferred to standard spreadsheet software packages.

7.6 SMMI Displays

The SMMI shall provide at least the following unique screens:

a) A logon screen which provides access to:
   i. the substation primary equipment main view for each of the 132, 33 and 11 kV equipment;
   ii. a main control system view;

iii. the alarm list;
iv. the event list;
v. the protection and control system programming tools; and
vi. the trending view.

b) A substation primary equipment main view for the 132, 33 and 11 kV primary equipment which shows a single line diagram of all primary equipment at that level as well as key analogue values. 33 & 11 kV equipment may be controlled from this view, while at the 132 kV level the bay views must be accessed for control of the 132 kV primary equipment.
c) Bay views for each of the 132 kV bays, from which the 132 kV equipment may be controlled. Detailed analogue values are to be displayed in these views.
d) A main control system view which displays the basic connectivity of the SLAN, together with the status of each device connected to the network, and allows access to detailed views of specific groups of devices connected to the network, such as a 132 kV bay's control and protection devices.
e) An alarm list with the filtering and management functions required.
f) An event list with the filtering and management functions required.
g) A menu from which the protection and control system programming tools may be accessed.
h) A trending view which provides a graphical view of user-definable trends.

A block with the text "INT" shall be displayed next to each item of primary plant in the operating display, and shall indicate whether or not the item may be operated due to interlocking by colouring the block green when operation is allowed, and red when operation is not allowed.

7.7 Automatic sequences

The following automatic sequences should be selectable from the SMMI:
a) automatic live load transfer at 132 kV level;
b) automatic transformer chop-over at 11 kV level in event of a main transformer failure; and
c) simultaneous closure of 11 kV circuit-breakers.

The processing and control of these sequences may not, however, take place within the SMMI and should instead be performed by the SIED.

7.8 Bay standardisation

It can be seen from the block schematic diagrams PS5-011 to PS5-014 that phase and earth fault over-current protection is used on all 132 kV panels, whether it be as back-up protection or as the only bay protection. It is proposed that the same "intelligent" base relay or terminal, that would include the basic common functions such as breaker fail, measurements display, basic disturbance recordings and load level alarm and trip, be used on all panels for these functions, to promote uniformity and operator confidence.

The disturbance recording abilities of the "base" relay must be indicated in the Schedule of Particulars and Guarantees. The requirements for a "Medium resolution" disturbance recorder are also given in the Schedule of Particulars and Guarantees. If the base relay does not meet these, separate "Medium resolution" disturbance recorders shall be incorporated in the relevant feeders, as indicated in the Price Schedules.

Both the main and the back-up relay on a bay could have measurement, event recording and disturbance recording. Tenderers may rationalise the allocation of the features between the relays, but always ensuring that the requirements for detailed, high-resolution event recording and disturbance recording are retained. Precise details as to the allocation of these functions shall be given in the tender.

7.9 Control Supplies

Duplicated 110 V station batteries/charger units are to be supplied, for reliability and redundancy in control, protection and tripping circuits. An automatic change-over switch of adequate rating shall be provided and the selected output bus-wired through the control cubicles, to provide redundancy in the supply to all bay controllers and station control units. Capacitive dip-proofing equipment shall be provided on the output to allow the control units and other equipment to "ride" through the changeover operation. Alternatively, suitably rated diodes may be used to obtain a "selected" supply.

The battery charger has a facility to transfer the supplies to its separate DC distribution boards from the one battery bank to the other, by means of a hand-operated selector switch. The automatic changeover switch described above shall not operate for manual selector switch operation on the battery charger. The hand-operated selector switch may be operated during maintenance. It is therefore of utmost importance that the control system not be affected by the normal operation of this switch.

If BYCs with provision for dual supply inputs are available and offered, the requirement for the automatic change-over switch will fall away.

Tenderers shall describe their proposed auxiliary supply arrangement for control units and in particular the operator station. It is of the utmost importance to have all control units and the operator station operative for at least 8 hours without AC main supply. Tenderers shall state the minimum standby time offered. Measurements shall be made on total.

8. SPECIFIC CONTROL SYSTEM DEVICES

8.1 132 kV Bay Controller (BYC)

The BYC shall be based on microprocessor technology and a real time operating system. The BYC performs all bay related functions, such as local control, command sequences, bay and station interlocking, data acquisition, data storage, event and alarm storage, outputs of commands and signal processing required for the different switchgear units of the bay.

The BYC shall preferably have an integral mimic capable of controlling and displaying the status of up to seven primary plant devices per bay, and have a user-definable layout to suit the substation physical layout. The mimic shall only allow operation if the bay has been selected to local control.

The following functions shall be provided:

a) Event handling with event buffering.
b) Acquisition of measured and counted values.
c) Execution and monitoring of commands.
d) Data pre-processing.
e) Data communication to the SMMI and connected subsystems.
f) Calculation of derived operational measured values.
g) Generation of group signals.
h) Interlocking.
i) Self-monitoring.
j) Mimic panel with local control facilities for each bay.

Auxiliary power shall be supplied from a separately monitored, automatic changeover circuit taken from a selected output of the duplicated station batteries.

The BYCs, with all related input and output equipment, are to be installed in the bay ICAP panels in the control room.

The electronic system has to be provided with functions for self-supervision and testing.

Each circuit board shall contain circuits for automatic testing of its own function.

Faults in a unit have to be indicated on the front panel of the unit. The time for fault tracing and replacement of a faulty unit shall be reduced to a minimum. The supervision shall also cover the power supply system, the internal system bus and the ability of the central processing unit (CPU) to communicate with the different printed circuit boards.

The function and design of the switchgear interlocking systems shall be reliable and safe. Perfect determination and processing of all switchgear positions of the whole substation must be ensured at all times. Unclear information, such as intermediate switchgear positions, switchgear faults, faulty data transfer, etc. must prevent non-permissible switching operations and state clearly, intelligently and exactly the reason for the prevention. Control, regulation and synchronising functions shall require perfect collection and processing of all information of the substation. The information must be up to date and valid. Mal-operation of control and regulation facilities such as on-load switching of an isolator, out of step operation of on-load tap change control, switching on in an asynchronous state, etc. shall be avoided. When the station level control (SMMI and gateway) and regulation facilities have failed, back-up control shall be possible via the bay local mimic, with retention of bay related interlocking.

The BYC must have spare capacity for future equipment. The input and output modules must have 10% spare capacity with a minimum of 2 inputs and 2 outputs spare. The BYC must have at least 2 spare positions for extra I/O modules. The RAM or on-board memory must have at least 20% spare capacity for programs once the application's requirements are met.

The interlocking software RAM or on-board memory must be backed-up via a battery back-up or non-volatile memory and in the case of a supply failure, on return of supply automatically resume their function. The software must be reprogrammable via the SMMI in a straightforward manner.

8.2 Substation Intelligent Electronic Device (SIED)

Numerous substation-common items are to be monitored and controlled. For this purpose a communicating IED shall be provided. Tasks for this device shall include:

a) Substation-common interlocking;
b) automatic sequence control;
c) substation common alarm monitoring; and
d) substation access control system monitoring.

Refer to the relevant I/O lists for details regarding items to be monitored and controlled by this device.

The device shall be capable of communicating directly with all necessary devices on the S-LAN in order to perform the required automation functions.

8.3 SGC and SGC Supervisor

The SGC shall be based on microprocessor technology and a real time operating system. The SGC performs all 11 and 33 kV bay related functions, such as command sequences, bay interlocking, data acquisition, data storage, event and alarm storage, outputs of commands and signal processing required for the different elements of the switchgear bay.

The following functions shall be provided:

a) Event handling with event buffering.
b) Acquisition of measured and counted values.
c) Execution and monitoring of commands.
d) Data pre-processing.
e) Data communication to the SMMI and connected subsystems.
f) Calculation of derived operational measured values.
g) Generation of group signals.
h) Interlocking.
i) Self-monitoring.

The SGC is to be installed in the 11 or 33 kV switchgear panels.

The electronic system has to be provided with functions for self-supervision and testing.

Faults in a unit have to be indicated on the front panel of the unit. The time for fault tracing and replacement of a faulty unit shall be reduced to a minimum. The supervision shall also monitor the power supply system, the internal system bus and the ability of the central processing unit (CPU) to communicate with the different printed circuit boards.

The function and design of the switchgear interlocking systems shall be reliable and safe. Perfect determination and processing of all switchgear positions of the whole substation must be ensured at all times. Unclear information, such as intermediate switchgear positions, switchgear faults, faulty data transfer, etc. must prevent non-permissible switching operations and state clearly, intelligently and exactly the reason for the prevention. Control, regulation and synchronising functions shall require perfect collection and processing of all information of the substation. The information must be up to date and valid. Mal-operation of control and regulation facilities such as on-load switching of an isolator, out of step operation of on-load tap change control, switching on in an asynchronous state, etc. shall be avoided.

The interlocking software RAM or on-board memory must be backed-up via a battery back-up or non-volatile memory and in the case of a supply failure, on return of supply automatically resume their function. The software must be reprogrammable via the SMMI in a straightforward manner.

Should the SGC be unable to provide these functions, an SGC Supervisor shall be provided to supplement the SGC in performing these functions.

8.4 Disturbance recording : particular requirements

Each 132 kV line shall have a medium resolution disturbance recorder, as defined in the schedule of particulars and guarantees, installed and set up to operate for any 132 kV or transformer protection operation in the substation, including the transformer bays.

Each 33 & 11 kV transformer incomer shall, as an option, have a medium resolution disturbance recorder, as defined in the schedule of particulars and guarantees, installed and set up to operate for any transformer bay protection operation and any protection operation in the suite of 33 & 11 kV panels.

Each 33 & 11 kV feeder shall have a low resolution disturbance recorder, as defined in the schedule of particulars and guarantees, installed and set up to operate for any feeder-specific protection operation.

Analysis software for the disturbance recorder data shall be integrated into the SMMI software, and shall operate without having to suspend execution of the SMMI software.

8.5 11 kV I/O module

A communicating I/O device shall be provided to allow control and status determination for the 11 kV bus couplers and bus sections (refer to drawing).

The device shall be a modern numerical, self-monitoring instrument. It shall offer full interrogation by the substation control system, time tagged event recording and plant control capability.

The nominal ratings of the I/O module shall be as follows :

a) Auxiliary voltage 110 V DC ± 20 %

b) Output relay make and carry for 0,2 s 30 A

c) Output relay carry continuously 5 A

d) Output relay break (DC) 50 W resistive or 25 W inductive ($^{L}/_{R}$ = 0,045)

e) Output relay break (AC) 1 250 VA

The I/O module shall perform continuous self-monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

Time tagged event recording with a 1 ms resolution incremented every millisecond shall be provided, with access via the communication port.

8.6 Router

The modular router shall be robust, compact, portable, user friendly, micro-processor controlled and offer the following:

a) An Ethernet card slot;
b) A WAN interface card slot; and
c) A serial card slot.

The serial WAN port on the router shall support asynchronous serial connections up to 115.2 Kbytes/s and synchronous connections such as Frame Relay, leased lines, Switched 56, Switched Multi-megabit Data Service (SMDS) and X25 up to 2.048 Mbytes/s.

The WAN interface on the router shall allow easy change of - or add of WAN interface cards.

The router shall be designed to be ‘plug and play”.

The modular router shall accommodate the following software capabilities:

a) PCMCIA cards from where pre-configured software can be loaded at a central site and be sent to remote sites.
b) At the remote sites the software should be accessible via PCMCIA cards by means of plugging it into the WAN, LAN or power cables.
c) A Web-browser and monitoring utility shall be available to the user.

9. CONTROL SYSTEM CAPABILITIES

9.1 General Software

The software shall consist of basic type tested software modules and standardised supplementary function modules, which are configured depending on the layout and operation concept of the substation.

Security of control selections is of paramount importance and every precaution shall be taken in the software and hardware design to ensure that false selection or execution of a control is rejected. Failure of a communication, partial or total, intermittent or permanent, shall not lead to a false control action.

The system software shall be standard software as offered to other customers, and the structure shall be specially designed for the important requirements of switchgear operation. The system shall be able to restart faultlessly and as quickly as possible after loss of supply voltage. All necessary information must be kept in memory in case of supply voltage outage.

It shall be possible to test the system with help of simulations and without any hazard or unwanted influence to the substation.

The following software functions relate to the substation control system and shall be included in the tender as a minimum:
a) Design of the data base including all substation data
b) Design of an overall display for each voltage level
c) Design of single line diagrams
d) Design of system status displays

9.2 Programming Language

The application programming shall be made in a programming language dedicated for substation automation applications. Programming and documentation shall be based on pre-programmed functional blocks available in a library. These blocks perform typical functions that should be familiar to a substation engineer who is used to design hard-wired logic. Programming of the SMMI and reconfiguration thereof shall be possible by the highest authority level user, and the programming language in all cases shall be an English-language-based programming language.

The programming language has to be graphical as far as possible. Functions shall be programmed in a modular way, where each module shall handle a well-defined task. It shall be possible to test, change, add or remove an application function.

Full information and software manuals shall be supplied by the Contractor to enable the Municipality to reprogram the control system if so desired.

9.3 Station Interlocking and Control Sequence

The control program shall include the possibility for future modification and extension of the station control. It shall be possible to do on-line engineering and reprogramming of the actual application, while the main task is still running in the background, i.e. events are still logged, measurement still stored, etc.

9.4 Bay Interlocking

The control units referred to in the following paragraphs imply the following devices:

a)	132 kV bay ICAP panels :	BYC
b)	33 kV panels :	SGC
c)	11 kV incomer and feeder relay panels :	SGC
d)	11 kV bus coupler and bus section relay panels :	SGC

The bay as well as the station-wide interlocking shall be performed in the individual control units. The station-wide interlocking evaluation shall require switch position indications from other bays (e.g. busbar disconnector, bus-coupler busbar earth), which are transferred to the corresponding control unit via the inter-bay bus.

No protection function may be interlocked through the control unit.

A normally open and a normally closed "change of state" contact from each item of primary equipment must be wired into the control unit.

The "change of state" contacts of each item of primary equipment must be used as a failsafe check of equipment operation or equipment malfunction. In the case of equipment malfunction an alarm identifying the specific item of equipment must be initiated and all further control of that bay disabled until this malfunction has been corrected. This must not only include "change of state" discrepancies but also other alarms like circuit-breaker lockout or spring not charged.

The interlocking at bay and substation level shall prohibit the incorrect operation and or sequence of operation of all items of primary equipment (e.g. isolator opening or closing on load).

Due regard must be given to the operating of the primary equipment during a "dead" or maintenance condition.

The BYC must control the supply to the motorised isolators and mag bolt interlocks where applicable. The contacts within the control unit must be sufficiently rated to perform these operations.

9.5 Interlocking Concepts and Specific Interlocking

Due to the different types of software interlocking methods offered by the manufacturers, specific interlocking requirements will be decided with the successful Tenderer. However, details regarding the general interlocking requirements are listed in the Addendum.

10. SUBSTATION CONTROL SYSTEM : MAN-MACHINE INTERFACE

10.1 General

The SMMI-system shall be a high performance operator station with one operator workplace. It shall be designed for advanced operator's communication. The following functions are required :

a) Presentation of user defined displays (single line diagrams, switching status and analogue values e.g. V, I, P, f, power factor), standard displays, trend curve displays and reports.
b) Effective and safe dialogues for manual control of the substation and for release of control sequences. "Select before operation" procedures are required.
c) Presentation of alarms and events on the operator's video display units and printouts on the printer.
d) Presentation of system status displays (status of BYCs, etc.).

The system software shall be loaded from a transportable medium (e.g. diskettes) and shall be stored in a memory with error correction and battery back-up power or non-volatile memory.

The SMMI shall include a bi-directional logic-seeking 9 or 24-pin dot-matrix printer with a standard parallel interface, and it shall be used for continuous listing of all events occurring in the substation. An ink-jet type printer will not be accepted. It shall be possible to select between at least the following functions for the printer on the SMMI in a easy and straightforward manner:

a) Continuously print all events required as or shortly after they occur, in chronological order;
b) disable continuous printing, in which case the printer buffer is not written to by the SMMI;
c) printing of any sorted or unsorted events from the SMMI event list; and
d) printing of any sorted or unsorted alarms from the SMMI alarm list.

On completion of the substation commissioning, a new ribbon shall be supplied and fitted to the printer.

The operator shall have access to the distributed databases via the SMMI. For control of the substation the operator will use a mouse and soft keys on the screen. The operation procedures shall be user friendly and easy to understand. Data entry is performed with the keyboard.

It shall be possible to design new pictures in an interactive dialogue without taking the total substation control system off-line. Access to the engineering tools shall be provided.

The system shall distinguish between alarm lists and event lists selected on the monitor by the operator. Besides screen displays of these lists, there shall be a print out of any alarm or event in an event log which shall be arranged in chronological order.

An audible alarm shall indicate abnormalities and all unacknowledged alarms shall be accessible from any screen selected by the operator.

The following items shall be presented by the SMMI :

a) Single line diagram showing the switching status;
b) substation overall alarm list;
c) section alarm list;
d) system status list;
e) substation overall event list;
f) section event list;
g) event and alarm log;
h) measured values; and
i) parameter setting (on request).

Tenderers shall allow sufficient time for detailed set-up of the operational procedures and displays in close co-operation with the City Municipality. This will ensure that the SMMI system "appearance" will be compatible with that of the master control system.

Examples of symbols preferred by the Municipality have been included in the Addendum for this part.

10.2 Process Displays

The operational status of the substation, measured values of currents, voltages, frequency, active and reactive powers shall be presented in the single line diagrams. These displays shall also present the status of process objects such as circuit-breakers, disconnectors and transformers.

To ensure a high degree of security against unwanted operation, a special operation procedure "select - confirm - execute" shall be provided. After "selection" the operator shall be able to recognise the selected device on the screen and all other switching devices shall be blocked.

The interlocking conditions shall be checked by the BYCs. The operator can only execute the command successfully if the device is not blocked and if no interlocking condition is violated. After command execution the operator shall receive a message, either about the new switching position or about the unsuccessful switching.

Primary equipment control level selection (local, remote or off) shall be indicated on the SMMI in all displays which show the affected device by means of a single letter or symbol, to be defined during detailed design of the system, and which shall appear next to the relevant device.

Items relating to primary equipment shall be monitored, and functions assigned (e.g. event logging, control command refusal, etc.) as indicated in the input, output and event sheets in the Addendum.

Transformer tap changing shall be operated from a dedicated dialogue in a single line diagram. Manual control shall be selected, and after selection the operator may issue a command for increase or decrease of tap changer position. The status of the tap changer control mode shall be displayed clearly in this dedicated dialogue as well as in the transformer bay view.

The synchro-check function shall allow circuit-breaker closing only if the voltages on both sides of the breaker fulfil the pre-set conditions as to magnitude, phase and frequency difference.

The operator shall be able to remotely control the status of the auto-reclose function, where implemented, at the SMMI or master control centre. The status of the auto-reclose function shall be displayed on all dialogues which display the relevant circuit-breaker, and shall be clearly displayed on the auto-reclose control dialog and the relevant bay view.

Clear indication of each portion of the single line diagram's voltage shall be displayed by means of line colouring on all of the single line diagram views as follows:

a)	Earthed	Green
b)	132 kV	Orange
c)	33 kV	Dark Blue
d)	11 kV	Light Blue
e)	Uncertain	Flashing yellow

The indication of the voltage for each item of primary plant as described above shall be checked for correctness by considering all available information in order to minimise the chance of an incorrect display.

10.3 Alarm List

Faults and errors in the substation shall be listed in the alarm list and shall be simultaneously transmitted to all control centres. It shall contain unacknowledged alarms and persisting faults, e.g. "Circuit-breaker low SF6 pressure". Date and time of occurrence shall be indicated, with an overall resolution of 10 ms or better.

The operator shall be able to acknowledge alarms on display. Acknowledged alarms shall be marked on the list.

Faults that appear and disappear without being acknowledged (fleeting alarms) shall be marked as such in the alarm list.

A chronological alarm list shall be presented on the display screen, and shall be able to be transferred to the event printer.

The user-definable alarm description shall have at least 28 characters, and grouping of alarms based on their source shall be possible.

10.4 Control System Status Display

The system status display shall show the substation control system configuration and the status of all devices of the system.

10.5 Event List

The event list shall contain events that are important for the control and monitoring of the substation. The type of event and its time of occurrence have to be displayed for each event, with a resolution of 10 ms or less.

The operator shall be able to call up the chronological event list on the monitor at any time for the whole substation or sections of it, as required.

The event list shall be capable of storing at least 500 events in a first-in-first-out (FIFO) buffer.

The chronological event list shall contain :

a) Position changes of circuit-breakers, disconnectors and earthing devices;
b) indication of all protective relay operations, with clear distinction of the different functions of multi-function relays;
c) fault signals from the switchgear;
d) exceeding setable upper and lower limits of analogue measured value;
e) loss of communication; and
f) user-defined inputs.

The user-definable event description shall have at least 30 characters, and grouping of alarms based on their source shall be possible.

It shall be possible to select separately for each event whether or not it will be logged and whether it will be logged on a rising edge, a falling edge or for both transitions.

10.6 Event and Alarm Log

The event and alarm log shall be the continuous listing of events and alarms on the event printer.

Events that occur when the printer is off-line due to lack of paper or other similar occurrence shall be queued in the SMMI until the printer is again available. Queuing shall not, however, occur if the event printing function has been disabled.

It shall be possible to conduct searches in the alarm and event lists based on any of the following:

a) Characters with "wildcards" (so that a search for "??IBM*" will display all events or alarms which have the third, fourth and fifth letters of their description matching "IBM");
b) time-period searches to obtain all events or alarms which occurred within a certain period of time on a specified date; and
c) functional group specific searches to obtain events or alarms which relate to a specific bay or the substation common items.

Typical event and alarm lists have been provided in the Addendum.

10.7 Power Supply

The supply shall be taken off the station batteries, via the automatic supply changeover unit described. Tenderers shall calculate the total standing and intermittent auxiliary supply load. The capacity of the battery banks shall be increased from the presently specified value, if needed, to allow a standby time, with control system operation and printing taking place, of at least 8 hours without AC mains supply for all protection and control functions.

10.8 Operator Station Hardware

The computer system shall be a high quality, high-speed industrial type with high reliability and immunity to electromagnetic interference. The Tenderer shall supply specific details regarding the computer's extraordinary ruggedness and suitability to extended terms of unattended operation in the substation environment. The main requirements are given in the Schedule.

The computer hardware shall, at a hardware level, be Energy Star compliant, and shall enter the following modes during periods of inactivity in the following sequence:

a) Computer monitor shutdown after an inactivity period of 10 minutes
b) Computer hard drive shutdown after an inactivity period of 10 to 30 minutes

Inactivity for the monitor shall be defined as no input activity from the local keyboard or mouse.

The operator station equipment shall be mounted in a lockable cubicle(s), with provision for a chair and a comfortable operating position for the operator. Space shall be provided for manuals, a writing area or desk and for locking away the operator's chair.

Manufacturers' MTBF figures shall be quoted for all hardware components of the operator station.

The printer described shall be positioned in a separately lockable compartment, in such a way that they are easy to reach and operate. It shall also be possible to utilise the printer from the engineering network connection.

Only a single station computer is required, but the hard drive system shall consist of two mirrored hard disk drives, which must be mirrored at a hardware level to minimise software dependency.

10.9 User Authority Levels

Access rights to the operator station shall be controlled by means of passwords. The allocation of user rights to each of the six levels required is shown in Table 1.

Individual users signing on to each level shall also be identified and logged.

11. REMOTE ENGINEERING WORKSTATION

11.1 General

Software for the existing REWs shall be provided and installed to allow protection engineers and service technicians to set up, do application programming, change and test the control system and analyse the behaviour of the control system and the primary network. Disturbance recorders and protection units shall be incorporated in the hardware configuration to allow access to event and disturbance recordings.

The system shall provide on-request information from protection terminals and disturbance recorders, comprising :

a) Reading of all indications;

b) resetting of all indications;
c) settings and configuration of all parameters;
d) measuring values at fault;
e) service values from analogue and digital inputs;
f) self supervision results; and
g) disturbance record analysis.

The E-LAN shall also have a communication port (LAN-extension) for data exchange with a remote centralised engineering workstation, via a multiplexed serial link.

The software of the REW shall consist of a flexible software package, handing both disturbance recorders and protection units. All programs shall be PC based.

Reading and setting of all parameters in the protection relays and changing between complete groups of parameters shall be possible. The editing of the parameters shall be done off-line. Fault recording for protection relays, each giving disturbance reports for 3 disturbances, shall also be included. It shall be possible to reset all values remotely.

Password access control shall be implemented.

Item No.	Function	Authorisation					
		Level 1 (MV operator)	Level 2 (HV operator)	Level 3 (Maint.)	Level 4 (Engineer)	Level 5 (Operator Supervisor)	Level 6 (System Administrator)
1.	Operator authorisation					√	√
2.	System Exit						√
3.	132 kV control		√			√	√
4.	11 kV control	√	√			√	√
5.	Alarm Acknowledge: 132 kV		√			√	√
6.	Alarm Acknowledge: 11 and 33 kV	√	√			√	√
7.	Print events and alarms	√	√	√	√	√	√
8.	Save log file to removable media				√	√	√
9.	Erase log file			√	√		√
10.	Program Trending curves				√		√
11.	View primary plant (132 kV)	√	√	√	√	√	√
12.	View secondary plant (11 and 33 kV)	√	√	√	√	√	√
13.	View control network	√	√	√	√	√	√
14.	Set protection Relays			√	√		√
15.	Substation local/ remote control	√	√			√	√
16.	System configuration						√

TABLE 1: USER OPERATING LEVELS

11.2 Disturbance Analysis

When disturbances occur on the network, various kinds of information are needed to analyse the fault and find the original cause, in as short a time as possible.

A communication program for manual or automatic collection of disturbance files to a PC shall be available. The automatic function shall poll the station at user-definable intervals. When new pre-selected disturbance recordings are available they shall automatically be transferred to the PC. The data collection program shall be integrated in the monitoring program.

The disturbance evaluation software shall include functions such as time, amplitude and angle measurement. Zooming in the time scale and independent magnitude scaling of each signal shall be possible and the software shall be able to handle 8 analogue and 8 digital signals in one window. The evaluation software shall accept the standard disturbance file format COMTRADE (IEE standard) and perform conversion between different formats which may be found in the substation.

A further option would be an expert system for automatic evaluation of disturbances. It shall include functions for handling of statistics and shall do accurate fault locator calculation using an algorithm that includes load compensation.

Tenderers shall give a detailed description of the evaluation software to be provided and the analysing and presentation features it offers.

12. SERVICE AIDS

12.1 General

All necessary software shall be provided for a laptop computer which is to be used as a service unit for on-site engineering, analysis and modifications. The software shall also enable the laptop to double as an REW.

Access to the SMMI shall be possible by means of a 10 Base-2 network BNC T-connection to the E-LAN from a laptop in order to access engineering data, program protection relays and make use of the local event printer.

12.2 Functions

The laptop-based service unit shall be used for the following purposes:

a) System entry
b) Application programming
c) Program testing
d) Fault tracing
e) Graphical program documentation
f) Loading and dumping of programs
g) Commissioning
h) Reading of values in the data base
i) Changing peripheral parameters and relay settings
j) Disturbance record analysis

12.3 Monitoring

The laptop-based service unit shall permit the user to investigate changes of status and analogues in the substation. The service aid shall be able to monitor data in the running substation control system and to present changing variables on the display screen, selected in tabular form or in graphic representation.

12.4 Display and Printouts

The program entry procedure shall be based on display screen techniques that provide the operator with visual control of the work performed.

The service aid shall be able to obtain data assimilated by the SMMI in order to allow for archiving and analysis.

12.5 Event Printer Compatibility

The event printer of the operator station shall be compatible with the service system computer's standard parallel printer port to allow it to be used for service printouts at the substation.

12.6 System Information

Tenderers must provide detailed information of the system hardware and software offered, and where the hardware has previously successfully been installed in a similar environment.

13. COMMUNICATION

13.1 Communication between BYCs and Protection Relays

If the protection relays do not communicate directly with the SMMI, a secondary communications bus may be installed to transfer the information required to the BYC. It shall allow transfer of information like events, alarms, operations, settings, status, measured values, time synchronisation etc. Tenderers shall give full particulars of this secondary or object bus and communication protocols.

Should this secondary bus be used for communication to the protection and other bay IEDs, data such as disturbance records shall take lower priority than digital and analogue information in order to avoid loss of general information during disturbance record uploading to the SMMI.

13.2 Substation Local Area Network (S-LAN) Communication

Data exchange shall be provided between bay and station control modules on a optical station data bus. Tenderers shall clearly state the physical properties and arrangement of the bus, the data protocols utilised and the speed of data update for analogue and digital values on the SMMI.

Analogue and digital values shall be updated at least every 2 seconds in the SMMI database and display, and shall take a higher priority than such information as disturbance records.

13.3 Communication to the Master Control Centre

Communication to a Master Control Centre (MCC) shall be provided via a gateway port. Details regarding the gateway are discussed elsewhere in this specification.

13.4 Protocol

Different protocols among manufacturers pose a major problem for a utility in terms of forward compatibility and compatibility among different elements of their system.

Tenderers shall report on the latest developments in this regard.

Tenderers shall clearly indicate the protocols proposed for the different communication levels and the disadvantages or advantages of the particular choices.

13.4.1 IEDs which have the ability to interface to relays with the IEC 870.5 VDEW, in addition to the Proprietary protocol, will be preferred.

14. TIME SYNCHRONISATION

14.1 Master Clock

A substation master clock shall be provided. The master clock shall synchronise the substation automation system internal clocks of the SMMI, the BYCs as well as the fault recorders.

14.2 Global Positioning System

The master clock shall be synchronised by a GPS (Global Positioning System) satellite receiver. A regular time telegram shall be sent to all control and protection units to allow a final time resolution of 10 ms or better for all event and alarm records.

15. PROTECTION DEVICES, FUNCTIONS AND ASSOCIATED ITEMS

15.1 General Information and Requirements

The protection equipment provided shall be suitable to protect the electrical system in the event of the occurrence of faults such as phase faults, earth faults, busbar faults, feeder faults, breaker failure, etc. The Contractor shall ensure that the equipment offered is suitable for the application and that the relay characteristics satisfy the tripping time and load current requirements. Should relays with different characteristics or operating principles to those specified hereafter be offered, the Tenderer shall state the reason for offering such a relay as well as the advantages of the said scheme over the one specified. The price for non-numerical relays shall be entered in the price schedule total if no offer is made on the numerical relay.

The protection measuring relays shall be based on the latest generation proven numerical technology, to allow a wide range of protection, control and measurement functions, with comprehensive communication facilities for integration with the overall substation control system. The system shall have forward compatibility with future equipment for a period of at least ten years.

Each relay element shall be provided with a sufficient number of correctly rated, electrically separate normally open contacts to cater for tripping of the two trip coils in each circuit-breaker directly, making use of two separate isolated DC supplies. Relay elements shall also be fitted with sufficient, suitable contacts for interconnecting to the bay processor and for blocking functions where necessary.

The circuit-breaker tripping supplies shall be provided from duplicated 110 V battery/charger units and shall be dedicated to tripping and related relay auxiliary supplies. The tripping supply circuits shall under no circumstances be used for closing, indication, monitoring, etc.

Redundancy shall be built into the tripping circuits by means of the following features:

a) Dual tripping supplies provided from duplicated 110 V battery/charger units.
b) Dual circuit-breaker tripping coils.
c) Main and back-up protection working in different modes and powered off different instrument transformers and power supplies.
d) Trip circuit supervision with circuit-breaker opened and closed on both tripping circuits.
e) Cross-tripping from relays to both tripping circuits.

Where trip contacts on relays are not adequately rated, high-speed shunt reinforcing contacts shall be provided. However, preference shall be given to direct operating relays. The Contractor shall present calculated values of the relevant parameters of tripping and closing circuits for approval of contact ratings.

All relays where possible shall be withdrawable, with suitable protection against open circuiting of current transformer circuits, where applicable. The tripping contacts of all relays shall also be so arranged that tripping does not occur while or when a relay is being withdrawn.

Operating of a relay element shall be clearly and positively indicated on the relay by an indicating light or alphanumeric display. The indication shall always positively identify the type of fault and where applicable the affected phase, busbar or bus-zone.

The adjustable settings on all relays shall be easily accessible, from the relay front panel, from the service aid (laptop), from the local SMMI and from the engineering network. At no time shall the downloading of new settings to the relay compromise the relay protection functions. Protection settings shall be completely alterable from the relay front panel, service aid (via the E-LAN), the REW and the SMMI.

Users shall be able to completely re-configure relays and protection functions via a service aid, the E-LAN and the SMMI.

Each protection relay and function shall have at least two complete setting groups, which may be selected from the relay front panel, a laptop computer, the E-LAN and the SMMI. The alternative setting group shall be selected by either energising an opto-isolated input assigned to this function, or by a suitable command via the serial communication port of the relay. These inputs shall be energised from an internally generated DC source and must not be affected by induced power frequency AC signals in the wiring.

Test blocks for each separate current transformer circuit shall be provided. The test block shall have 14 sockets and 28 terminals to allow, through the insertion of a test plug, short circuiting of the CT circuits and secondary injection testing by external testing equipment, or current measurement to be made while the circuit is in service. Insertion of the multi-finger test plug shall isolate the trip contacts of the relays whilst allowing external monitoring of the trip contacts. Three multi-finger and three single-finger test plugs, complete with shorting and bridging links, shall be provided with the test blocks.

Relays and auxiliary coils specified for operation from a nominal 110 V DC substation battery supply shall operate reliably and satisfactorily at any voltage between minimum limits 80 % to 120 % of 110 V DC, and shall be capable of withstanding the voltage level associated with boost charging of the station battery. Where relays require auxiliary power at a voltage other than 110 V DC, provision shall be made for the necessary DC to DC convertor equipment. Preference shall, however, be given to equipment operating directly from 110 V DC.

The relays shall all be of robust construction and shall have a positive action without chatter.

All relays shall be flush mounted.

The manufacturer's name, type and designation number and ordering code of each type of relay offered, together with the corresponding pamphlet or brochure reference shall be entered by the Tenderer in the Schedule of Particulars and Guarantees. The necessary brochures with sufficient information on each device, including the explanation of the order code shall be provided.

Where applicable, the ordering code of the relay shall also be specified as an indication of the choice of options which are intended to be supplied.

Full details, including any technical literature, descriptive and illustrative publications and catalogue pamphlets of the protection scheme and equipment offered shall be included in the Tender Document.

15.2 Particular Requirements

Various protection relays are covered in the remainder of this clause and in the Particulars and Guarantees. Information about the specific protection schemes covered by this enquiry is included in the following clause and in the form of block schematic diagrams of the schemes required.

The final arrangement of the protection circuits shall be agreed with and shall be to the approval of the Engineer.

The stated requirements are the City Municipality's minimum requirements for the protection of the various circuits and Tenderers are at liberty to expand on the requirements detailed hereunder.

15.3 Two terminal digital current differential protection

Digital current differential protection relays shall be supplied as the main unit protection on the 132 kV overhead transmission line or cable feeders where indicated.

The relay shall consist of a modern numerical, self monitoring IED utilising programmable scheme logic to provide multiple and independent tripping. It shall offer a user friendly interface, a display of measured steady state and fault quantities, isolated serial communication, remote setting and interrogation by the substation control system and time tagged event/disturbance recording to a 1 ms resolution.

The differential protection relay shall obtain it's power supply from a dedicated DC Main Trip Supply circuit, and shall function independently of any control IEDs in the bay.

The relays shall communicate via dedicated optical fibre channels for current comparison and inter-tripping.

The current differential relay shall evaluate each phase current separately at both ends utilising the current amplitude and phase angle.

CT saturation detection or dual slope bias restraint characteristics must be utilised to stabilise the relay during through faults.

The relay shall allow direct inter-tripping via opto inputs. A prerequisite of this feature would be clear alarm indication descriptions and the origin of the inter-trip clearly defined at all ends of the protected zone.

The relay must perform continuous self monitoring and shall not trip when a relay or communication error occurs. A separate output relay that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

Comprehensive computer based test facilities and the software for it shall be provided, to allow the relay to be thoroughly tested during commissioning, routine maintenance and fault finding operations.

The optical fibres for the relay communication will be available in the station communications cubicle, and are normally terminated with ST type optical connectors. The Contractor will be responsible for the installation and connection of the optical fibres from the relay panel to the communications cubicle. The particulars of the optical fibres are as follows :

a)	Type of fibre	Single mode glass fibre
b)	Max attenuation level at 1 300 nm	0,5 dB/km
c)	Cut-off wavelength	1 100 nm to 1 310 nm

The contractor shall install only single mode glass fibre for connection to the communications cubicle, and shall select the correct communications interface unit for the relay to suit the wavelength and attenuation of the installed system.

The feeders that are to be protected are short. The exact lengths of the optical fibre-links and an optical loss budget will be provided to the Contractor on request.

Current transformer details are given in the relevant part of this specification.

15.4 Combined transformer differential, HV and LV restricted earth fault protection relay

The relay shall consist of a modern numerical, self-monitoring IED utilising programmable scheme logic to provide independent transformer biased differential protection, overfluxing protection and restricted earth fault protection separately on the HV and LV sides of the transformer. It shall offer a user friendly interface, a display of measured steady state and fault quantities, alternative setting groups, isolated serial communication, remote setting and full interrogation by the substation control system, time tagged event/disturbance recording, plant control capability and start contacts.

The combined differential/REF relay shall obtain it's power supply from a dedicated DC Main Trip Supply circuit, and shall function independently of any control IEDs in the bay.

The relay shall be stable for all through-faults without compromising the sensitivity to in-zone faults.

The biased differential protection shall utilising six biased current inputs (two per phase) and be able to compensate internally for CT ratio and vector group mismatch.

The differential protection operation shall be blocked for normal magnetising in-rush currents (inrush restraint), by means of either a high-speed waveform recognition technique or a second harmonic restraint technique.

The restricted earth fault (REF) protection for the HV and LV side of the transformer shall utilise two additional inputs, one from each of the transformer neutral circuits. Separate trip elements shall be provided for each of the REF functions.

The differential protection shall detect over-fluxing (over-excitation) of the transformer and allow for a definite time delayed alarm output as well as an inverse time delayed trip output. A 3-phase VT will be installed (under part 11 of this Contract) on the LV side of the transformer for this purpose.

The relay shall have programmable output relays which can be allocated to the different relay functions.

The relay shall perform continuing self monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

An alternative group of settings shall be provided for both the phase fault and earth fault protection functions. The alternative setting group shall be selected by either energising an opto-isolated input assigned to this function, or by a suitable command via the serial communication port of the relay. These inputs shall be energised from an internally generated DC source and must not be affected by induced power frequency AC signals in the wiring.

The relays shall provide and display the following control and measurement features :

a) Measured or derived quantities such as phase currents and zero sequence currents. When CT ratios are entered into the relay, measured quantities and settings shall be displayed in primary quantities.

b) Circuit breaker maintenance data ie. sum of the square of the fault current interrupted by the circuit breaker for each individual phase and also the number of times the relay has issued a trip command.

c) Fault records such as setting the trip LED and displaying the responsible protection function(s) and fault currents.

Time tagged event recording with a 1 ms resolution incremented every millisecond shall be provided. This data must be automatically uploaded to the SMMI as soon as the recording has been completed, and the storage facilities within the relay shall allow for first-in-first-out buffering of the event records.

15.5 132 kV Busbar Protection

A busbar protection scheme comprising one zone per connected busbar of the station and an overall check-zone (utilising separate CTs) shall be supplied to detect busbar faults quickly and selectively and thereby isolate the faulty zone only, with the minimum damage occurring.

Busbar protection schemes offered may be either of the static or numerical type.

Should a numerical scheme be offered, the scheme should be integrated into the substation ICAP system.

The design of the protection scheme shall be based on the biased low or medium impedance current differential principle offering protection against phase-to-phase and phase-to-earth faults. The protection scheme shall be based on the latest generation of numerical technology, to allow a wide range of protection, control and measurement functions, with comprehensive communication facilities for integration with the overall substation control system. The system shall have forward compatibility with future equipment for a period of at least ten years.

The lay-out of the busbars and the number of circuits to be incorporated are depicted on the accompanying single line drawing. The busbar scheme and central unit shall be configured for all the future feeders, bus-sections and bus-couplers. Measuring units shall only be provided for present bays, as far as possible, without compromising the future upgrading to a complete scheme.

The busbar protection scheme shall preferably operate from dual redundant power supplies for the purpose of continuity of operation. Alternatively, the busbar protection scheme shall obtain it's power supply from a dedicated DC Supply circuit connected to the main battery bank, and shall function independently of any control IEDs in the bay.

Each zone measuring unit shall have integral CT circuit supervision which must detect CT circuit faults, flag these faults and prevent mal-operation of the protection scheme during normal system operation. It must not be necessary for the CT circuit supervision to await an over-current situation to detect a problem.

Each zone measuring unit shall have two separate measuring elements, one of which operates for the differential current exceeding the current setting threshold (differential detection) while the other element must operate for the differential current exceeding the through current bias (over-current start detection). Both elements must operate in order to allow a busbar fault output to occur.

In order for a busbar fault to be acknowledged and acted on, the main and check measuring unit outputs must both operate.

The busbar protection scheme shall perform self-supervision and provide local indication and alarm outputs should any element of the scheme become faulty.

Current transformer circuits are to be wired directly to the busbar protection scheme and must not be routed through the isolator auxiliary contacts. The busbar protection scheme must perform its function via "busbar imaging" and obtain plant status via isolator and circuit-breaker auxiliary contacts.

Comprehensive test facilities shall be provided.

The protection shall retain full stability in the event of a through fault.

The busbar protection shall accept inputs from external breaker fail protection relays which shall activate bus-zone trip auxiliary relays to disconnect all the circuits connected to the affected busbar zones(s).

The busbar protection scheme shall automatically detect the closing of two busbar selector isolators in the same bay and immediately combine the two bus zones and disable the main and backup trip circuits of the bus coupler circuit-breaker (Bus coupler "solid"). Any busbar fault detected after combination of the two busbar zones must strip both busbars.

The detection of the movement of the busbar selector isolators shall be based on the changing of state of the outermost limit contacts N or G.

Local indication on the busbar protection panel and alarm outputs to the SMMI shall be provided to indicate the combination of bus zones.

In order to ensure the stability of the busbar protection, the resistance of the secondary CT circuit wiring shall be taken into account, and the resistance of this wiring reduced to a minimum.

The busbar protection schemes shall be housed in free-standing protection panels in the control room. In the case of a distributed busbar protection scheme the main unit must be housed in a free standing protection panel. Data transfer between bay units and central units shall be via optical fibre links to ensure immunity to electromagnetic interference.

15.6 Combined over-current and earth fault protection relay/function

The multi-function relay must perform the bay standardisation function described. Where bay VT's are not available, an accurately derived or imaged busbar voltage shall be supplied to the relay for voltage and power measurement information.

The relay shall be a modern numerical, self-monitoring instrument utilising programmable scheme logic to provide multiple, independent three-phase and earth fault protection curves. It shall offer a user friendly interface, a display of measured steady state and fault quantities, alternative setting groups, isolated serial communication, remote setting and full interrogation by the substation control system, time tagged event and disturbance recording, plant control capability and start contacts.

The functions required of the combined over-current/earth fault protection may, alternatively, be incorporated into the BYC, should the BYC be suited to this purpose.

The relay shall obtain it's power supply from a dedicated DC Backup Trip Supply circuit, and shall function independently of any control IEDs in the bay. Alternatively, should the relay functionality be implemented within the BYC, it shall make use of the selected supply provided to the BYC.

Over-current elements shall conform to the following :

a) The relays shall contain three independent over-current stages for both phase elements ($I_{>}$, $I_{>>}$, $I_{>>>}$) and for earth fault elements $I_{o>}$, $I_{o>>}$, $I_{o>>>}$). Measurement shall be based on the Fourier derived value of the power frequency component, with harmonics up to and including the sixth suppressed.

b) The $I_{>}/I_{o>}$ elements shall operate when the power frequency component of the current exceeds the set threshold. The time/current characteristic associated with these elements must provide a selection of inverse definite minimum time (IDMT) curves, or be setable to a fixed (definite) time delay.

c) The $I_{>>}/I_{o>>}$ and $I_{>>>}/I_{o>>>}$ elements shall provide instantaneous functions that are not affected by offset waveforms, such as those occurring with power transformer inrush currents. This shall allow the instantaneous elements to be set down to 35% of the anticipated peak transformer inrush current. To a first approximation, the peak inrush is given by the reciprocal of the per unit series reactance of the transformer. These over-current stages shall also have selectable definite time settings.

The relay shall be provided with a start function (and programmable relay output) that responds to the current exceeding either the $I_{>}$ or $I_{o>}$ thresholds.

The relay shall have programmable output relays (quantified in the Particulars and Guarantees) that can be individually and collectively allocated to the different relay over-current functions.

The relay shall perform continuing self monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

An alternative group of settings shall be provided for both the phase fault and earth fault protection functions. The alternative setting group shall be selected by either energising an opto-isolated input assigned to this function, or by a suitable command via the serial communication port of the relay. These inputs shall be energised from an internally generated DC source and must not be affected by induced power frequency AC signals in the wiring.

The relays shall provide and display the following control and measurement features :

a) Measured or derived quantities such as phase currents and zero sequence currents. When CT ratios are entered into the relay, measured quantities and settings shall be displayed in primary quantities.
b) Circuit breaker maintenance data ie. sum of the square of the fault current interrupted by the circuit breaker for each individual phase and also the number of times the relay has issued a trip command.
c) Fault records such as setting the trip LED and displaying the responsible protection function(s) and fault currents.

Breaker failure protection with internal and external initiation and a programmable relay output shall be available as an integral relay feature.

Time tagged event recording with a 1 ms resolution incremented every millisecond shall be provided, with access via the communication port.

15.7 Transformer standby earth fault protection relay

The relay shall be a modern numerical, self-monitoring instrument utilising programmable scheme logic to provide multiple, independent three-phase and earth fault protection curves. It shall offer a user friendly interface, a display of measured steady state and fault quantities, alternative setting groups, isolated serial communication, remote setting and full interrogation by the substation control system, time tagged event/disturbance recording, plant control capability and start contacts.

The relay shall obtain it's power supply from a dedicated DC Main Trip Supply circuit, and shall function independently of any control IEDs in the bay.

The earth fault elements shall conform to the following :

a) The relays shall contain three independent, single-phase earth fault over-current stages ($I_{o>}$, $I_{o>>}$, $I_{o>>>}$). Measurement shall be based on the Fourier derived value of the power frequency component, with harmonics up to and including the sixth suppressed.
b) The $I_{o>}$ element shall operate when the power frequency component of the current exceeds the set threshold. The time/current characteristic associated with this element must provide a selection of inverse definite minimum time (IDMT) curves or be setable to a fixed (definite) time delay.
c) The $I_{o>>}$ and $I_{o>>>}$ elements shall operate when the power frequency component of the current exceeds the set threshold. The time/current characteristic associated with this element must be setable to a fixed (definite) time delay.

The relay shall be provided with a start function (and programmable relay output) that responds to the current exceeding the $I_{o>}$ thresholds.

The relay shall have programmable output relays that could be allocated to the different relay functions.

The relay shall perform continuous self-monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

An alternative group of settings shall be provided for the earth fault protection functions. The alternative setting group shall be selected by either energising an opto-isolated input assigned to this function, or by a suitable command via the serial communication port of the relay. These inputs shall be energised from an internally generated DC source and must not be affected by induced power frequency AC signals in the wiring.

The relays shall provide and display the following control and measurement features :

a) Measured or derived quantities. When CT ratios are entered into the relay, measured quantities and settings shall be displayed in primary quantities.
b) Circuit breaker maintenance data ie. sum of the square of the fault current interrupted by the circuit breaker for each individual phase and also the number of times the relay has issued a trip command.

c) Fault records such as setting the trip LED and displaying the responsible protection function(s) and fault currents.

Time tagged event recording with a 1 ms resolution incremented every millisecond shall be provided, with access via the communication port.

15.8 Transformer voltage regulating relay

The relay shall be a modern numerical, self-monitoring instrument utilising programmable scheme logic to provide multiple, independently programmable settings for each measuring element and timer. It shall offer a user friendly interface, a display of measured quantities, isolated serial communication, remote setting and full interrogation by the substation control system, time tagged event/disturbance recording, plant control capability and start contacts.

The relay shall obtain it's power supply from a DC Control Supply circuit, and shall function independently of any other control IEDs in the bay.

The relay shall provide the following voltage regulating features:

a) The tap change controller's regulating voltage, deadband, initial activation time delay and inter-tap time delay shall be user setable.
b) Line drop compensation shall be provided which simulates resistive and reactive components of the voltage drop across a feeder.
c) An over-current situation on any or all of the three phases shall be provided to inhibit tap changing (i.e. the device shall provide three phase over-current blocking).
d) Voltage blocking (setable in the range of 70% to 100% of the nominal voltage) shall be provided to inhibit tap change operations.
e) Should a VT failure be detected, the voltage blocking function shall not inhibit tap changing.

The relay shall provide the following supervisory functions:

a) Tap changer position display and control from the front of the unit.
b) User-selectable automatic and manual control of the tap changer, with manual tap changing being possible from the front of the relay and remotely via the communications port.
c) Tap changing in progress shall be clearly indicated on the relay.
d) Tap changer runaway detection to detect incorrect tap changer operation, inhibit further operation and present an alarm.

The relay shall be able to provide the tap position and the transformer voltage as default displays, with preference given to the display of actual primary system voltage values. The type of tap position indication transducer or method must be determined in co-operation with the ICAP equipment and transformer suppliers

The relay shall perform continuous self-monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

Control of the voltage regulating relay shall take place as follows:

a) If the relay is on remote and the transformer bay is switched to remote control mode, the tap position must be selectable from the SMMI or the SCADA, whichever is in control of the substation;

b) If the relay is on remote and the transformer bay is switched to local control mode, the relay must be manually controllable from the bay local position; and

c) If the relay is on auto, the tap position shall be automatically selected by the voltage regulating relay regardless of the substation and bay control mode selected.

15.9 132 kV Inter-trip Send and receive facilities

Inter-tripping shall be facilitated via the digital protection channels, which form a part of the communication equipment specified elsewhere in this Enquiry document.

Provision shall be made on the terminal blocks of each panel for terminating the inter-trip circuit loops to the yard marshalling kiosk and isolator and back to the fibre optic communication equipment panel via the relay panel.

Inter-trip circuits shall be taken through isolating MCBs with auxiliary contacts for control system monitoring.

Where possible the digital current differential relay will be used for the inter-trip send medium via an optic isolated input on the relay. This will serve as a back-up inter-trip, as indicated on the block diagrams.

Two spare normally open contacts shall be provided on the inter-trip send relay, over and above the full relay contact requirement.

A self-resetting auxiliary inter-trip receive relay is used to cross-trip to the two trip circuits. It also provides a contact to the BYC for inter-trip receive indication.

15.10 132 kV synchronising-check relay and busbar voltage imaging

Busbar VT's are not normally provided.

A reflected busbar 3-phase voltage, sourced from incomer line VTs and derived from each bay primary equipment configuration, must be bus-wired through each panel to provide the "running" busbar voltage reference for synchronising.

The reflected busbar voltages must also be used for the measurement and indication on the bus- coupler, bus-section and transformer panels, or other bays where there are no VT's available.

Where required, a synchronising-check relay is to be incorporated, so that connecting-up of two systems through the circuit-breaker may only take place whilst the voltages of the two systems are synchronised or close to synchronism. Provision shall also be made for dead-line and dead busbar charging. The relay shall measure phase angle difference and slip frequency, and shall block for differential voltage above setting.

The synchronising-check scheme shall be designed so as to prevent the circuit-breaker from closing if the operator holds the control switch in the closed position and waits for the synchronising-check relay to operate.

Overriding the relay synchronisation check function shall be performed via a clearly marked push-button mounted on the protection and control panel.

15.11 132 kV Line automatic reclosure

The relay shall be a modern numerical, self-monitoring instrument utilising programmable scheme logic to provide multiple, independent reclose actions. It shall offer a user friendly interface, a display of measured quantities, alternative setting groups, isolated serial communication, remote setting and full interrogation by the substation control system, time tagged event/disturbance recording, plant control capability and start contacts.

The relay shall obtain it's power supply from a dedicated DC Main Trip Supply circuit, and shall function independently of any control IEDs in the bay. Alternatively, should the relay function be implemented within the BYC, it shall make use of the selected supply provided to the BYC.

The relay shall perform continuing self monitoring. A separate output relay, that has one make and one break contact, shall be provided to indicate both healthy and relay defective conditions.

The relay shall provide the following functions:

a) Four-shot, three phase auto-reclosing with independent control of the time characteristics for each of the different stages of the reclosing cycle.
b) Manual closing of the circuit-breaker shall start the relay reclaim timer, whilst manual tripping shall lock out reclosure. When the line is energised onto a fault the instantaneous protection shall operate and no reclosing shall be initiated.
c) A clearly marked centre-return switch shall be provided on the panel to override the auto-reclosing function.
d) The relay shall take cognisance of the circuit-breaker spring status.
e) The relay shall clearly indicate and communicate the auto-reclose in progress state.

The relay shall have the following time settings:

a)	Close pulse	0,1 to 2 s
b)	Dead time 1	0,25 to 180 s
c)	Dead time 2	1 to 180 s
d)	Dead time 3 and 4	10 to 200 s
e)	Reclaim time	1 to 180 s

An alternative group of settings shall be provided. The alternative setting group shall be selected by either energising an opto-isolated input assigned to this function, or by a suitable command via the serial communication port of the relay. These inputs shall be energised from an internally generated DC source and must not be affected by induced power frequency AC signals in the wiring.

The relay shall clearly indicate whether or not auto-reclosing is enabled, and also indicate when an auto-reclosing cycle is in progress.

Time tagged event recording with a 1 ms resolution incremented every millisecond shall be provided, with access via the communication port.

Auto-reclosing must be inhibited if the bay main protection relay is faulty.

15.12 Pilot-wire biased differential relay

Due to the Municipality's standardisation on the GEC HO4 biased differential "Translay" relay, only these relays will be accepted.

15.13 132 kV Trip Circuit Supervision

Both trip coils and the main and back-up DC trip supplies must be monitored by a relay with the circuit-breaker in the open and the closed position.

Separate supervision relays shall be used for each of the trip circuits, and one of the relays may reside in the bay controller.

The relay must be suitably slugged to prevent false alarming due to voltage dips caused by faults on other circuits, or due to the "change-over" action from one element to the other when a circuit-breaker is tripped.

The relay must operate at ± 40% of rated voltage and reactivate at ± 80% of rated voltage.

Relay internal resistors must be suitably rated for the circuit-breaker trip coils.

15.14 Auxiliary latching and flagging trip relays

These relays shall be of the latching, hand reset type with flag indication.

15.15 Auxiliary relays for inter-tripping

These inter-trip receive relays shall be of the self-resetting type without any flag indication.

16. PROTECTION SCHEMES

This section summarises the composition of each bay's protection scheme. The protection devices referred to below are specified in the previous clause.

16.1 132 kV overhead line bay protection

Refer to the drawing for details regarding this bay's protection scheme.

The main overhead line protection shall be the digital current differential protection relay specified. Circuit-breaker closing shall be inhibited (by the BYC) should the main protection relay fail.

The backup protection shall consist of a combined backup over-current and earth-fault relay, as specified, which shall also fulfil the role of bay standardisation as described.

Supplementary functions to be included are as follows:

a) Trip circuit supervision for both the main and backup circuit-breaker trip circuits, with a software circuit-breaker close control lockout should both circuits be faulty.
b) Busbar voltage imaging.
c) Synchronism checking (only as an option in the price schedule).
d) Automatic reclosing of the circuit-breaker (only as a price option in the price schedule).
e) Breaker fail logic implemented in the backup relay.

16.2 132 kV Bus coupler bay protection

Refer to the drawing for details regarding this bay's protection scheme.

The main and only protection for this bay shall be the combined over-current and earth-fault relay specified, which shall also fulfil the role of bay standardisation as described.

Supplementary functions to be included are as follows:
a) Trip circuit supervision for both the main and backup circuit-breaker trip circuits, with a software circuit-breaker close control lockout should both circuits be faulty.
b) Busbar voltage imaging.
c) Synchronism checking (only as an option in the price schedule).
d) Breaker fail logic implemented in the main relay.

16.3 132/33 & 132/11 kV Transformer bay protection

Refer to the drawings for details regarding this bay's protection scheme.

The first main protection for this bay shall be the combined biased differential and HV and LV restricted earth fault relay specified.

The second main protection consists of the Buchholz trip repeat relay and the transformer tank over-pressure trip repeat relay. This circuit is to obtain its power supply via the DC Backup Supply, and shall also perform cross-tripping as prescribed for the protection relays.

The third main protection consists of the transformer standby earth fault protection relay.

Failure of any main protection relay shall inhibit closure of the transformer HV circuit-breaker.

The backup protection shall consist of a combined backup over-current and earth-fault relay on the transformer HV side, as specified, which shall also fulfil the role of bay standardisation as described.

Supplementary functions to be included are as follows:
a) Trip circuit supervision for both the main and backup circuit-breaker trip circuits, with a software circuit-breaker control lockout should both circuits be faulty.
b) Busbar voltage imaging.
c) Breaker fail logic implemented in the backup relay.

16.4 132 kV busbar protection

The 132 kV busbar protection scheme shall be implemented as described.

16.5 33 kV Transformer incomer protection

Refer to the drawing for details regarding this bay's protection scheme.

The only protection installed in the switchgear instrument cubicle shall be the combined over-current and earth-fault protection relay specified, as well as the auxiliary tripping relays. Circuit-breaker closing shall be inhibited should the protection relay fail. This relay shall also fulfil the role of bay monitoring and control as indicated in the block diagram.

Supplementary functions to be included are as follows:
a) Busbar voltage imaging.
b) Blocking and breaker fail logic (refer to drawing).

16.6 33 kV Overhead line feeder protection

Refer to the drawing for details regarding this bay's protection scheme.

The main feeder protection shall be the Translay HO4 relay specified. Circuit-breaker closing shall not be inhibited (by the BYC) should the main protection relay fail.

The backup protection shall consist of a combined backup over-current and earth-fault relay, as specified, which shall also fulfil the role of bay monitoring and control as indicated in the block diagram.

Supplementary functions to be included are as follows:
a) Busbar voltage imaging.
b) Blocking and breaker fail logic (refer to drawing).

16.7 33 kV Bus section protection

Refer to the drawing for details regarding this bay's protection scheme.

The bus section protection shall consist of a combined backup over-current and earth-fault relay, as specified, which shall also fulfil the role of bay monitoring and control as indicated in the block diagram.

The only supplementary function required is busbar voltage imaging.

16.8 33 kV busbar protection

Refer to the drawing for details regarding this protection scheme.

The functions required in this scheme are as follows:

a) Feeder blocking of transformer 1 and 2 (TX1 & TX2) incomer and the bus section definite time trip outputs via the feeder over-current starter element for feeder faults. Since the intention is to operate the transformers in parallel, the single relay blocking outputs from feeders 1 and 2 should be commoned.
b) The feeder relay shall not block the transformer incomer or bus section for a busbar zone fault, and the bus section definite time will be set lower than the transformer definite time, to allow them to trip in sequence and thus obtain discriminative tripping of the two busbar zones.
c) Immediately upon detection of a feeder breaker fail condition, the feeder relay must remove the blocking signal to enable the bus section and the relevant TX definite time element to trip the bus section circuit-breaker and the correct incoming circuit-breaker.
d) The transformer incomer relay shall, for a definite time over-current trip, trip the circuit-breaker and operate a latching, flagging, hand-reset relay which shall inhibit re-closing of the 11 kV transformer circuit-breaker.
e) The bus section relay shall, for a definite time trip, inhibit re-closing of the bus section circuit-breaker.
f) Should the transformer incomer or bus section relay detect its own breaker fail condition, the 132 kV transformer circuit-breaker should be tripped and operate a latching, flagging, hand-reset relay which shall inhibit closing of the 132 kV transformer circuit-breaker.

16.9 11 kV Transformer incomer protection

Refer to the drawing for details regarding this bay's protection scheme.

The only protection installed in the switchgear instrument cubicle shall be the combined over-current and earth-fault protection relay specified, as well as the auxiliary tripping relays. Circuit-breaker closing via the control system shall be inhibited should the protection relay fail. This relay shall also fulfil the role of bay monitoring and control as indicated in the block diagram.

Supplementary functions to be included are as follows:

a) Busbar voltage imaging.
b) Blocking and breaker fail logic (refer to drawing).

16.10 11 kV Main feeder protection

Refer to the drawing for details regarding this bay's protection scheme.

The main feeder protection shall be the Translay HO4 relay specified. Circuit-breaker closing via the control system shall not be inhibited should the main protection relay fail.

The backup protection shall consist of a combined backup over-current and earth-fault relay, as specified, which shall also fulfil the role of bay monitoring and control as indicated in the block diagram.

Supplementary functions to be included are as follows:

a) Busbar voltage imaging.
b) Blocking and breaker fail logic (refer to drawing).

16.11 11 kV bus coupler protection

No protection functionality is required for the bus coupler. Control of these panels should therefore be implemented with a communicating I/O module as described in the control paragraphs.

16.12 11 kV bus section protection

No protection functionality is required for the bus coupler. Control of these panels should therefore be implemented with a communicating I/O module as described in the control paragraphs.

16.13 11 kV busbar protection

Refer to the drawing for details regarding this protection scheme.

The functions required in this scheme are as follows:

a) Feeder blocking of both transformer A and R incomer (TXA & TXR) definite time trip outputs via the feeder over-current starter element for feeder faults. The outputs shall be separate relay outputs, and each transformer will have a single set of buswires to each relevant panel (i.e. transformer R is connected to all feeders, but transformer A is only connected to section A's feeders).

b) Immediately upon detection of a feeder breaker fail condition, the feeder backup relay must remove the blocking signal to enable the relevant TX definite time element to trip the incoming circuit-breaker.

c) The feeder backup relay shall not block the transformer incomer for a busbar zone fault.

d) The transformer incomer backup relay shall, for a definite time over-current trip, trip the 11 kV circuit-breaker and operate a latching, flagging, hand-reset relay which shall inhibit closing of the transformer 11 kV circuit-breaker.

e) Should the transformer incomer backup relay detect a breaker fail condition, it shall trip the 132 kV transformer circuit-breaker via a latching, flagging, hand-reset relay which shall inhibit closing of the 132 kV transformer circuit-breaker.

17. DEMONSTRATION OF SYSTEM

Tenders must be prepared to arrange a fully working display of the main components of the control and protection equipment to demonstrate the system's functions and capabilities to the client or his representative. This demonstration will take place at the request of the client. Visits to completed, functional substations and meetings with other clients could form a part of the client's inspection.

Time for in-depth, detailed inspection and familiarisation shall be set aside, to allow the client to assess the advantages and limitations of the new concept of highly integrated control and protection systems.

18. SPARES

A comprehensive list of each different part, which could be considered as a possible spare, shall be submitted with the offer, stating descriptions, quantities and prices.

19. INSPECTION AND TESTING

Refer to Part C2.1, Specifications 4, Part 1 for requirements regarding the inspection and testing of equipment and systems.

20. DRAWINGS AND DESCRIPTIVE LITERATURE

Refer to Part C2.1, Specifications (Section 4), Part 1 for requirements regarding the drawings and descriptive literature.

21. INPUTS, OUTPUTS, LOGIC AND EVENT LISTS

Refer to Appendixes for this information.

PART 12.1.1 : APPENDIXES PROTECTION & CONTROL

SPECIFICATION No. : APC09/01

CONTENTS

Appendix A.1

Standard Symbols to be used on the Substation Control Computer and or Bay Controller

Green		Circuit Breaker open (Green outline only)
Red		Circuit Breaker closed
Yellow White		Circuit Breaker status unknown
Green		Isolator open (Green outline only)
Red		Isolator closed
Yellow White		Isolator status unknown
Green	INT	Device interlock correct for operation
Red	INT	Device interlock will refuse operation
	L	Local Control (Circuit breaker, Isolator)
	A	Auto-Reclose enabled
	T	Test Position
	BCSL	Bus Coupler solid
	LBBT AVAIL	Live Busbar Transfer Available

Appendix A.2

Typical Hard Wired Inputs per Bay\Device type

#	Source	Contact State		Abbreviation
1.	**132 kV Circuit Breaker Mechanism Box (Sterrewag-T Substation)**	CB-	CB Mechanism box open	CB mo
		CB-	Closed	CB 52a
		CB-	Gas density lockout	CB gl
		CB-	Gas low	CB ga
		CB-	Manual operation handle inserted	CB mh
		CB-	On local	CB lc
		CB-	Open	CB 52b
		CB-	Protection Plant Manual Close	CB pmc
		CB-	Protection Plant Manual Open	CB pmo
		CB-	Spring charge mcb tripped	CB mcb
		CB-	Spring not charged	CB snc
2	**132 kV Circuit Breaker Mechanism Box (Aries Substation)**	CB-	CB Mechanism box open	CB mo
		CB-	Closed	CB 52a
		CB-	Gas density lockout	CB gl
		CB-	Gas low	CB ga
		CB-	Manual operation handle inserted	CB mh
		CB-	On local	CB lc
		CB-	Open	CB 52b
		CB-	Protection Plant Manual Close	CB pmc
		CB-	Protection Plant Manual Open	CB pmo
		CB-	Spring charge mcb tripped	CB mcb
		CB-	Spring not charged	CB snc
		CB-	Spring not charged	CB snc
3	**132 kV Main Busbar Isolator Mechanism Box**	IBM-	Closed	IBM m
		IBM-	Isolator Mechanism box open	IBM mo
		IBM-	Manual operation handle inserted	IBM mh
		IBM-	Motor supply mcb tripped	IBM mcb
		IBM-	On local	IBM lc
		IBM-	Open	IBM n
4	**132 kV Reserve Busbar Isolator Mechanism Box**	IBR-	Closed	IBR m
		IBR-	Isolator Mechanism box open	IBR mo
		IBR-	Manual operation handle inserted	IBR mh
		IBR-	Motor supply mcb tripped	IBR mcb
		IBR-	On local	IBR lc
		IBR-	Open	IBR n
5	**132 kV Cable Isolator Mechanism Box**	IC-	Closed	IC m
		IC-	Isolator Mechanism box open	IC mo
		IC-	Manual operation handle inserted	IC mh
		IC-	Motor supply mcb tripped	IC mcb
		IC-	On local	IC lc
		IC-	Open	IC n
6	**132 kV Transformer Isolator Mechanism Box**	IT-	Closed	IT m
		IT-	Isolator Mechanism box open	IT mo
		IT-	Manual operation handle inserted	IT mh
		IT-	Motor supply mcb tripped	IT mcb
		IT-	On local	IT lc
		IT-	Open	IT n
7	**132 kV Busbar Maintenance Earth Switch Mechanism Box**	EMB	Closed	EMB m
		EMB	Open	EMB n
8	**132 kV Cable Maintenance Earth Switch Mechanism Box**	EMC-	Closed	EMC m
		EMC-	Open	EMC n
9	**132 kV Cable Earth Switch Mechanism Box**	EC-	Closed	EC m
		EC-	Open	EC n
10	**132 kV Main Busbar B\C Earth Switch Mechanism Box**	EBM-	Closed	EBM m
		EBM-	Open	EBM n
11	**132 kV Main Busbar B\C Maintenance Earth Switch Mech. Box**	EMM-	Closed	EMM m
		EMM-	Open	EMM n
12	**132 kV Reserve Busbar B\C Earth Switch Mechanism Box**	EBR-	Closed	EBR m
		EBR-	Open	EBR n
13	**132 kV Reserve Busbar B\C Maintenance Earth Switch Mech. Box**	EMR-	Closed	EMR m
		EMR-	Open	EMR n
14	**132kV Transformer Maintenance Earth Switch Mechanism box**	EMT-	Closed	EMT m
		EMT-	Open	EMT n
15	**132kV Transformer Earth Switch Mechanism box**	ET-	Closed	ET m
		ET-	Open	ET n
16	**132/11 kV Transformer Bay Specific Inputs (HV/LV Panel)**	TX -	132kV Back Up Intertrip	132 BINT
		TX -	132kV Main Intertrip	132 MINT
		TX -	Backup trip circuit fail alarm	BU TCF
		TX -	Bay Controller Internal Relay Failure	BYC irf
		TX -	Breaker Fail Buszone Strip	BF BZS
		TX -	Bucholtz trip	BH T

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		TX -	Bus Bar protection Internal relay failure	BBP irf
		TX -	Bus Bar Protection Trip	BBP trip
		TX -	DC closing supply fail	DC CSF
		TX -	DC motor supply fail	DC MSF
		TX -	Live Busbar Transfer Available	LBT avail
		TX -	LV Bay Controller Internal Relay Failure	LV irf
		TX -	Main Protection Internal Relay Failure	MNP irf
		TX -	Main Protection Mechanical Failure Trip	MNP mec
		TX -	Main Protection Trip	MNP trip
		TX -	Main trip circuit fail alarm	M TCF
		TX -	Oil temperature trip	OT T
		TX -	Tap Change Local	TC lc
		TX -	Tap Position Indicator	TP I
		TX -	Voltage Regulating relay Internal auto / manual	VRR am
		TX -	Voltage Regulating relay Internal Relay Failure	VRR irf
		TX -	Winding temperature trip	WT T
17	**132/11 kV Transformer External Inputs (HV/LV panel)**	TX -	11kV Winding Temperature Alarm	11 WTA
		TX -	11kV Winding Temperature Trip	11 WTT
		TX -	132 kV Winding Temperature Alarm	132 WTA
		TX -	132 kV Winding Temperature Trip	132 WTT
		TX -	Breather Alarm	BR A
		TX -	Bucholtz Alarm	BH A
		TX -	Bucholtz Trip	BH T
		TX -	Bus Bar Selection	BB sel
		TX -	Fan Alarm	FN A
		TX -	Fan MCB Tripped	FN MCB
		TX -	Oil Level Alarm	OL A
		TX -	Oil Temperature Alarm	OT A
		TX -	Oil Temperature trip	OT T
		TX -	Over Pressure Trip	OP T
		TX -	Tap change Incomplete	TC INC
		TX -	Tap change over pressure trip	TC OPT
18	**132 kV Cable Bay Specific Inputs**	C-	Bay Controller Internal Relay Failure	BYC irf
		C-	Breaker failure Bus Zone Strip	BF BZS
		C-	Bus Bar protection Internal relay failure	BBP irf
		C-	Bus Bar Protection Trip	BBP trip
		C-	DC closing supply fail	DC CSF
		C-	DC motor supply fail	DC MSF
		C-	Inter Trip receive	IT R
		C-	Inter trip receive circuit isolation	I RCI
		C-	Inter trip send circuit isolation	I SCI
		C-	Live Busbar Transfer Avaiable	LBT avail
		C-	Main trip circuit fail alarm	M TCF
		C-	VT mini circuit breaker tripped	VT mcb
19	**132 kV Bus Coupler Specific Inputs**	BC-	Main trip circuit fail alarm	M TCF
		BC-	DC closing supply fail	DC CSF
		BC-	DC motor supply fail	DC MSF
		BC-	Bus Bar Protection Trip	BBP Trip
		BC-	Bus Bar protection Internal relay failure	BBP irf
		BC-	Bus Bar Selection	BB sel
		BC-	Breaker failure Bus Zone Strip	BF BZS
		BC-	Bay Controller Internal Relay Failure	BYC irf
		BC-	Bus Coupler Solid	BC SL
20	**11kV Breaker mech. Box**	CB-	Protection Plant Manual Close	CB pmc
	(Incomer and Main Feeder)	CB-	Protection Plant Manual Open	CB pmo
		CB-	Closed	CB 52a
		CB-	Open	CB 52b
		CB-	On local	CB lc
		CB-	Spring charge mcb tripped	CB mcb
		CB-	Manual operation handle inserted	CB mh
		CB-	Spring not charged	CB snc
		CB-	Top busbar selected	CB tbs
		CB-	Bottom busbar selected	CB bbs
		CB-	Umbilical cord command open main	UC com
		CB-	Umbilical cord close command	UC cc
		CB-	Main Trip Circuit Fail	M TCF
21	**11kV Breaker Earth switch**	ECB -	Circuit Breaker earth closed	ECB m
		ECB -	Circuit Breaker earth open	ECB n
22	**11kV Transformer bay Specific inputs (11kV)**	CB-	11kV Main Protection Intertrip	11 MINT
		CB-	132kV breaker Fail Initiate	132 BFI
		CB-	132kV circuit breaker a contact	132 CBa
		CB-	132kV circuit breaker b contact	132 CBb
		CB-	Busbar Blocking Signal	BBLK
23	**11kV Feeder bay Specific inputs (11kV)**	CB-	11kV Incomer Circuit Breaker a Contact	CBa inc

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		CB-	11kV Incomer Circuit Breaker b Contact	CBb inc
		CB-	11kV Bus Coupler Circuit Breaker a Contact	CBa bc
		CB-	11kV Bus Coupler Circuit Breaker a Contact	CBb bc
		CB-	11kV Bus Section Circuit Breaker a Contact	CBa bs
		CB-	11kV Bus Section Circuit Breaker a Contact	CBb bs
24	**11kV Breaker mech. Box**	CB-	Closed	CB 52a
	(Bus Coupler and Bus Section)	CB-	Manual operation handle inserted	CB mh
		CB-	On local	CB lc
		CB-	Open	CB 52b
		CB-	Protection Plant Manual Close	CB pmc
		CB-	Protection Plant Manual Open	CB pmo
		CB-	Spring charge mcb tripped	CB mcb
		CB-	Spring not charged	CB snc
		CB-	Umbilical cord close command	UC cc
		CB-	Umbilical cord command open main	UC com
25	**Substation General Inputs**		Access Control ID (16 bit)	AC (0-15)
			Aux. Protection optic fibre MUX non-urgent alarm	AOF NA
			Aux. Protection optic fibre MUX remote alarm	AOF RA
			Aux. Protection optic fibre MUX urgent alarm	AOF UA
			Backup battery charger DC earth fault	BBC EF
			Backup battery charger AC supply fail	BBC F
			Backup battery loss	BBL
			Bay controller fail	BCF
			Backup DC supply fail	BDC F
			Backup DC supply mcb trip	BDC MCB
			Backup DC supply overvoltage	BDC OV
			Backup DC supply undervoltage	BDC UV
			132 kV Busbar protection Zone 1 trip	BZ 1T
			132 kV Busbar protection Zone 2 trip	BZ 2T
			132 kV Busbar protection common alarm	BZ CA
			132 kV Busbar protection Check Zone trip	BZ CHT
			132 kV Busbar protection out of service	BZ OOS
			GPS receiver fail	GPS F
			GPS synchronism lost	GPS SL
			Intruder Alarm	I A
			Main battery charger DC earth fault	MBC EF
			Main battery charger AC supply fail	MBC F
			Main battery loss	MBL
			Main DC supply fail	MDC F
			Main DC supply mcb trip	MDC MCB
			Main DC supply overvoltage	MDC OV
			Main DC supply undervoltage	MDC UV
			Protection optic fiber MUX non-urgent alarm	POF NA
			Protection optic fibre MUX remote alarm	POF RA
			Protection optic fiber MUX urgent alarm	POF UA
			Substation under Local Control	SUB LOC
			Substation under Remote Control	SUB LOC'
			Substation AC supply 1 fail	SUBAC 1
			Substation AC supply 2 fail	SUBAC 2

Typical Analogue Inputs to the Control System

#	ANALOGUE QUANTITY	UNIT	Decimal	SOURCE	TARGET			
					SINGLE LINE	BAY SINGLE LINE	DATA TRENDING	SCADA
1.	**132 kV Cable Bay**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
	Neutral Current	A	0	Base Relay				
	R-Y Line Voltage	kV	1	Base Relay		✓	✓	
	Y-B Line Voltage	kV	1	Base Relay	✓	✓	✓	✓
	B-R Line Voltage	kV	1	Base Relay		✓	✓	
	Three phase power	kW	0	Base Relay		✓	✓	✓
	Three phase apparent power	kVA	0	Base Relay	✓	✓	✓	✓
	Three phase reactive power	kVAr	0	Base Relay		✓	✓	✓
	Power Factor	pu	2	Base Relay		✓	✓	✓
2	**132/11 kV Transformer Bay HV Side**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
	Neutral Current	A	0	Base Relay				
	R-Y Line Voltage	kV	1	Base Relay		✓	✓	
	Y-B Line Voltage	kV	1	Base Relay	✓	✓	✓	✓
	B-R Line Voltage	kV	1	Base Relay		✓	✓	
	Three phase power	kW	0	Base Relay		✓	✓	✓
	Three phase apparent power	kVA	0	Base Relay	✓	✓	✓	✓
	Three phase reactive power	kVAr	0	Base Relay		✓	✓	✓
	Power Factor	pu	2	Base Relay		✓	✓	✓
3	**11 kV Transformer Incomer**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
	Neutral Current	A	0	Base Relay				
	R-Y Line Voltage	kV	1	Base Relay		✓	✓	
	Y-B Line Voltage	kV	1	Base Relay	✓	✓	✓	✓
	B-R Line Voltage	kV	1	Base Relay		✓	✓	
	Three phase power	kW	0	Base Relay		✓	✓	✓
	Three phase apparent power	kVA	0	Base Relay	✓	✓	✓	✓
	Three phase reactive power	kVAr	0	Base Relay		✓	✓	✓
	Power Factor	pu	2	Base Relay		✓	✓	✓
4	**132 kV Bus Coupler Bay**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
	Neutral Current	A	0	Base Relay				
	R-Y Line Voltage	kV	1	Base Relay		✓	✓	
	Y-B Line Voltage	kV	1	Base Relay	✓	✓	✓	✓
	B-R Line Voltage	kV	1	Base Relay		✓	✓	
	Three phase power	kW	0	Base Relay		✓	✓	✓
	Three phase apparent power	kVA	0	Base Relay	✓	✓	✓	✓
	Three phase reactive power	kVAr	0	Base Relay		✓	✓	✓
	Power Factor	pu	2	Base Relay		✓	✓	✓
4	**11kV Main feeder**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
	Neutral Current	A	0	Base Relay				
	R-Y Line Voltage	kV	1	Base Relay		✓	✓	
	Y-B Line Voltage	kV	1	Base Relay	✓	✓	✓	✓
	B-R Line Voltage	kV	1	Base Relay		✓	✓	
	Three phase power	kW	0	Base Relay		✓	✓	✓
	Three phase apparent power	kVA	0	Base Relay	✓	✓	✓	✓
	Three phase reactive power	kVAr	0	Base Relay		✓	✓	✓
	Power Factor	pu	2	Base Relay		✓	✓	✓
5	**11kV Bus Section**							
	Red phase current	A	0	Base Relay		✓	✓	
	Yellow phase current	A	0	Base Relay	✓	✓	✓	✓
	Blue phase current	A	0	Base Relay		✓	✓	
6	**Substation General**							
	Main battery charger output voltage	V	2	SIED			✓	✓
	Main battery charger output current	A	2	SIED			✓	✓
	Backup battery charger output voltage	V	2	SIED			✓	✓
	Backup battery charger output current	A	2	SIED			✓	✓

Appendix A.4

Typical Hard Wired Outputs per Bay\Device Type

#	Source	Operation	Abbreviation
1	**132 kV Cable Incomer Bay**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Circuit breaker	Open	CB cobu
	Main busbar selector isolator	Close	IBM cc
	Main busbar selector isolator	Open	IBM com
	Reserve busbar selector isolator	Close	IBR cc
	Reserve busbar selector isolator	Open	IBR com
	Line isolator	Close	IL cc
	Line isolator	Open	IL com
	Earth line mag bolt supply	Enable	EL ms
	Bay Controller Inter Trip Send	Send	BYC its
	Breaker fail Bus Zone Strip	Send	BF BZS
	Bay Controller Internal Relay Fail	Send	BYC irf
	Bus Bar Protection Trip	Send	BBP trip
	Bus Bar Protection Internal Relay Fail	Send	BBP irf
2	**132/11 kV Transformer Bay (HV)**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Circuit breaker	Open	CB cobu
	Main busbar selector isolator	Close	IBM cc
	Main busbar selector isolator	Open	IBM com
	Reserve busbar selector isolator	Close	IBR cc
	Reserve busbar selector isolator	Open	IBR com
	132kV Breaker Failure Initiate	Send	132BF i
	Main protection Intertrip to 11kV	Send	11MINT
	Bay Controller Internal Relay Fail	Send	BYC irf
	Breaker fail Bus Zone Strip	Send	BF BZS
	Bay Controller Inter Trip Send	Send	BYC its
	Bus Bar Protection Trip	Send	BBP trip
	Bus Bar Protection Internal Relay Fail	Send	BBP irf
	Bus Bar Selection	Send	BB sel
	Main Protection	Send	MNP mech
	Main Protection Trip	Send	MNP trip
	Main Protection Internal Relay failure	Send	MNP irf
	Voltage Regulator Relay Raise	Send	VRR r
	Voltage Regulator Relay Lower	Send	VRR l
	Voltage Regulator Relay Internal Relay Failure	Send	VRR irf
	Voltage Regulator Relay Auto Manual	Send	VRR am
3	**11 kV Transformer Incomer (MV)**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Bay Controller Internal Relay Fail	Send	BYC irf
	11kV B/U Protection trip to 132kV Main Protection Realy	Send	132 MINT
	11kV B/U Protection trip to 132kV B/U Protection Realy	Send	132 BINT
4	**132 kV Bus Coupler Bay**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Circuit breaker	Open	CB cobu

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	Main busbar selector isolator	Close	IBM cc
	Main busbar selector isolator	Open	IBM com
	Reserve busbar selector isolator	Close	IBR cc
	Reserve busbar selector isolator	Open	IBR com
	Earth reserve busbar mag bolt supply	Enable	EBR ms
	Earth main busbar mag bolt supply	Enable	EBM ms
	Breaker fail Bus Zone Strip	Send	BF BZS
	Bus Coupler Solid	Enable	BC SL
	Bay Controller Internal Relay Fail	Send	BYC irf
	Bus Bar Protection Trip	Send	BBP trip
	Bus Bar Protection Internal Relay Fail	Send	BBP irf
5	**11 kV Main Feeder (MV)**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Bus Bar Blocking Signal	Send	BB BLK
	Bay Controller Internal Relay Fail	Send	BYC irf
6	**11 kV Bus Coupler (MV)**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
7	**11 kV Bus Section (MV)**		
	Circuit breaker	Close	CB cc
	Circuit breaker	Open	CB com
	Bay Controller Internal Relay Fail	Send	BYC irf
8	**Substation General (SIED)**		
	Reset intruder alarm	Send	IA RST
	Busbar protection reset	Send	BP RST
	Combine buszones	Send	CBZ
	Main battery charger "Boost Charge ON"	Send	MB BO
	Backup battery charger "Boost Charge ON"	Send	BB BO

Typical Physical and Logic Interlock and Sequences to be Implemeted at Bay Level

#	Primary Plant	Status	Symbol	Logic
1.	**132kV Cable Circuit Breaker**	Closed	CB	52a * 52b'
		Open	CB'	52a' * 52b
		State change in progress	#CB	52a' * 52b'
		Discrepancy	?CB	52a * 52b OR 52a' * 52b' * timeout
		Ready for open command	CBro	CB * CBgl' * CBsnc'
		Ready for close command	CBrc	CB' * IBM * IBR' * IC * EMB' * EMC' * EC' * SY * CBgl' * CBsnc' * ITR' * (CBmtcf'+CBbtcf')
				OR
				CB' * IBM' * IBR * IC * EMB' * EMC' * EC' * SY * CBgl' * CBsnc' * ITR' * (CBmtcf'+CBbtcf')
				OR
				CB' * IBM' * IBR' * IC' * EMB * EMC
				OR
				CB' * IBM * IBR * IC * EMB' * EMC' * EC'
2	**132kV Transformer Circuit Breaker**	Closed	CB	52a * 52b'
		Open	CB'	52a' * 52b
		State change in progress	#CB	52a' * 52b'
		Discrepancy	?CB	52a * 52b OR 52a' * 52b' * timeout
		Ready for open command	CBro	CB * CBgl' * CBsnc'
		Ready for close command	CBrc	CB' * IBM * IBR' * EMB' * 11kVECB' * EMT' * CBgl' * CBsnc' * MPRF' * (CBmtcf'+CBbtcf')
				OR
				CB' * IBM' * IBR * EMB' * 11kVECB' * EMT' * CBgl' * CBsnc' * MPRF' * (CBmtcf'+CBbtcf')
				OR
				CB' * EMB * EMT * IBR' * IBM'
3	**132kV BC Circuit Breaker**	Closed	CB	52a * 52b'
		Open	CB'	52a' * 52b
		State change in progress	#CB	52a' * 52b'
		Discrepancy	?CB	52a * 52b OR 52a' * 52b' * timeout
		Ready for open command	CBro	CB * CBgl' * CBsnc'
		Ready for close command	CBrc	CB' * IBM * IBR * EMR' * EBR' * EMM' * EBM' * SY * CBgl' * CBsnc' * BYCirf' * (CBmtcf'+CBbtcf')
				OR
				CB' * IBM' * IBR' * EMM * EMR
4	**132kV Main-BB Selector Isolator**	Closed	IBM	IBMn * IBMm'
		Open	IBM'	IBMn' * IBMm
		State change in progress	#IBM	IBMn' * IBMm'
		Discrepancy	?IBM	IBMn * IBMm OR IBMn' * IBMm' * timeout
		Ready for open command	IBMro	CB' * IBM * IBR' * EMB' * IBMmh'
				OR
				CB * IBM * IBR * EMB' * IBMmh' * BCSL
		Ready for close command	IBMrc	CB' * IBM' * IBR' * EMB' * IBMmh'
				OR
				CB' * IBM' * IBR * EMB' * IBMmh' * BCSL
5	**132kV Reserve-BB Selector Isolator**	Closed	IBR	IBRn * IBRm'
		Open	IBR'	IBRn' * IBRm
		State change in progress	#IBR	IBRn' * IBRm'
		Discrepancy	?IBR	IBRn * IBRm OR IBRn' * IBRm' * timeout
		Ready for open command	IBRro	CB' * IBR * IBM' * EMB' * IBRmh' * EMC'
				OR
				CB' * IBR * IBM * EMB' * IBRmh' * BCSL
		Ready for close command	IBRrc	CB' * IBM' * IBR' * EMB' * IBRmh'
				OR
				CB' * IBM * IBR' * EMB' * IBRmh' * BCSL
6	**132kV Cable Isolator**	Closed	IC	ICn * ICm'
		Open	IC'	ICn' * ICm
		State change in progress	#IC	ICn' * ICm'
		Discrepancy	?IC	ICn * ICm OR ICn' * ICm' * timeout
		Ready for open command	ICro	CB' * IC * EC' * EMC' * ICmh'
		Ready for close command	ICrc	CB' * IC' * EC' * EMC' * ICmh'
7	**132kV Maintenance Earth Busbar**	Closed	EMB	EMBn * EMBm'
		Open	EMB'	EMBn' * EMBm
		State change in progress	#EMB	EMBn' * EMBm'
		Discrepancy	?EMB	EMBn * EMBm OR EMBn' * EMBm' * timeout
		Ready for open command	EMBro	EMB * IBR' * IBM' * CB'
		Ready for close command	EMBrc	EMB' * IBR' * IBM' * CB'
8	**132kV Maintenance Earth Cable-Side**	Closed	EMC	EMCn * EMCm'
		Open	EMC'	EMCn' * EMCm
		State change in progress	#EMC	EMCn' * EMCm'
		Discrepancy	?EMC	EMCn * EMCm OR EMCn' * EMCm' * timeout
		Ready for open command	EMCro	EMC * IC' * CB' * IBR' * IBM'
		Ready for close command	EMCrc	EMC' * IC' * CB' * IBR' * IBM'
9	**132kV Cable Earth Side**	Closed	EC	ECn * ECm'
		Open	EC'	ECn' * ECm
		State change in progress	#EC	ECn' * ECm'
		Discrepancy	?EC	ECn * ECm OR ECn' * ECm' * timeout
		Ready for open command	ECro	EC * IC' * NOVOLT
		Ready for close command	ECrc	EC' * IC' * NOVOLT
10	**132kV Main Busbar Earth**	Closed	EBM	EBMn * EBMm'
		Open	EBM'	EBMn' * EBMm
		State change in progress	#EBM	EBMn' * EBMm'
		Discrepancy	?EBM	EBMn * EBMm OR EBMn' * EBMm' * timeout
		Ready for open command	EBMro	CB' * EBM * IBM' * IBR' * NOVOLT
		Ready for close command	EBMrc	CB' * EBM' * IBM' * IBR' * NOVOLT
11	**132kV Maintenance Earth MBB-Side**	Closed	EMM	EMMn * EMMm'
		Open	EMM'	EMMn' * EMMm
		State change in progress	#EMM	EMMn' * EMMm'
		Discrepancy	?EMM	EMMn * EMMm OR EMMn' * EMMm' * timeout
		Ready for open command	EMMro	CB' * EMM * IBM' * IBR'
		Ready for close command	EMMrc	CB' * EMM' * IBM' * IBR'
12	**132kV Reserve Busbar Earth**	Closed	EBR	EBRn * EBRm'
		Open	EBR'	EBRn' * EBRm
		State change in progress	#EBR	EBRn' * EBRm'
		Discrepancy	?EBR	EBRn * EBRm OR EBRn' * EBRm' * timeout
		Ready for open command	EBRro	CB' * EBR * IBM' * IBR' * NOVOLT
		Ready for close command	EBRrc	CB' * EBR' * IBM' * IBR' * NOVOLT
13	**132kV Maintenance Earth RBB-Side**	Closed	EMR	EMRn * EMRm'
		Open	EMR'	EMRn' * EMRm
		State change in progress	#EMR	EMRn' * EMRm'
		Discrepancy	?EMR	EMRn * EMRm OR EMRn' * EMRm' * timeout
		Ready for open command	EMRro	CB' * EMR * IBR' * IBM'
		Ready for close command	EMRrc	CB' * EMR' * IBR' * IBM'
14	**132kV Maintenance Earth Transformer**	Closed	EMT	EMTn * EMTm'
		Open	EMR'	EMTn' * EMTm
		State change in progress	#EMR	EMTn' * EMTm'
		Discrepancy	?EMR	EMTn * EMTm OR EMTn' * EMTm' * timeout
		Ready for open command	EMRro	CB' * EMT * IBR' * IBM' * 11kV CB' (racked out)
		Ready for close command	EMRrc	CB' * EMT' * IBR' * IBM' * 11kV CB' (racked out)
15	**11kV Circuit Breaker**	Closed	CB	52a * 52b'
		Open	CB'	52a' * 52b
		State change in progress	#CB	52a' * 52b'
		Discrepancy	?CB	52a * 52b OR 52a' * 52b' * timeout
		Ready for close command	CBrc	52a' * 52b * 132CB

Appendix A.6

Typical input Zone Tags for Events

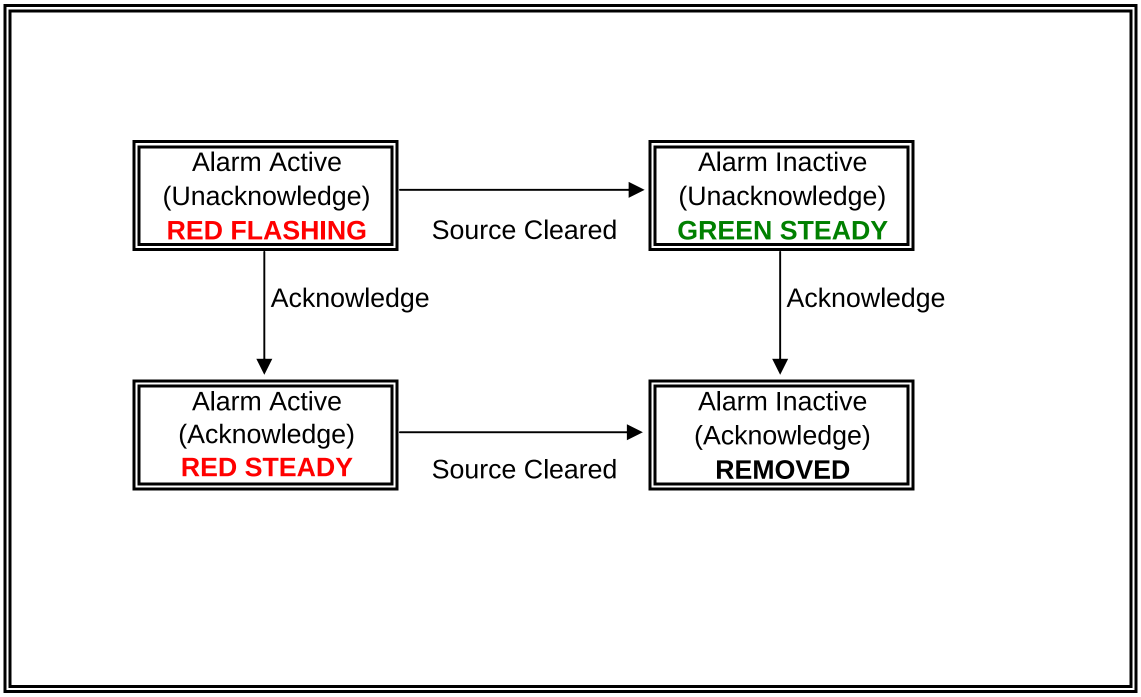
Source Bay 012	Voltage 345	Device Source 678	OP Code 9	Description
AR_				Aries
BC_				Bus Coupler
TRF_				Transformer
INC_				Incomer
BS_				Bus Section
MF_				Main Feeder
	132			132kV
	11			11kV
		_CB		Circuit Breaker
		IBM		Main Busbar Isolator
		IBR		Reserve Busbar Isolator
		_IC		Cable Isolator
		EMB		Maintenance Earth Busbar
		EML		Maintenance Earth, Line Side
		_EC		Cable Earth
		EBM		Earth, Main-BB Side (BC)
		EMM		Maintenance Earth, Main-BB Side (BC)
		EBR		Earth, Reserve-BB Side (BC)
		EMR		Maintenance Earth, Reserve-BB Side (BC)
		EMT		Maintenance Earth, Transformer
		BYC		Bay Controller
		MNP		Main Protection
		BUP		Backup Protection
		BBP		Busbar Protection
		MFR		Multi-Function over-current relay
		VRR		Voltage Regulating relay
			P	Protection
			M	Measurement
			A	Alarm & Indication
			E	Internal errors or communication
			C	Control

EXAMPLES :

INPUT ZONE	**DESCRIPTION**
AR1_132_BYCE	Aries Feeder1 132kV bay, comms/internal errors, main protection device
AR1_132_MNPP	Aries Feeder1, 132kV bay, Main protection trip.

Appendix A.7

Substation Control Computer Alarm Life Cycle



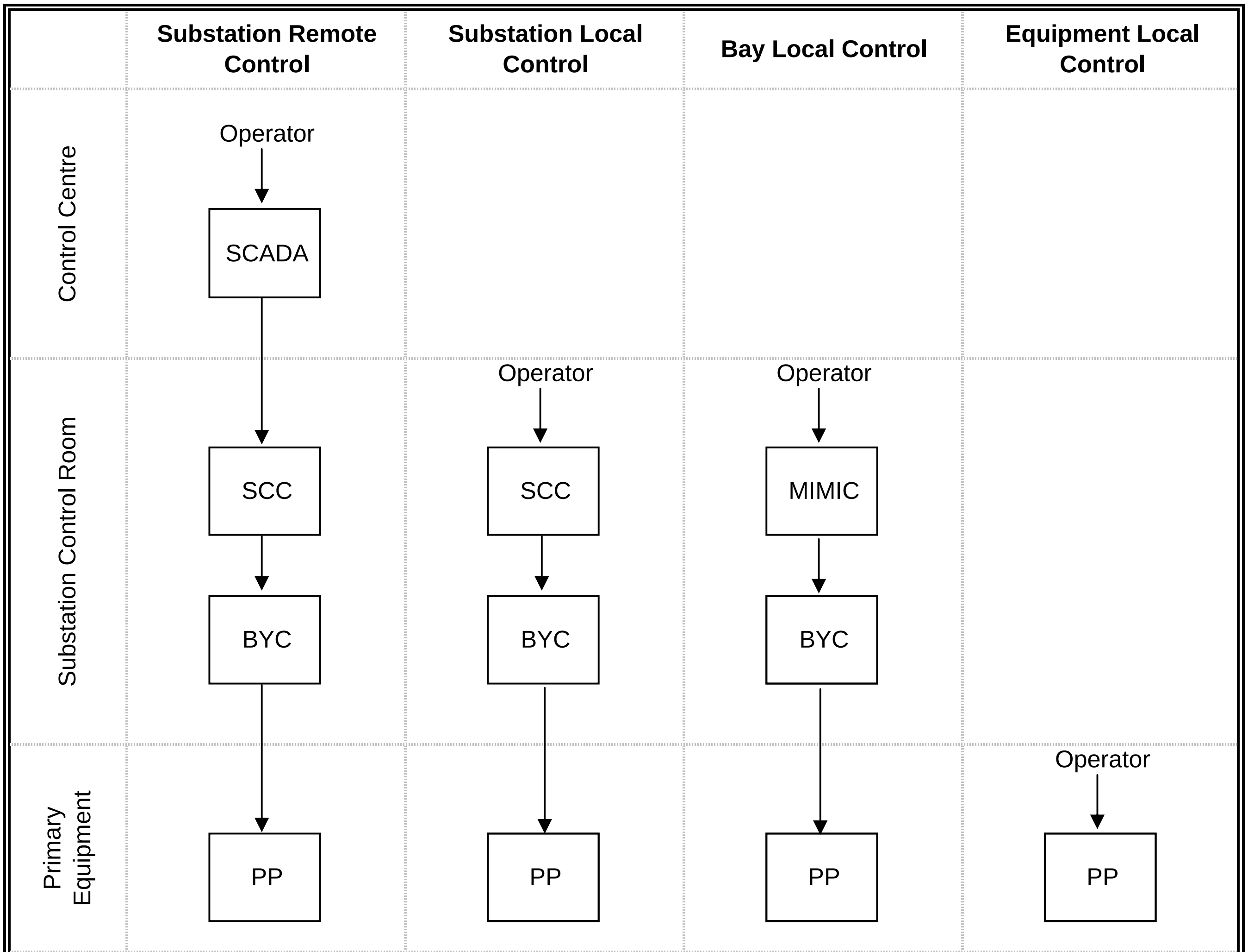
Appendix A.8 2010/03/10

Typical Alarm and Eventhandling Philosophy to be Applied

Object Code	Event Description		Logic	Destination			
	Source	Status		Mimic	Event	Alarm	SCADA
AR_132BBPP	Busbar prot zone 1 trip	Operate	BZ1T	√	√	√	√
AR_132BBPP	Busbar prot zone 1 trip	Reset	BZ1T'				
AR_132BBPP	Busbar prot zone 2 trip	Operate	BZ2T	√	√	√	√
AR_132BBPP	Busbar prot zone 2 trip	Reset	BZ2T'				
AR_132BBPP	Busbar prot check zone trip	Operate	BZCHT'	√	√	√	√
AR_132BBPP	Busbar prot check zone trip	Reset	BZCHT'				
AR_132BBPP	Busbar prot station trip	Operate	BZST	√	√	√	√
AR_132BBPP	Busbar prot station trip	Reset	BZST'				
AR_132BBPA	Busbar prot comm alarm	On	BZCA		√	√	√
AR_132BBPA	Busbar prot comm alarm	Off	BZCA'				
AR_132BBPA	Busbar prot out of service	Active	BZOOS	√	√	√	√
AR_132BBPA	Busbar prot out of service	Not Active	BZOOS'				
AR_132BBPC	Bus zones	Combined	BZCOM		√		√
AR_132BBPC	Bus zones	Not Combined	BZCOM'				
AR_132BYCE	AR bay controller comms fail	Active	BCF		√	√	√
AR_132BYCE	AR bay controller comms fail	Not Active	BCF'				
BC_132BYCE	BC bay controller comms fail	Active	BCF		√	√	√
BC_132BYCE	BC bay controller comms fail	Not Active	BCF'				
AR_SIDA	Main DC supply fail	Active	MDCF	√	√	√	√
AR_SIDA	Main DC supply fail	Not Active	MDCF'				
AR_SIDA	Main DC supply under-voltage	Active	MDCUV		√	√	√
AR_SIDA	Main DC supply under-voltage	Not Active	MDCUV'				
AR_SIDA	Main DC supply over-voltage	Active	MDCOV		√	√	√
AR_SIDA	Main DC supply over-voltage	Not Active	MDCOV'				
AR_SIDA	Main AC charger supply fail	Active	MBCF		√	√	√
AR_SIDA	Main AC charger supply fail	Not Active	MBCF'				
AR_SIDA	Main MCB tripped	Active	MMCBT	√	√	√	√
AR_SIDA	Main MCB tripped	Not Active	MMCBT'				
AR_SIDA	Main DC earth fault	Active	MBCEF		√	√	√
AR_SIDA	Main DC earth fault	Not Active	MBCEF'				
AR_SIDA	Main battery loss	Active	MBL		√	√	√
AR_SIDA	Main battery loss	Not Active	MBL'				
AR_SIDA	Backup DC supply fail	Active	BDCF	√	√	√	√
AR_SIDA	Backup DC supply fail	Not Active	BDCF'				
AR_SIDA	Backup DC supply under-voltage	Active	BDCUV		√	√	√
AR_SIDA	Backup DC supply under-voltage	Not Active	BDCUV'				
AR_SIDA	Backup DC supply over-voltage	Active	BDCOV		√	√	√
AR_SIDA	Backup DC supply over-voltage	Not Active	BDCOV'				
AR_SIDA	Backup AC charger supply fail	Active	BBCF		√	√	√
AR_SIDA	Backup AC charger supply fail	Not Active	BBCF'				
AR_SIDA	Main MCB tripped	Active	MMCBT	√	√	√	√
AR_SIDA	Main MCB tripped	Not Active	MMCBT'				
AR_SIDA	Main DC earth fault	Active	MBCEF		√	√	√
AR_SIDA	Main DC earth fault	Not Active	MBCEF				
AR_SIDA	Main battery loss	Active	MBL		√	√	√
AR_SIDA	Main battery loss	Not Active	MBL'				
AR_SIDA	GPS sync lost	Active	GPSSL		√	√	√
AR_SIDA	GPS sync lost	Not Active	GPSSL'		√	√	√
AR_SIDA	GPS receiver fail	Active	GPSF		√	√	√
AR_SIDA	GPS receiver fail	Not Active	GPSF'		√	√	√
AR_SIDA	Substation control	Remote	SUBLOC'		√		√
AR_SIDA	Substation control	Local	SUBLOC		√		√
AR_SIDA	Prot MUX alarm	On	POFA		√	√	√
AR_SIDA	Prot MUX alarm	Off	POFA'				
AR_SIDA	Prot MUX remote alarm	On	POFRA		√	√	√
AR_SIDA	Prot MUX remote alarm	Off	POFRA'				
AR_SIDA	Aux MUX alarm	On	AOFA		√	√	√
AR_SIDA	Aux MUX alarm	Off	AOFA'				
AR_SIDA	Aux MUX remote alarm	On	AOFRA		√	√	√
AR_SIDA	Aux MUX remote alarm	Off	AOFRA'				
AR_SIDA	Substation AC supply 1 fail	Active	SUBAC1		√	√	√
AR_SIDA	Substation AC supply 1 fail	Not Active	SUBAC1'				
AR_SIDA	Substation AC supply 2 fail	Active	SUBAC2		√	√	√
AR_SIDA	Substation AC supply 2 fail	Not Active	SUBAC2'				
AR_SIDA	Intruder alarm	On	IA		√	√	√
AR_SIDA	Intruder alarm	Off	IA'				
AR_SIDA	Authorised	Entry	IA(0-15)		√		√
AR_SIDA	Authorised	Exit	IA(0-15)		√		√

Appendix A.9

Required Levels of Substation Exclusive Control



SCADA : Supervisory Control & Data Acquisition system
SCC : Substation Control Computer
BC : Bay Controller
PP : Primary Plant
MIMIC : Bay Local Painted/Tiled Mimic (If not supported by Bay Controller)

PART 13.1 : LOW VOLTAGE AC WALL MOUNTED CHANGE-OVER & DISTRIBUTION PANEL

SPECIFICATION N0 : LV.01/0-97

CONTENTS

1. SCOPE

This Specification covers the supply and delivery of wall mounted sheet steel low voltage AC distribution board(s).

2. STANDARDS

The board shall be manufactured to comply with the appropriate requirements laid down in SABS-1180 and the moulded circuit breakers with SABS-156.

3. QUALITY OF MATERIAL AND WORKMANSHIP

All materials used on these boards shall be new, of approved quality and of the class most suitable for the intended use.

Workmanship shall be of the highest standard and shall in all respect be subject to approval by the Engineer.

4. TECHNICAL REQUIREMENTS

4.1 General

The sheet steel board(s) shall be manufactured and fitted in accordance with the following technical requirements.

4.2 Equipment

The board shall be suitable for a 240/415 volt three phase four wire supply system with a short circuit level of 5 kA for 3 seconds. The rating of the busbars and incomer shall be 200 amperes.

The board shall be equipped with the following type and number of miniature type moulded case circuit-breakers to SABS-156 for the outgoing circuits:

a) 4 off triple pole 100 ampere, plus neutral;

b) 4 off triple pole 30 ampere, plus neutral;

c) 1 off single pole 60 ampere, plus neutral;

d) 3 off single pole 30 ampere, plus neutral; and

e) 2 off single pole 5 ampere, plus neutral.

The board shall be equipped with manual supply change-over facilities and the main supply shall be supervised by a time delayed under voltage relay as per drawing C-86 in Section IV.

4.3 Steel Board(s)

The minimum thickness of the sheet steel that the board(s) are to be manufactured from is 2 mm.

Overall dimensions of the panels shall be as follows:

a) Height - 735 mm;

b) Width - 1530 mm; and

c) Depth - ± 365 mm.

Suitable provision shall be made for wall mounting of the board(s).

All surfaces to be painted shall be cleaned completely from rust, scale, grease or other spoil by sandblasting and/or acid pickling prior to painting.

Ferrous parts, shall have an acid phosphate treatment before applying priming coats.

The exterior surfaces of the panels required as detailed in drawing C-86 shall be finished in the colour Cloud Grey - SABS 1091-1975, colour No F48, Munsell Ref.2.5 PB7,5. The interior surfaces shall be finished in a white gloss paint.

4.4 Labelling

The board shall be fitted with main label, circuit labels and danger labels to approval.

Labels shall be made of durable materials to approval. Metal labels where used shall be engraved or etched. Labels made of Trafolite or other similar materials shall have engraved lettering. Dymotape or similar types of labels shall not be used. All labels shall be fixed mechanically.

Refer also to Section III Part 1.4.

4.5 Chop-Over

A change-over (chop-over) contactor arrangement shall be provided to switch between the two 3 phase auxiliary supplies.

The changeover shall be controlled by a setable time delayed under-voltage relay.

The voltage being monitored by the under-voltage relay shall be selectable from the two auxiliary supplies. The under-voltage relay shall be either a 3 phase unit or two single phase units coupled phase to phase on the 3 phase supply to be monitored.

4.6 Drawings

Full drawing inclusive of equipment single line diagrams shall be submitted prior to manufacture for approval.

The quantity and positions of these distribution boards are shown in the building/civil drawings.

PART 13.2 : 110 V BATTERY CHARGER

SPECIFICATION No : BC09/008

CONTENTS

1. SCOPE

This Specification covers silicon-controlled rectifier type battery chargers suitable for charging battery's from a nominal 400/230 V 50 Hz alternating current supply, and includes a battery management system. The charger shall be voltage controlled and current limiting.

The size of the battery charger shall be calculated by the Tenderer, who shall state in detail how the figure was derived. He shall take into account the normal static load of the protection and any other devices as well as the UPS (if applicable).

If called for in the schedule of Particulars and Guarantees, this Specification also covers the associated DC distribution board(s), complete with the busbars, switchgear, relays, alarm and indication equipment to be housed with the charger unit.

2. STANDARDS

The battery charger(s) and associated equipment to be supplied against this Specification shall comply fully with the requirements thereof, the particulars and guarantees stated by the tenderer in the Schedule of Particulars and Guarantees and the relevant requirements in the latest edition of the following standard specification :

a) NRS 026:1993 Battery charger - industrial type.

3. GENERAL

The station battery is required for permanent indoor installation at an unmanned substation to provide DC power supplies for:

a) continuous and intermittent relay energising;

b) continuous and intermittent alarm and position indication signalling;

c) intermittent operation of tripping coils and contactors;

d) intermittent operation of closing coils and contactors;

e) intermittent energising of control circuits and interlocking circuits;

f) continuous supervision of control and protection circuits;

g) intermittent operation of motor - driven isolators and transformer tap changers;

h) operation of emergency lights; and

i) stand-by duties such as emergency operation of solenoid - operated switchgear.

Reliability of operation and full availability on demand at any time are of the utmost importance. The battery equipment shall operate unattended between scheduled maintenance intervals over a lifetime of at least 20 years.

4. BATTERY CHARGER

4.1 AC Supply

The battery charger may be fed off overhead lines which are exposed to severe lightning and switching surges.

A pilot light shall be provided on the charger to indicate when the AC supply to the charger is switched on. The pilot light shall preferably be of the LED type.

4.2 Battery Charger Requirements

The battery charger to be supplied with each complete battery. Solid state micro processor controlled will be acceptable. Tenderers shall give full details of the unit offered.

To facilitate equalising charging after a prolonged AC mains supply failure or charger failure the charger shall be fitted with boost charging facilities which must be both manually initiated and automatically controlled either by means of a timer or other suitable control circuitry. To prevent unauthorised operation of boost charging the initiating device shall be concealed or shall be lockable. After elapse of the set boost charging time, the charger shall revert back to trickle float charging automatically. Boost charging must also have the facility to be able to be initiated externally via the SCADA. system.

4.3 Battery Management System

A battery management system shall provide the following :

a) Independent battery charging management;

b) control operator intervention;

c) charger boost control via SCADA and local controls;

d) comprehensive alarm systems;

e) charge currents from 5 amps to 500 amps;

f) indication of DC and AC voltages and current;

g) plug-in system;

h) separate power supply has dual AC and DC input;

i) continual battery monitoring after power failure;

j) automatic calculation of AH capacity;

k) controls two parallel chargers and loads; and

l) charger protection.

Protection shall be achieved by a double pole moulded case circuit-breaker. In the case of 3-phase units, triple pole breakers shall be used. All circuit breakers shall be equipped with auxiliary contacts for alarm indication.

The charger shall be self-protecting against overload and external faults to the extent that accidental short circuiting of the charger output terminals will not cause any damage to the charger. Current limiting in addition to protection devices such as breakers is preferred.

A device shall be provided on the DC side of the charger to prevent the battery from discharging into the internal circuits of the charger in the event of failure of the DC output of the charger.

5. CHARGER CUBICLE

5.1 Construction

Approved vermin-proof ventilation shall be provided at or near the top and bottom of the enclosure.

Combustible or flammable materials shall not be used in the construction of the enclosure excluding painting.

All cubicles shall be arranged for front access. Front access shall be by means of stiff side-hinged, lift-off doors which shall be lockable. In the case of a door, the door handle shall not stand proud of the cubicle.

Cubicles shall be spacious enough to permit full and easy access to all terminals and equipment mounted in the cubicle. However the overall dimensions of any cubicle shall not exceed the following limiting dimensions :

a) Overall height 1 950 mm;

b) overall length (dual chargers) 1 200 mm; and

c) overall depth 600 mm.

All cubicles shall be provided with a brass earth terminal stud not less than 10 mm in diameter for earthing the cubicle.

5.2 Cable Gland Plate

The charger cubicle shall be arranged for bottom cable entry bearing in mind that a large number of cables are to be terminated. Suitable, removable gland plates of acceptable dimensions and located in approved positions shall be provided for glanding of incoming and outgoing cables. The gland plate shall consist of at least five removable sections mounted at 300 mm height from the ground, shall be freely accessible and no equipment shall be mounted within a distance of 300 mm above the gland plates in order to facilitate drilling of gland holes on site. Gland plates shall be left unpunched and the minimum thickness of the gland plates shall be 2,5 mm.

5.3 Earth Arrangements

All potential free metal parts in the charger shall be earthed to the cubicle which in turn shall be earthed to the substation earth for which purpose an earthing stud is to be provided in the cubicle.

The metal screen between the primary and secondary windings of the rectifier transformer shall be earthed directly to the earthing terminal.

6. DC DISTRIBUTION BOARD

DC distribution board(s) incorporating the change over switch equipped with the necessary busbars, busbar connections, DC circuit-breakers , cable terminal blocks, labels and warning notices shall be provided for the distribution of the output of the battery/charger unit. The distribution board shall be of the totally enclosed type with front access by means of side-hinged, lift-off doors. The busbars and all "live" terminals shall be covered by a removable front cover plate to prevent accidental contact when doing switching.

The DC distribution board(s) shall not be incorporated in the charger cubicle but be separate, to be installed on a wall at 1.6 metres above ground level.

Cubicles shall be spacious enough to permit full and easy access to all terminals and equipment mounted in the cubicle. However the overall dimensions of any cubicle shall not exceed the following limiting dimensions :

a) Overall height 600 mm;

b) overall length (dual chargers) 1 500 mm; and

c) overall depth 300 mm.

All cubicles shall be provided with a brass earth terminal stud not less than 10 mm in diameter for earthing the cubicle.

Provision shall be made to isolate the DC distribution board(s) from the battery/charger unit(s) by means of a double pole moulded case DC circuit-breaker(s) of appropriate rating which will be installed between the selector switch and the outgoing DC circuit breakers.

The DC board(s) shall be provided with the number of outlet circuits specified in the Schedule of Particulars and Guarantees. Each outlet circuit shall be protected by a double pole, miniature type moulded case circuit-breaker of the specified rating, with auxiliary contacts for alarm indication, as called for in the Schedule of Particulars and Guarantees.

Moulded case circuit-breakers shall comply with SABS 156.

6.1 Manual Change-Over Selector Switch

Manual change-over selector switch for dual charger and dual distribution board shall be of the base mounted type.

A separate distribution board shall be equipped with a manually operated change-over selector switch which shall be arranged to facilitate the following switching:

a) Left hand position - DB one and DB two connected to charger one and battery one;

b) centre position - DB one connected to charger one and battery one and DB two connected to charger two and battery two; and

c) right hand position - DB one and DB two connected to charger two and battery two.

A three position switch, three ways without an "off" position shall be provided. Since both the positives and negatives of charger one and charger two distribution boards are to be switched simultaneously a 4-pole switch is required. This 4-pole switch must be “make before break “ with diodes to prevent any voltage surges or dips during the changeover as well as any possible backfeeds.

Manual change-over selector for dual charger and single distribution board.

A separate distribution board shall be equipped with a manually operated change-over selector switch which shall be arranged to facilitate the following switching:

a) Left hand position - DB connected to charger one and battery one; and

b) right hand position - DB connected to charger two and battery two.

A two position switch, two ways without an "off" position shall be provided. Since both the positives and negatives of charger one and charger two are to be switched simultaneously a 2-pole switch is required. This 2-pole switch must be "make before break " with diodes to prevent any voltage surges or dips during the changeover as well as any possible backfeeds.

The change-over selector switch shall be an air-break, on-load switch complying with the requirements of SABS 152. The switch chamber shall have a continuous load current and thermal current rating not less than 100 A at 250 V. The switch shall be rated for uninterrupted duty and for utilisation category DC - 22 in terms of SABS 152.

The switch shall be rated for an operating voltage no less than 250 V.

The wiring of the selector switch shall be as shown on the single line diagram issued with the enquiry. The switch shall be mounted at the top, in the centre of the distribution board's front panel (viewed from the front).

The selector switch shall be of the spring assisted type, shall change over by snap action and shall be arranged for independent manual operation. The switch shall preferably be of the rotating type and shall have wiping (make before break) type contacts. Plain contacts will not be acceptable.

The selector switch shall be fitted with bolted type terminals suitable for accommodating 25 mm^2 cable lugs. Terminal bolts shall be M16 minimum.

The change-over selector switch shall be fitted with a suitable and robust operating lever or handle preferably of the lever type equipped with padlocking facilities in each position. The coupling of fixing of the handle to the operating shaft shall be to approval.

Labels shall be in accordance with Clause 6.3.

6.2 Wiring, Terminals, Ferrules

Wiring shall be colour coded and ferrule marked in accordance with NRS 003-1:1994 and such ferrule marking as may be shown on schematic diagrams that may be issued with the enquiry. For identification purposes identical ferrule markers of approved type shall be fitted to both ends of each wire. Ferrule markers shall be of a durable insulating material having a reasonable glossy finish to prevent the adhesion of dirt. Ferrule markers shall be marked clearly and permanently and shall not be affected by moisture, heat or battery acid. Unless otherwise approved, ferrule markers shall be white with black lettering.

All wiring shall be taken to terminals and wires shall not be jointed or teed between terminal points. Terminals shall be of the insertion double ended pinch bar type. Terminals shall be suitable to accommodate at least two 4 mm^2 wires but not more that two wires shall be connected to an end of an insertion type terminal. Unless terminals are of the fully insulated type, suitable insulating barriers shall be provided between terminals. Terminal strips shall be suitably labelled and terminals shall be numbered to facilitate identification. All terminal strips shall have a minimum of 20% spare terminals.

6.3 Labels and Designation Plates

Labels shall preferably have black lettering on a white background but danger plates and warnings shall have red lettering on a white background.

Suitable notices warning against malpractices such as incorrect operation of equipment, or any practice which may endanger the safety of the operator or other personnel, shall be provided when and as required. Such notices shall be to the approval of the Engineer in all respects.

Letter types and sizes for all labels shall be to approval.

Sufficient blank labels of the same type and size as that fitted on the board shall be supplied with the board for those positions where spare space for future possible circuit-breakers have been called for.

In addition to a designation label for the change-over switch, the switch shall be equipped with labels corresponding to the switch positions tabulated below.

Manual change-over selector switch for dual charger and dual distribution boards :

POSITION OF SWITCH	LABEL INSCRIPTION
Left-hand	DB one and DB two connected to charger one and battery one.
Centre	DB one connected to charger one and battery one. DB two connected to charger two and battery two
Right-hand	DB one and DB two connected to charger two and battery two.

Manual change-over selector switch for dual charger and single distribution board :

POSITION OF SWITCH	LABEL INSCRIPTION
Left-hand	DB connected to charger one and battery one
Right-hand	DB connected to charger two and battery one

7. INSPECTION AND TESTING

The City Electrical Engineer or his representative shall have access to the manufacturer's premises at all reasonable times, and shall have the power to inspect and examine the materials and workmanship of the equipment during its manufacture there.

If the manufacturing of the equipment or part thereof takes place on other premises, the successful Tenderer shall obtain permission for inspection as per the foregoing paragraph.

The successful Tenderer shall give at least seven (7) days notice to the Engineer of any material being ready for testing in order that he may be present, or arrange with his representative to be present, if he so desires.

No inspection or passing by the Engineer or his representative shall relieve the Contractor from his contractual obligations or exonerate him from any of his guarantees.

8. TESTS AND TEST CERTIFICATES

8.1 Routine Tests

Tests shall be carried out to prove the operation of the alarms and to determine current drain of alarm relays.

Voltage insulation test on transformer and wiring.

Measuring of output ripple voltage.

9. MANUALS AND DRAWINGS

Refer to Part 1.4.

PART 13.3 : 110V BATTERIES & BATTERY STANDS

SPECIFICATION No: BBS09/008

CONTENTS

1. SCOPE

This Specification covers a rechargeable station storage battery composed of series connected secondary cells (accumulators) of the lead-acid type having the voltage rating(s) called for in the Schedule of Particulars and Guarantees. The Specification includes inter-cell connections, hardware and battery stand.

The size of the battery shall be calculated by the Tenderer, who shall state in detail how the figure was derived. He shall take into account the normal static load of the protection and any other devices as well as the UPS (if applicable). The battery shall be dimensioned to give satisfactory service for 8 hours supply failure.

See also Part 5.1 for further details of the battery chargers.

2. STANDARDS

The battery, and associated equipment to be supplied against this Specification shall comply fully with the requirements thereof, the particulars and guarantees stated by the Tenderer in the Schedule of Particulars and Guarantees and the relevant requirements in the latest editions of the following standard specifications:

a) SABS 1632 Vented - type lead acid cells and batteries.

3. GENERAL

The station battery is required for permanent indoor installation at an unmanned substation to provide DC power supplies for:

a) continuous and intermittent relay energizing;

b) continuous and intermittent alarm and position indication signalling;

c) intermittent operation of tripping coils and contactors;

d) intermittent operation of closing coils and contactors;

e) intermittent energizing of control circuits and interlocking circuits;

f) continuous supervision of control and protection circuits;

g) intermittent operation of motor-driven isolators and transformer tap changers;

h) operation of emergency lights;

i) stand-by duties such as emergency operation of solenoid-operated switchgear; and

j) continuous running of UPS for the MMI.

Reliability of operation and full availability on demand at any time are of the utmost importance. The battery equipment shall operate unattended between scheduled maintenance intervals over a lifetime of at least 20 years.

Provision is usually made for the battery to be installed in a separate battery room on a special stand. Particulars of the actual arrangement to be supplied under this contract is given in the Schedule of Particulars and Guarantees.

4. BATTERY

4.1 Battery Cells

Batteries shall be of the lead-acid low-maintenance type designed for use in substations over long periods. The Tenderer shall state what type of battery cell he is proposing, and what the expected life of a properly-maintained battery would be. The Tenderer shall further give details of the type of battery cell proposed.

Battery cells shall be housed in tough, transparent plastic or glass containers. The Tenderer shall state what material the housings are made of.

All cells shall be supplied complete with electrolyte in a fully-charged condition. The exterior parts of every cell shall be clean, dry and free from contamination. The supplier shall take the necessary precautions to prevent spillage of electrolyte or cell discharge during transit.

Each cell shall bear the manufacturer's name or trade-mark and the type number. In addition, every cell shall be marked permanently with an identification number for record purposes. The cells in each individual battery shall be numbered consecutively starting with No 1 at the positive end. Identification marking of cells shall be to the approval of the Engineer.

The bank of battery cells shall be earthed in the centre. The poles of the battery shall not be earthed.

4.2 Battery Voltage

Throughout the lifetime of the battery the efficiency of a discharge - recharge cycle of the battery shall not fall below the following values:

a) Ampere-hour efficiency 90%; and

b) Watt-hour efficiency 75%.

4.3 Inter-cell Connections and Terminals

Inter-cell connections shall preferably be flexible to some degree to prevent stress on cell terminals. Tenderers shall state how this is achieved.

All batteries shall be supplied complete with all necessary inter-cell connections and with the necessary main terminal connections. Tenderers shall submit their recommendations for connecting up separately-mounted batteries with their respective chargers and shall quote for the supply of such connecting up equipment.

All inter-cell connections and main terminal connections shall be of the bolted type. Inter-cell connections shall be designed for low contact resistance throughout the lifetime of the battery. Unless otherwise agreed bolts and nuts used for inter-cell connections and terminal connections shall be made of lead, cadmium-plated phosphor bronze or stainless steel, and shall be free of anti-corrosive lubricants. Only flat washers shall be used.

4.4 Battery Accessories

Each individual battery shall be supplied complete with the following accessories or as detailed in the attached schedule of Particulars and Guarantees:

a) One syringe type hydrometer with a specific gravity scale range of approximately 1,100 to 1,300;

b) one electrolyte thermometer with a range of approximately 0 ºC to 40 ºC; and

c) one cell bridging connector.

The price of the above accessories shall be included in the price of each complete battery.

5. BATTERY STAND

Battery stands shall be freestanding and be of strong, rigid and robust construction and suitable in every way for the lifetime support of the battery.

The battery cells shall be accessible from all sides, and not be mounted against a wall. It shall be possible to walk around the battery to have access to all cells.

Unless otherwise approved, battery stands shall be constructed of plastic sections. All joints, voids and crevices shall be filled properly to prevent the ingress of electrolyte.

Maximum overall length of stand (regardless of single tier) single row or (double tier) double row shall not exceed 2 327 mm.

Maximum overall height of double tier stand (excluding height of top tier batteries) not to exceed 1 250 mm.

Maximum overall width of single row stand not to exceed 400 mm.

Maximum overall width of double row stand not to exceed 850 mm.

Minimum clearance between the top of cells in bottom tier and the underside of the lowest support in tier above, shall not be less than 400 mm.

Minimum height to the top of the bottom support from floor level shall not be less than 100 mm.

Double row stands shall either be level or terraced type as called for in the Schedule of Particulars and Guarantees. In the case of terraced type stands the difference in support levels between the front and rear row shall not be less than 100 mm and shall not exceed the height of a cell. The top of the battery shall not be higher than 1 500 mm. It shall in all cases be possible to see the whole end view of each battery cell so that any sediment will be clearly visible.

6. INSPECTION AND TESTING

The City Electrical Engineer or his representative shall have access to the manufacturer's premises at all reasonable times, and shall have the power to inspect and examine the materials and workmanship of the equipment during its manufacture there.

If the manufacturing of the equipment or part thereof takes place on other premises, the successful Tenderer shall obtain permission for inspection as per the foregoing paragraph.

The successful Tenderer shall give at least seven (7) days notice to the Engineer of any material being ready for testing in order that he may be present, or arrange with his representative to be present, if he so desires.

No inspection or passing by the Engineer or his representative shall relieve the Contractor from his contractual obligations or exonerate him from any of his guarantees.

7. TESTS AND TEST CERTIFICATES

a) Tests to be certified

The equipment to be supplied shall successfully pass the following tests and/or shall be certified to have been successfully type tested in accordance with the specified requirements in the relevant test certificates:

a) Battery load test after installation;

b) capacity test;

c) suitability for floating battery operation;

d) endurance discharge cycle test;

e) charge retention test; and

f) short-circuit current test.

PART 13.4 : PILOT CABLE TERMINATION PANEL

SPECIFICATION No : PB 02/1-97

CONTENTS

1. SCOPE

This specification covers the supply and delivery of wall-mounted sheet-steel cubicles suitably fitted for the termination of pilot cables.

2. QUALITY OF MATERIAL AND WORKMANSHIP

All materials used on these cubicles shall be new, of approved quality and of the class most suitable for the intended use.

Workmanship shall be of the highest standard and shall in all respects be subject to approval by the Engineer.

3. TECHNICAL REQUIREMENTS

3.1 General

The sheet steel cubicle(s) shall be manufactured and fitted as detailed in drawing A-1507 and in accordance with the following technical requirements.

3.2 Steel Cubicle(s)

The minimum thickness of the sheet steel that the cubicle(s) are to be manufactured from is 2 mm.

Overall dimensions of the cubicles(s) shall be as follows :

a) Height - 2400 mm;

b) width - 800 mm; and

c) depth - 600 mm.

The cubicle(s) shall be provided with a front door to give access to the full area available for the equipment and to permit installation of pilot cables via the front door opening.

The door of the panel shall be left-hand opening with lift-off hinges and locking mechanism.

Suitable provision shall be made for wall mounting and fixing of the cubicle(s).

All surfaces to be painted shall be cleaned completely from rust, scale, grease or other spoil by sandblasting and/or acid pickling prior to painting.

Ferrous parts shall have an acid phosphate treatment before applying priming coasts.

The exterior and interior surfaces of the cubicles(s) shall be finished in the colour Cloud Grey - SABS 1091 - 1975, colour No F48.

The cubicle(s) shall be arranged for bottom cable entry and one opening measuring 500 mm x 80 mm shall be cut in the bottom plate, which shall then be covered with a total of five 100mm x 100mm (screwed down) removable gland plates.

3.3 Mounting Facilities in Cubicles

To facilitate the mounting of a pilot board, holes must be provided in the chassis-plate.

3.4 Pilot Cable Termination Board and Terminals

An insulated board, 10 mm Tufnol or equivalent shall be mounted inside the pilot cable termination cubicle onto the studs welded inside the rear of the cubicle, the full width and height of the internal back of the board.

The pilot board shall be fitted with the specified number of link terminal blocks (3 vertical rows), arranged in two vertical rows from the bottom upwards. The centres of the sets of terminals shall be 140 mm to both sides of the vertical centreline of the board.

The terminal blocks shall be strictly in accordance with the general requirements of the Technical Specification, using Klippon type SAKR terminal blocks.

Three vertical sections of 50 mm x 50 mm surface trunking shall be mounted from gland plate level to 110 mm from the top of the cubicle on each side and in the centre of the terminal blocks onto the Tufnol board. The surface trunking shall be of the ribbed (slotted) plastic type with clip open covers.

3.5 Earthing

A bare copper earth bar, of minimum dimensions 30 mm x 3,5 mm and extending the width of the cubicle, shall be provided in a suitable position in the cubicle near to the gland plate. The earth bar shall be bolted to the cubicle frame. Unless otherwise approved, all earthing connections to the earth bar shall be bolted connections.

An M12 bolted connection shall be provided for connecting up to the station earth.

3.6 Labelling

Labels shall be made of durable materials to approval. Metal labels where used shall be engraved or etched. Labels made of Trafolite or other similar materials shall have engraved lettering. Dymotape or similar types of labels shall not be used. All labels shall be fixed mechanically.

PART 14.1: BUILDING & CIVIL WORKS

SPECIFICATION No: CIV/1-98/Z

CONTENTS

1. SCOPE

A separate standard specification for Municipal Civil Engineering Works second eddition 1991 is part of this specification.

Tenderers must ensure that they are in possession of such a Specification.

2. GENERAL

All building works form an integral part of this contract, including the supply, cartage and off-loading of all materials, as well as subsequent clean up of the site.

Contractors will be permitted to use Sub-Contractors specialised in this field for the execution of this part of the works. A list of proposed sub-contractors shall be submitted with the Tender. The final list shall be approved by the Engineer.

The Builder employed for construction of the switch room, shall have demonstrated his ability in the field of substation buildings in addition to domestic buildings.

2.1 Extension of Time due to Abnormal Rainfall

Extension of time due to abnormal rainfall shall be determined by means of Method 1, if rainfall records and/or values derived from rainfall records are supplied in TABLE 1 : below.

2.1.1 Method 1 : Rainfall Formula Method

The rainfall records and/or values derived from rainfall records (TABLE 1:), from a suitable rainfall station near the Site, shall be considered suitable for the determination of extension of time due to abnormal rainfall in accordance with this method.

Extension of time arising from abnormal rainfall, shall be calculated separately for each calender month or part thereof, for the full period of completion of the Contract, including any extension thereof, in accordance with the rainfall formula given below.:

V = (Nw - Nn) + (Rw - Rn) / x

If V is negative and its absolute value exceeds Nn, then V shall be taken as equal to minus Nn.

If V is positive and greater than the number of calender days in the calender month under consideration, V shall be taken as equal to the number of calender days in the relevant calender month.

The symbols shall have the following meanings:

V	=	extension of time in calendar days in respect of the calendar month under consideration.
Nw mm or	=	actual number of days during the calendar month on which a rainfall of Y more has been recorded.
Rw	=	actual rainfall in mm for the calendar month under consideration.
Nn a	=	average number of days as derived from existing rainfall records, on which rainfall of Y mm or more has been recorded for the calendar month.
Rn rainfall	=	average rainfall in mm for the calendar month, as derived from existing records.
X	=	20, unless otherwise provided.
Y	=	10, unless otherwise provided.

The total extension of time shall be the algebraic sum or the monthly totals for the period under consideration. However, if the grand total is negative, the time for completion shall not be reduced on account of abnormal rainfall. Extension of time for parts of a month shall be calculated by pro rata values of Nn and Rn being used.

The factor (Nw - Nn) shall be considered to represent a fair allowance for variations from the average number of days during which rainfall exceeds Y mm and wet conditions prevented or disrupted work.

The factor (Rw - Rn) / x shall be considered to represent a fair allowance for variations from the average number of days when wet conditions further to that allowed for by the factor (Nw - Nn), prevented or disrupted work during the calendar moth.

Accurate rain gaugings shall be taken at a suitable point on Site and the Contractor shall, at his own expense, take all necessary precautions to ensure that the rain gauges cannot be interfered with.

This formula does not take into account further or concurrent delays which could be caused by other abnormal climatic conditions such as floods which have to be determined separately.

TABLE 1 : Rainfall data available :

Rainfall Station : De Wildt

MONTH	Rn (mm)	Nn (days)
January	88.7	3.3
February	102.1	3.3
March	107	3.5
April	40.5	1.1
May	19.3	0.4
June	5.3	0.1
July	1.5	0.1
August	1.9	0.1
September	19.1	0.6
October	60.3	2
November	88.1	3
December	90.9	3.7
Yearly Average	52.1	1.8

2.2 Water Supply

No provision of site domestic water and fire hydrant services will be made. At the site the Contractor will supply and erect 2500 litre water tank with a 6 meter stand.

2.3 Domestic Main Valve

A 20 mm main valve shall be located externally at 600 mm above ground level on the wall of the building at each site. It shall be a cast brass full way to SABS 776, Class 6 with non rising spindle and female ends.

3. STORM WATER

The design and installation of a storm water and erosion protection scheme form part of this.

4. MISCELLANEOUS ITEMS

4.1 Danger notices

Supply and fix in position to be pointed out on side, the following notices required in terms of the Regulations to the Occupational Health and Safety Act, 1993

a) Notice prohibiting unauthorised persons for entering the substation.

b) Notice prohibiting any unauthorised persons from handling or interfering with electrical apparatus;

c) Notice containing directions as to procedure in case of fire;

d) Notice containing directions as to resuscitation of persons suffering from the effects of electric shocks.

The above notice shall be combined and applied by painting to a single steel sheet.

4.2 Fire Extinguisher

Supply and secure in position, three 9 kg Dry Chemical Power type fire extinguishers, complete with polyurethane treated meranti base boards and all fittings at each of the three sites.

These units shall comply with SABS 810 : 197

5. SOIL POISONING

Allow for soil poisoning over the whole site before the 100 mm stone cover is applied having first removed all weeds, grasses and roots of whatever undergrowth exists on the site, all in accordance with SABS 0124. Soil insecticides shall comply with SABS 1164 and 1165.

6. CONCRETE

6.1 Trenches (In Switchyard)

All cable trenches shall be constructed as shown on the drawings.

6.2 Equipment Foundations

Transformer and NEC plinths shall be cast in situ to dimensions stated on the relevant drawing.

Foundations for equipment supporting structures, line termination and support structures shall be located by the Contractor to suit his equipment. The drawings only show typical arrangement for measuring purposes. All foundations (other than transformer and NEC plinths) shall be constructed with the top surface 75 mm clear of the stone layer with all edges bevelled to 40 mm. All equipment foundations throughout the site shall finish on the same level on any one platform.

The exposed surfaces of all cast concrete plinths shall be smooth and without any exposed aggregate.

The design of foundations for equipment and supporting structures shall be undertaken by a Professional Engineer whose services shall be retained by the Contractor at his own expense. The calculations shall be made available to the Engineer and approved by him before any work is done on site.

7. EXTERNAL WORKS

All external works of a civil nature are included in this contract, including the supply, cartage and off-loading of all materials.

Contractors will be permitted to use Sub-Contractors specialized in this field for the execution of this work.

Only experienced Sub-Contractors will be permitted to undertake this work. The quality of all civil works shall conform to accepted good practice and shall follow the Code of Practice applicable, and will be subject to inspection by the Engineer.

The Engineer will have the right to refuse the employment by the Contractor of any Sub-Contractor who, in his own opinion is incompetent or inexperienced for the kind of work he is called upon to perform.

8. SITE CLEARANCE

Remove all grass, weeds, undergrowth of whatever nature, level all humps and knolls, fill all hollows, remove all boulders, stones and other obstructive protrusions to form a flat area across the whole site, though not necessarily horizontal.

Throughout the contract period, the site shall be kept free of weeds and grass. On completion of the site works when the contract is at an end, the whole area shall be poisoned and thereafter the 100 mm stone cover applied.

9. FENCING

9.1 Perimeter Fence and Gates

Construction of the entire perimeter fence and gates, as per drawings (C-1007, C-1008), forms part of this contract, and shall be to the Engineers approval.

The fence and gates shall be erected as soon as the grading operations are complete, and shall be used to safeguard the site against entry of unauthorized persons.

Security of the site throughout the contract period is the Contractor's responsibility. To this end it would be in the Contractor's best interest to have an electricity supply made available as early as possible for security lighting. The cost will be for the Contractor's account.

The early erection of the fencing will not relieve the Contractor of the guarantee on the fencing which will only commence when first delivery is taken of the whole installation.

PART 14.2 : YARD STONE

SPECIFICATION NO : YS09/01

CONTENTS

1. SCOPE

This specification covers the requirements for the stone surfacing of the yard.

2. INTERPRETATIONS

2.1 Supporting Specifications

The stone surfacing shall be con`structed in accordance with:

a) SABS 1083-1976. Table 7 single sized crushed stone for Roads.
See table on page 2

b) This specification

3. MATERIALS

3.1 Stone

Stone shall be clean, hard, durable and sound crushed stone of 26,5mm nominal size, approved by the Project Manager and details of the stone being offered shall be submitted timeously. The stone shall be of norite, granite, quartzite, dolomite or any other approved igneous rock. Sandstone or furnace slag will not be acceptable

Samples of the stone shall be submitted in good time to the Engineer for approval and no stone, other than the samples, shall be delivered to the site before the Engineer's written approval has been obtained.

3.2 Weedkiller

Weedkiller shall be in accordance with the terms of clause 5.3.

4. CONTRACTOR'S EQUIPMENT

The Contractor shall ensure the provision of suitable construction equipment for the construction of the stone surfacing in compliance with the requirements of the specification.

5. CONSTRUCTION

5.1 Surface Preparation

After the completion of the earthworks and just before the application of the stone surfacing the Contractor shall clear the area of all vegetable growth and ensure that the underlying wearing course layer is compacted to 93% Mod AASHTO density.

5.2 Laying of Stone

The stone shall be spread over the compacted surface of the yard, levelled and lightly rolled to a finished thickness of 100 mm or as otherwise specified on the drawings.

5.3 Weed Killer

A granular or liquid weedkiller suitable for the soil to be treated, the climate and the general site conditions shall be applied before or after the spreading of the stone surface.

Choice and application of the weedkiller to be used shall be carried out only by a pest control operator with a current registration certificate covering the field of weed control, issued in terms of Government Notice R1 449 dated 1 July 1983.

The application of weedkiller shall be guaranteed by the Contractor to provide a 95% effective control of growth of all types of vegetation for a period of 2 years from the date of application.

Any growth, in excess of 5% of the area treated, which occurs within the guarantee period shall be removed and re-treated at the Contractor's expense.

The Contractor shall exercise due care while applying the weedkiller to ensure that vegetation, animals or persons on areas adjoining the site are not affected by movement of the weedkiller through wind, rain or transport by water. He shall be responsible for any claim which may be made by adjoining property owners for damages resulting from his activities.

6. TOLERANCES

The average finished thickness of the stone layer shall be at least 100 mm or as otherwise specified on the drawings, and nowhere shall the finished thickness be less than 15 mm less than the specified average finished thickness.

7. TESTING

Not applicable.

8. MEASUREMENT AND PAYMENT

The rates as scheduled in the Bill of Quantities shall cover the cost of all activities, labour, materials and testing required for the provision of the relative item in accordance with the drawings and specification.

SABS 1083-1976

TABLE 7- SINGLE-SIZED CRUSHED STONE FOR ROADS

1	2	3	**4**	5	6	7	8	9
Property	Requirements - Nominal size of stone, mm							
Grading, %(m/m) of material passing Sieves of nominal aperturesize, mm	53,0	37,5	**26,5**	19,0	13,2	9,5	6,7	4,75
75.0	100							
53.0	85-100	100						
37.5	0-30	85-100	**100**					
26.5	0-5	0-30	**85-100**	100				
19.0		0-5	**0-30**	85-100	100			
16.0				0-30	100			
13.2			**0-5**		85-100	100		
9.5				0-5	0-30	85-100	100	
6.7					0-5	0-30	85-100	100
4.75						0-5	0-30	85-100
3.35							0-5	0-30
2.36								0-5

PART 15.1 : ELECTRICAL INSTALLATION OF SUBSTATION BUILDING, YARD LIGHTNING & LIGHTNING PROTECTION

SPECIFICATION No : EI.01/0-97

CONTENTS

1. SCOPE

This specification covers the supply, delivery, installation, testing, commissioning, handing over and a limited period of maintenance of the hereunder mentioned, in accordance with the specification and schedules of particulars and guarantees.

The complete conduit, wiring and accessories for the lighting and small power installation as indicated on the drawings.

The semi-recessed distribution board.

The lighting luminaries complete with lamps as specified.

The extractor fan.

Yard lighting.

Lightning Protection.

2. APPLICABLE STANDARDS

The complete electrical installation in the Pretoria City Council's substation buildings shall be carried out in accordance with the SABS Code of Practice for the Wiring of Premises number 0142 as amended and the requirements of the specification and shall be to the complete satisfaction of the Supply Authority and the City Council's Electrical Inspector.

The arrangement of supply authorities tests and any financial implications thereto shall be the responsibility of the electrical Sub-Contractor.

Due allowance shall be deemed to have been made in the price Schedules for these costs.

3. BUILDERS WORK

The main building Contractor shall be responsible for the supply and installation of all sleeve pipes required. The "chasing in" of conduits, droppers, etc., shall be the responsibility of the electrical Contractor. The builder shall provide an opening for the battery room extractor fan of 400 mm wide by 400 mm high.

4. CONDUIT AND CONDUIT ACCESSORIES

Conduits used in the execution of this contract shall be of the steel screwed or PVC type, concealed in concrete and brickwork. Conduit and Conduit Accessories shall comply with the relevant SABS Standards.

5. CONDUCTORS AND CABLES

Conductors and cables shall be of the stranded-copper PVC insulated type in accordance with SABS 150 as amended.

The wiring shall be installed using the "Looping In" system. The use of connectors, etc, in conduit boxes will not be accepted.

6. LIGHTING OUTLET POINTS AND FITTINGS

Lighting outlet points shall be installed in the positions indicated on the drawings.

Lighting circuits shall be wired by means of 1,5 mm PVC insulated conductors in 20 mm dia conduit, unless otherwise indicated or approved.

Lighting switches shall be equal and similar to those manufactured by either "MK" or "Litemaster" masterlite range. They shall be suitable for fitting into standard conduit boxes, and shall be fitted with piano type toggles and ivory steel cover plates.

The electrical connection into the totally enclosed surface mounted flameproof fluorescent luminaire in the battery room shall be from the end of the luminaire only. This connection shall comprise three PVC conductors, live, neutral and earth, contained 20 mm corrosion resistant flexible conduit.

No switches shall be allowed in the battery room, but shall be mounted outside the door to the satisfaction of the Engineer.

Luminaires shall be similar or of equal and approved type and manufactured to those specified and shall include all lamps and fluorescent tubes. Incandescent luminaires shall have ES type lamp holders unless otherwise specified. Ballasts shall carry the SABS mark. Luminaires shall be fixed to ceilings and walls by approved methods. Fluorescent lamps shall be cool white in colour. The complete luminaires shall be suitable for operation at a voltage of 240 V.

7. DESCRIPTION OF LUMINAIRES

Type A : Two tube, 65 watt, fluorescent.

The surface mounted double tube industrial type luminaire shall be complete with two 65 watt lamps, switch start control gear, internal wiring and positive type lamp holders.

Type B : Two tube, 40 watt, Class 1, Division 1, fluorescent.

The luminaire shall be manufactured to comply with the SABS specification No 1031-1976 (Class 1, Division 1) for use in explosive gas atmospheres. In addition to the statutory requirements the luminaire shall incorporate a single central locking bolt to open the bowl with one single grasp.

Type C : Incandescent, 100 watt, ES, ceiling luminaire.

The ceiling mounted totally enclosed type luminaire shall be comprise a black gallery equipped with a 100 watt ES incandescent lamp with an opal polycarbonate type diffuser. All internal wiring shall be insulated by heat resisting silicone insulation with fibreglass sleeving.

Type D : Bulkhead fitting.

The fitting shall be of the bulkhead polycarbonate bowl, dust-proof and watertight type complete with a 22 Watt, high freq. flourescent Lascon Britelite 11 or equivalent. The fitting shall be suitable for ceiling or wall mounting in either the vertical or horizontal position. All internal wiring shall be insulated by heat resisting silicone insulation with fibreglass sleeving.

8. SWITCHED SOCKET OUTLET POINTS

Flush mounted, three pin, 16 ampere rated, switch socket outlet points shall be installed in the positions indicated on the drawings.

Switched socket outlet circuits shall be wired by means of 2,5 mm^2 PVC insulated conductors and a 2,5 mm^2 PVC copper earth conductor in 20 mm diameter conduit. Switch socket outlet points mounted directly in walls shall be suitable for mounting in 100 mm x 100 mm x 50 mm deep standard plug boxes. They shall be mounted above the work tops of desks, counters and work benches and at a height of 1 400mm above finished floor level.

Switch socket outlet points shall be rated for 16 amperes at 240 volts. They shall be fitted with piano type toggles and ivory steel cover plates and shall be equal and similar to those manufactured by either "MK" or "Litemaster" masterlite range.

9. EXTRACTOR FAN

The Contractor shall supply and install a 240 mm diameter built-in wall extractor fan in the battery room.

The fan shall be explosion proof and equal to the "Woods G.P." type. It shall be completed with diaphragm plate, wire guard and louver shutters to fit the 400 x 400 mm opening, and shall be to approval.

The fan shall be of the continuous running type. The connection into the fan shall be by 3 - 1,5 mm^2 PVC conductors in a 20 mm dia. weather proof flexible conduit from dome lid fitted into a flush mounted circular conduit box directly above the fan.

10. EARTHING

The Contractor shall be responsible for the earthing of all outlet and switch points, steel ceilings, roof, roof gutters and down pipes where necessary to comply with the requirements of the Code of Practise.

11. INCOMING POWER SUPPLY

The incoming power supply, main switchboard, and the power cables between the main switchboard and the small power and lighting distribution boards shall be supplied and installed under a separate main installation contract.

12. EARTH LEAKAGE UNITS

Earth leakage units shall comply with SABS 767 of 1964 as amended. Unless shown otherwise on drawings, the moulded case units shall have a fixed sensitivity of 30 mA and be complete with integral test button.

13. MINIATURE CIRCUIT-BREAKERS

Where miniature circuit-breakers are specified, these shall be fully in accordance with SABS 156-1964 for lighting, heating and domestic purposes.

14. DISTRIBUTION BOARDS

All boards shall be commercially manufactured and assembled in metal enclosures arranged for semi-flush mounting on walls. Each wall mounted board shall be mounted at a height of 1,5 m measured from the floor to the bottom edge of the enclosure, unless otherwise directed elsewhere in the documents. All metal enclosures shall be fabricated from sheet steel having an adequate gauge to ensure a rigid, robust construction, free from distortion. Each enclosure shall be of adequate size to accommodate all components necessary or specified elsewhere in the documents plus the required spare ways and spare space. The interior of all enclosures shall be white baked and all external surfaces grey hammertone baked enamel.

Each enclosure shall be complete with a sheet steel front panel. The front panel shall :

a) Be firmly fixed by fine threaded or non-pointed self tapping cheese-head screws on all edges to the enclosure but it shall readily removable by the use of a screwdriver. Each fine threaded screw shall be screwed into a minimum thickness of 3 mm of a metal or where self tapping screws are used, these shall only be used in conjunction with self tapping clip-in spring nuts;

b) be neatly cut to permit switch and MCB operating toggles to protrude through, meters to be read and other gear where fitted to be accessible. The panel shall conceal all cable ends, conductors, connections, contacts, busbars and equipment shall be mounted on the front panel;

c) be cut for all spare spaces and these spare apertures shall be neatly and adequately blanked off;

d) be closely fitted to the enclosure and all apertures shall be closely fitted to the equipment mounted behind to minimise ingress of vermin and dust; and

e) be finished to match the outside of the enclosures.

Each enclosure shall be designed to have 25% spare MCB space available after all necessary or specified components are assembled within.

Each enclosure shall be installed with its sides vertical, top and bottom horizontal and square, on or within the wall. All conduits to and from the tray shall be securely and effectively bonded to the enclosure, each using a male bush inside the enclosure, screwed into a coupling fitted to the conduit outside the enclosure. The male bush shall be properly tightened using a proper tool.

In any event pliers, hammers and chisels shall not be used to tighten the male bushes. Where necessary, in the case of a metal conduit, to ensure a properly tightened joint with good earth continuity, the sub-contractor shall fit a steel lock-nut on the conduit before the coupling and shall screw the lock-nut into the coupling. Where a roof space exists above a flush mounted distribution board, spare conduits shall be installed for each spare space into an accessible position in the roof space blanked off.

Each distribution board shall :

a) Be designed for miniature circuit-breakers, all mounted within the enclosure. In any one board or number of boards on one site all miniature circuit-breakers shall be of the same manufacture; and

b) be internally wired with conductors from the main switch to the busbars having the same current rating as the conductors feeding the distribution board. Conductors from the busbars to outgoing protection shall be :

   i. Rated to the full value of the outgoing protection, and

   ii. rated not less than half the rating of the main switch unless otherwise permitted in writing by the Engineer;

   iii. be provided with phase, neutral and earth busbars installed behind the front panel. All phase and neutral bars rated over 60 ampere and all busbars in 3-phase distribution boards shall be of flat tinned copper rigidly mounted and adequately supported on insulators with adequate spacing and clearance. Earth bars shall be mounted directly on to the back of the enclosure. Each connection to or from the a phase or neutral bar shall have its own brass fixing screws, washer and nut, and where a round insulated solid conductor is used, the busbar end of the conductors shall be connected by two set screws or an approved sweating lug with brass screws, washers and nuts;

   iv. be provided with a substantial earth stud on the bottom of the enclosure. The earth stud shall pass through and be fixed by means of nuts and washers on both sides of the enclosure with nuts and lock-nuts provided inside and outside. An adequately rated bare earth conductor shall connect the earth stud to the earth bar inside the enclosure; and

   v. be complete with all miniature circuit-breakers arranged in rows, mounted on rigid metal bases. Each miniature circuit-breaker shall be separately and readily removable from the board without disturbing adjacent miniature circuit-breakers, busbars, or other equipment.

Non-automatic or isolating switches in a board shall be mounted within the enclosure on a rigid metal base, with operating handles protruding through the front panel, preferably matching the miniature circuit-breakers.

Each way in the distribution board shall be labelled using 8 mm letters engraved on trafolite or similar approved material, white on black background, by numbering each MCB. A permanent index card shall be fixed on the inside of the front door or adjacent to the board behind a clear perspex or similar approved sheet so that it can be easily read without having to be removed. The index card shall be of good quality white cardboard and of adequate size for recording full details of each way.

15. LABELS

Labels on the fascia panel shall be fixed below each MCB, these shall be secured by means of screws. Designation, source of supply and warning labels shall be fitted externally to distribution board by means of screws.

Labels fixed to distribution boards by means of glue are not acceptable.

Labels shall be to the Engineer's approval.

16. DRAWINGS AND TECHNICAL DETAIL

The drawings indicating the proposed lighting and small power installation shall form part of this specification.

Details of drawings and technical details to be provided by the Tenderers and successful Tenderer are as follows:

a) General arrangement of distribution boards; and

b) technical details of luminaires offered.

17. MANUFACTURER'S WORKS

The Engineer reserves the right to inspect, test of observe testing of all items of plant and equipment constituting the contract at the manufacturer's works.

18. TESTS

Insulation resistance tests shall be carried out as detailed in the wiring code, the testing pressure being 500 volts. The result of these testes shall be submitted to the Engineer in duplicate.

The continuity of each conduit run or earth wire shall be tested between the distribution switch board and the most distant point of the run.

A test shall be made to verify that all non-linked single pole switches have are fitted in the phase conductors.

A test to determine the sensitivity of earth leakage units shall be carried out.

Verifying tests will be carried out at the site by the Engineer after erection is completed.

19. MAINTENANCE PERIOD

The maintenance period shall be three months commencing from the date on which the whole of the works shall be deemed to be taken over from the Contractor (first delivery).

20. GENERAL

All outlet boxes up to 100 x 100 mm are measured as one item regardless of the number of entries.

Conduit boxes shall always include the fixing to the conduit with locknuts and bushes as specified.

Industrial switch and plug units shall include the fixing to conduit as specified.

Outlet boxes shall be without covers and draw boxes shall include covers, screws, etc.

Light switches, switch plugs, etc. shall include screws, cover plates and other equipment specified.

All fittings and accessories shall always include the connections thereto. All lighting luminaires shall be complete with lamps and tubes.

21. FLOODLIGHTING

Supply 400 W, high pressure sodium floodlights equipped with 250 W miniature Tungsten

Halogen lamp as auxiliary light source, and mount three on each of the lightning protection poles, in the locations shown on the drawings.

The floodlighting luminaires shall be fed from the photocell controlled contactor in DB.LV by means of 4,0 mm² 4-core PVC.PVC.SWA.PVC cable, run via the control cable ducts and underground trenches. The floodlights shall be LASCON type L14 -ST 400 HPS/AL 250 or approved equal.

22. PHOTOCELL

A photocell switch unit shall be mounted on a suitable bracket on the face of the switch room building, and shall be wired to DB LV by means of 1,5 mm PVC-insulated conductors in 20 mm conduit, to control exterior lighting as per circuit shown.

The unit shall consist of a photocell, thermal driving mechanism and single pole switch, with a separate by-pass single pole switch.

The outer casing shall be of vandal-proof material and weather-proof, and not subject to deterioration due to ultra-violet radiation.

The unit shall incorporate a plug-in base.

Switch-on shall occur at approximately 54 lux, and switch-off at 108 lux. These levels shall be adjustable. The sensitivity shall be independent of voltage fluctuations.

A built-in time delay of at least 15 seconds shall render the unit insensitive to light impulses of short duration.

Photocell units shall be equal and similar to M&G or GRÄSSLIN type units.

23. WELDING OUTLET

Supply and install a 63A, 4 pole and earth outdoor switch socket constructed from moulded plastic material, as " Marechal " manufacture, complete with matching plug top, and connect to DB.LV by means of 16 mm 4-core PVC.PVC.SWA.PVC copper cable.

24. SUBSTATION EARTH BARS

Supply and fit six substation earth bars, of sufficient length to accommodate the number of earthing conductors to be connected allowing only one connection per bolt.

Bolts to be M10 cadmium-plated.

Earth bars to be of 50 mm x 3 mm minimum cross-section, securely fixed to the cable trench walls by means of spacers and concrete anchors, allowing a space of at least 40 mm behind the bar.

25. NEUTRAL POINT EARTHING: 400V SYSTEM

Interconnect the following points by means of 70 mm single bare copper conductor:

a)	Aux. Transformer neutral terminal	:	Transformer tank;
b)	Aux. Transformer tank	:	Substation earth bar; and
c)	DB LV earth bar	:	Substation earth bar.

26. DC SUPPLY UNITS : EARTHING

Connect the two DC supply control units to the substation earth bar by means of 70 mm bare copper conductors.

27. LIGHTING PROTECTION MASTS

27.1 Foundations

The foundations shall be designed and constructed in accordance with the relevant specification, taking all requirements for stability as set out in this specification, into account.

27.2 Construction of Masts

Each mast shall be constructed to form tapering totally enclosed column, as slender as possible, taking structural design requirements into account.

Masts shall be installed at the positions as indicated on the drawings.

The masts shall have an appropriate height above the foundations.

The structural design shall comply in all respects with SABS Standard Building Regulations, and, in particular, with following SABS Codes of Practice:

SABS 0160- 1980: General procedures and loadings to be adopted for the design of buildings.

SABS 0162 - 1980: The structural use of steelwork

The appropriate maximum wind speed to be used for design purposes shall be selected by reference to SABS 0160.

Tenders shall contain full particulars of the structural design of the mast, which particulars shall bear the signature of a competent registered Professional Engineer taking responsibility for the design.

Free standing lightning structures shall be composed of tubular sections wherein each section is locked into its mating section by means of a drive fit, the whole to provide a rigid suitable structure.

Unless otherwise approved, the mast shall be designed with minimum safety factors of 2.5.

The mast shall be of high tensile steel to SAE/AISI 950X specification to a minimum tensile strength of 500 MPa.

Each completed section is to be hot-dipped galvanised after fabrication including all jointing pieces, flanges and nuts and bolts.

The last 3 m of the specified height may be a tube of minimum outside diameter of 50 mm.

The largest dimension at the base shall not exceed 1 metre.

The use of incompatible materials without satisfactory separation will not be acceptable.

Where the height of the mast exceeds 20 metres it shall be fitted with a ladder and cage which shall comply with the OHAS Act of 1994.

Approved means shall be provided for plumbing the mast after erection to compensate for any ground settlement.

Any condensate inside the pole shall be adequately drained at the base and no pockets shall exist where water could accumulate.

Adequate provision shall be made for earthing of this mast. At least two separate earth connections of 150 mm² copper section shall be made to the main earth mesh.

The cone of protection affordable by a mast shall be determined by assuming a protective angle of 30° (unless otherwise approved) and the area between two masts shall be treated according to the South African Bureau of Standards Code of Practice (SABS 03 - 1985: The protection of structures against lightning).

Code of Practice (SABS 03-1985: The protection of structures against lighting).

27.3 Quality Management System

The manufacturer will be required to apply an appropriate Quality Management System at the design, manufacture, and installation stages of the high masts.

The procedures as laid down in SABS ISO 9000 *Quality Systems*, will be used as a basis for evaluation of the manufacturer's Quality Management System.

Should the manufacturer's system be found to fall short of the requirements as set out in the SABS Code, the masts may be rejected.

27.4 Site Assembly

If masts are not delivered to the site as complete pre-manufactured units, but in parts to be assembled on site, the tender must contain full and detailed information as to the method of site assembly and structural stability of such assembled masts. The acceptability of site-assembled masts will be at the sole discretion of the Engineer.

27.5 Design Parameters

Masts shall be adequately designed to withstand the static and dynamic stresses imposed by the mast itself together with all luminaires and ancillary equipment fitted, under the wind loading conditions as selected from SABS 0160. The maximum permissible deflection at the top of the mast when subject to the above speed shall not exceed 2,5 % of the height of the mast above the base plate. The mast design shall be such that wind induced oscillations are minimised.

In addition to the requirements of the above clause, the design of the masts shall be adequate to resist, during raising and lowering and in the horizontal position, the wind forces specified in the above clause from the worst direction, as well as self-weight including luminaires and any inertial effects due to sudden stoppage.

Particular attention shall be paid to slip joints of site assembled masts, to ensure that slip joints do not show the slightest sign of movement after simulation of the conditions set out as above. A sample mast, selected at random by the Engineer from the first batch to be delivered, may be subjected to such tests at the manufacturer's works before delivery of any mast is effected.

27.6 Mounting

The masts shall be designed to accommodate a hinge connecting the mast shaft to a 1,4 m long foundation stub, which stub shall be imbedded into the reinforced concrete foundation.

The mast shaft and foundation stub shall have a flange to which the hinge is welded. Flanges shall be free from laminations.

Supplementary gussets shall be provided.

Two locking bolts with washer, nuts and locknuts, with standard SABS metric threads, all hot dip galvanised, shall be provided.

27.7 Provision for Floodlight Mounting

A bracket suitable for bolting on of the floodlights with a weather shielded 30 mm diameter cable access hole, shall be provided at a suitable height above the foundation level.

Refer to the layout drawings for the location of the floodlight with respect to the mast lowering direction.

27.8 Seal

The top of the mast shall be effectively sealed against the ingress of moisture.

27.9 Corrosion Proofing

All masts and associated ferrous parts shall be hot dip galvanised to SABS 763 Type of article

A.

The mass of galvanised coating shall be determined in accordance with the non-destructive method under Clause 6.3 of the above SABS specification.

No welding, drilling of holes, etc., that would expose the under-lying steel, shall be carried out after galvanising.

27.10 Cable Access

Provision shall be made for underground cable entry into the mast foundation stub, and through the mast shaft to the luminaire via a weather-protected 30 mm diameter hole below the luminaire mounting bracket.

27.11 Earthing

The mast shaft shall be earthed directly to an earthing peg by means of 70 mm flexible copper conductor connected directly to the moving part of the mast, routed via the cable access duct. This conductor shall be looped within the mast base to eliminate strain on it when the mast is lowered.

27.12 Cradle

A cradle shall be provided for each mast lowered down towards the substation building as protection for the fence running across the front of the transformers. The cradle shall be provided complete with foundation.

27.13 Raising & Lowering Mechanism

One raising and lowering device, whether electrical, hydraulic or mechanical, shall be provided for the masts on the site.

If the masts offered are not the hinge down type, but have a light fitting cradle which is lowered and raised for maintenance of the light fittings, this is quite acceptable. In this instance the raising and lowering device shall be self contained within the base of the mast.

27.14 Alternative Raising and Lowering Mechanism

Tenders may offer balanced scissors masts combined with detachable lightning arrestor head as an alternative to the mast and winch system specified above. Suitable cradles must also then be provided for the mast to rest on when in the lowered position. Other parameters remain unchanged.

28. PROTECTION OF BUILDING AGAINST LIGHTNING

Lightning protection bonding shall be provided in accordance with SABS.

PART 16.1 : 132KV STEEL LATTICE GANTRIES

SPECIFICATION No : GS.1/0-97

CONTENTS

1. GENERAL

These supporting structures shall be of the fully galvanised steel lattice type.

2. COMPLIANCE WITH THE SOUTH AFRICAN OCCUPATIONAL HEALTH AND SAFETY ACT OF 1983 (AS AMENDED)

The Contractor shall be responsible to comply in all respects with the requirements of the above Act with regard to supporting structure construction and site work.

No extra payment will be considered for any provision the Contractor may have to make to comply with the Act as all such costs will be taken as having been provided for in the scheduled prices.

The Engineer shall have the power to instruct the Contractor to alter, replace or otherwise provide for any item which is necessary to comply with the Act.

3. QUALITY OF MATERIAL AND WORKMANSHIP

The structures shall be manufactured and constructed to the highest standards of workmanship and all materials used under this Contract shall be new and of approved qualities and of the class most suitable for working under the conditions specified, and shall withstand the variations of temperature and atmos-pheric conditions arising under working conditions without distortion or deterioration or the setting up of undue stresses in any part, such as to affect the efficiency, suitability and reliability of the installation.

Workmanship shall be of the highest standard and shall in all respects be subject to approval by the Engineer.

Execution of the work shall incorporate every reasonable precaution and provision for the safety of all those concerned.

4. STEELWORK

Where applicable all structural members shall be standard metricated section mild steel.

All members shall where applicable be of rolled steel sections. All such members shall be cut to jig and all bolt holes shall be drilled or puched to jig prior to galvanising.

All structures shall be provided with such holes, bolts and fittings as may be necessary to accommodate insulators and other apparatus and to secure the structures to their respective foundations.

No bolt holes shall be more than 1,5 mm larger than the corresponding bolt diameter and drifting and reaming of holes on site after galvanising will not be allowed.

All bolts, nuts and other fittings shall be hot dip galvanised unless otherwise approved and all bolts shall as far as conveniently possible, be fitted with the bolt head on the outer face of any structure, rather than the nut. The minimum diameter of bolts used to fix members shall be:

a) Stressed members .... 16 mm; and

b) bracing members .... 12 mm.

The length of bolts shall be such that when fitted the maximum projection through the nut shall be 15 mm and the minimum 6 mm. Under no circumstances shall the screwed portion of any bolt fall within the shearing plane between members.

The centres of all bolt holes in plate members shall not be less than one bolt diameter from the edge of such a member.

Proper precautions shall be taken to ensure that structures are not strained or damaged in any way during transport or erection of the structures.

Care shall be taken in the design to allow for any additional vertical loads to which the structure may normally be subjected during erection of any equipment.

5. EARTHING

A hole to clear a 16 mm diameter bolt, drilled approximately 200 mm above the foundation, to facilitate earthing of the structure, shall be provided on every column of each structure.

PART 17.1 : OPTICAL FIBRE BASED TELEPROTECTION & COMMUNICATION EQUIPMENT

SPECIFICATION No: COM/0-98

CONTENTS

1. SCOPE

This chapter specifies the requirements for communications equipment with regard to the project, which includes dedicated communications equipment for protection signalling purposes and dedicated equipment for voice and data communications.

To render a sufficient communications service to the Metering-, Protection-, and Control Divisions of Pretoria Electricity, adequate communication links have to be established with equipment and infrastructure. The equipment will be the optical fibre terminal equipment and the infrastructure the optical fibre cables installed between Buffel and Soshanguve substation on the power lines. The services commonly rendered are the following :

1.1 Protection System Communications

Installed on request exclusively for the use of protection relays to communicate with each other for sending 1st, 2nd or 3rd stage tripping and ARC blocking signals. This is a specialised application supplied on request of the Protection Division.

1.2 Data Communications

Used to transport data from the Quality of Supply and Tariff Metering, Remote Control, SCADA and Fault Recorders to the Control Centre or centralised office sites. Channels are configured as point-to-point or point-to-multipoint, depending on the equipment capabilities and requirements.

1.3 Voice Frequency Communications

Telephone services are essential for verbal communications with the Control Centre during switching operations. Service personnel also need to phone the office for advice or information when locating faults. The use of voice frequency modems is very limited, but serves as a temporary means for data communications.

Clause 4 will cover the technical and general requirements for the establishing of a teleprotection service to the Protection Division of Pretoria Electricity. Clause 5 covers all general and technical specifications for a reliable voice and data communications service for several users within Pretoria Electricity.

2. DEFINITIONS

Protection System Communications : A dedicated set of communications infrastructure for protection relays to exchange their protection signals on.

Data Communications : Non-verbal digital data transmission for the purpose of monitoring conditions of indicators and remotely measure variables at the control centre and for transporting control signals from the control centre to the remote substations.

Voice Frequency Communications : Verbal or data communications using the voice frequency band. Verbal communications provided by means of extending the private automatic exchange's lines over the communications network.

Infrastructure : The presently installed and the to be installed base of optical fibre cable, patch panels, multiplexers and related communication equipment to realise the provision of communication services to operate the electricity network.

3. STANDARDS

The equipment offered against this specification shall comply fully with the requirements thereof. Any deviation from this specification shall be clearly stated.

Alternative offers will be considered, providing the equipment offered complies fully with the minimum requirements of this specification.

The tenderer shall submit a detailed statement of compliance or non-compliance and reasons (if any) for each and every requirement called for in this specification.

Any non-conformance not indicated will render the supplier liable for any expenses incurred by Pretoria Electricity to make good the non-conformance.

3.1 Works Content

The tenderer shall be responsible for the manufacturing or sourcing and delivery to site of the equipment, accessories and/or options and the carrying out of installation works in installing the said equipment, accessories and/or options, asked for in this specification.

The tenderer shall be required to source, transport to his workshops and deliver to site after fitment of equipment any cabinet, rack or tray needed in order to install the equipment called for in this specification.

3.2 General Requirements

The tenderer/supplier shall comply to ISO9002. A copy of such a compliance certificate shall be included with this enquiry.

Delivery and installation costs shall be included in the Schedule Of Prices, where requested.

Preference shall be given to equipment with extended warranties.

The tenderer shall submit a separate price in the Schedule of Prices on each item (Equipment, Accessories and Options) asked for in this specification. Each item shall be listed separately.

A separate Schedule Of Prices shall be completed for alternative offers with the same detail as requested in 2.5.4.

Equipment offered with a higher or better specification asked for in this tender shall be considered.

The successful tenderer shall submit a complete itemised invoice, describing all the equipment, accessories and technical documentation of the equipment delivered.

Each unit shall be packed in a container with all the accessories. The packaging shall be robust to prevent damage to the equipment when transported by public transportation.

Pretoria Electricity reserves the right to visit the factory to inspect the manufacturing process at any time during normal office hours.

The tenderer shall submit a list of references with this document.

3.3 Training

The successful tenderer shall present a course in the installation, maintenance and configuration of the equipment to at least four (4) staff members.

The City Electrical Engineer shall be satisfied as to the standard, duration and contents of the course.

The cost of the course shall be quoted and included in the Schedule of Prices.

3.4 Maintenance

The City Electrical Engineer shall be satisfied that the successful tenderer carries adequate stock or has access to a complete range of spare parts for the equipment offered and has adequate service facilities to maintain the equipment for a period of 10 years.

3.5 Demonstration

Tenderers shall be prepared to demonstrate their equipment offered, as specified in this document before the tender is awarded, at no extra cost. The tenderer shall also demonstrate that the equipment is working correctly in his workshop before delivering equipment to site.

3.6 Guarantee

The tenderer shall guarantee all the equipment offered in this tender against defects arising from faulty materials, design or workmanship for a minimum period of twelve (12) calendar months from the date of delivery.

The tenderer shall repair and make good at his own expense and to the satisfaction of the City Electrical Engineer any omissions from the statement of work and defects arising or becoming noticed during the guarantee period.

If any faults or defects are not rectified within a reasonable period, the City Electrical Engineer may arrange for the equipment to be repaired at the suppliers expense.

The tenderer shall collect and deliver any faulty equipment during the guarantee period, the costs of such transportation shall be for the suppliers account.

3.7 Execution of Orders

Tenderers are reminded that orders placed against accepted quotation are to be executed in strict accordance with the accepted specification and within the quoted delivery period.

The Pretoria City Council shall not be held responsible for any losses incurred by tenderers should the tender not be awarded.

The City Council reserves the right to accept the whole or any portion of this tender.

4. COMPACT FIBRE OPTIC BASED TELEPROTECTION EQUIPMENT

The equipment supplied shall comply fully to CCITT Rec. G.703.10, G.732 and G.958.

The equipment offered shall be tested against surge voltages, insulation and impedance in accordance to IEC 255-4, Class III.

Equipment offered shall be interchangeable and / or adaptable with existing equipment in use and shall interact seamlessly with the equipment base already installed, which is equivalent or similar to the FOX6+/20 range of compact multiplexers.

The serial number of the equipment supplied shall be engraved or imbedded on a label on the outside of the modules or housing.

The equipment shall be used between primary infeed substations with drop and insert facility at various teed-off substations.

The equipment offered shall have a universal bus, an omnibus and time slot through-connection as a standard feature.

In some cases installation work will not be required, but the successful tenderer is not relieved from the responsibility to make sure that the equipment supplied operates reliable and according to specification.

Detail specifications are as follows :

4.1 Power Supply

the supply shall be protected against RF interference; and

the supply shall be fitted with an Over and Under voltage protection to prevent damage to the equipment in use.

The power supply shall be galvanically isolated with short circuit protection and shall be fitted with an externally accessible fuse.

Please refer to the Schedule of Particulars and Guarantees for additional information.

4.2 Multiplexer

Please refer to the Schedule of Particulars and Guarantees for detail.

4.3 Alarm and Oscillator unit.

Please refer to the Schedule of Particulars and Guarantees for detail.

4.4 Digital Protection Interface

The Digital Protection Interfaces will interface electrically to the intertripping protection relay. An intertrip signal will be sent across the infrastructure to the distant relay to effect a line trip.

Please refer to the Schedule of Particulars and Guarantees for detail.

4.5 Asynchronous data interface

The asynchronous data interface has to be a standard feature in the backplane of the equipment. It should be capable of being configured as a point-to-point link or a multi-drop data bridge.

Please refer to the Schedule of Particulars and Guarantees for detail.

4.6 Binary interface

The binary interface shall be capable of transmitting 8 input/output signals via one 64 kbit/s time slot in full duplex.

All the input/output connectors shall be galvanically and optically isolated, except for the auxiliary voltage source.

In transmission interference or in transmission loss the unit shall store the last output states or reset all the jumpers.

4.7 Accessories and Options

Please refer to clause 4.75.11 for specifications on accessories and options for both Teleprotection and Communications items.

5. COMPACT FIBRE OPTIC BASED COMMUNICATIONS EQUIPMENT

Specifications in general must include and comply to the following :

The equipment supplied shall comply fully to CCITT Rec. G.703.10, G.732 and G.958.

The equipment offered shall be tested against surge voltages, insulation and impedance in accordance to IEC 255-4, Class III.

Equipment offered shall be interchangeable and / or adaptable with existing equipment in use and shall interact seamlessly with the equipment base already installed, which is equivalent or similar to the FOX-U range of compact multiplexers.

The serial number of the equipment supplied shall be engraved or imbedded on a label on the outside of the modules or housing.

The equipment shall be used between substations for protection, SCADA, telephones, etc., with drop and insert facility at various substations.

The equipment offered shall have a universal bus, an omnibus and capable of time slot through-connection.

In some cases installation work will not be required, but the successful tenderer is not relieved from the responsibility to make sure that the equipment supplied operates reliable and according to specification.

The following elements have to comply to the following specific specifications:

5.1 Power Supply.

The supply shall be protected against RF interference according to EN55022 of 4/87.

The supply shall be fitted with an Over and Under voltage protection to prevent damage to the equipment in use.

The power supply shall be galvanically isolated with short circuit protection and shall be fitted with an externally accessible fuse.

Chopper clock frequency shall be synchronised to the 64kHz system clock to minimise in-band interference

Test points on the front panel shall be available with a visual indication on the front panel when output voltage fails.

Please refer to the Schedule of Particulars and Guarantees for more technical detail.

5.2 Equipment Chassis

The construction of the equipment chassis shall be such that it is 19" rack mountable with the width of slots number 1 to 17 of 8M and the width of slots 18 and 19 of 14M. Chassis with units have to be designed to achieve EMC Directive 89/336/EEC, meet EN55022 (1993) Class B for emission and meet EN50082-1 (1992) for immunity to noise. All internal connections are to be made by the backplane.

Please refer to the Schedule of Particulars and Guarantees for more technical detail.

5.3 Control Card

The digital cross-connection of time slots on 64 kbit/s and on 2 Mbit/s levels resides within this module

Controls the functionality of a drop & insert multiplexer

Shall be equipped to permit conference circuits to be set up by means of time slot sharing.

The module shall act as the main clock supply to the whole multiplexer unit.

Monitoring of the entire system and alarm generation.

Availability of an Embedded Operations Channel for maintenance purposes is essential

5.4 64kbits/s Data interface

The 64 kb/s data interface shall enable the creation of Engineering Overhead Channels to enable the remote configuration and monitoring of the communications equipment, metering information or SCADA. Refer to the Schedule of Particulars and Guarantees for details.

5.5 Universal data interface

The Universal Data Interface shall enable the creation of Super-Rate (n x 64kb/s) primary rate connections to enable a Router Network to interlink several Local Area Computer Networks.

5.6 Telephone Subscriber Line interface

The Telephone Subscriber Line interface card shall emulate the telephone exchange line to the Subscriber Unit and shall comply to the specifications in the Schedule of Particulars and Guarantees.

5.7 Telephone Exchange Line interface

The Telephone Exchange Line interface card shall emulate the Subscriber Unit to the telephone exchange line and shall comply to specifications in the Schedule of Particulars and Guarantees.

5.8 Ringing generator

The Ringing Generator shall supply the Subscriber Unit with a ringing current via the Telephone Subscriber Line interface when the telephone exchange presents a ringing current to the Telephone Exchange Line interface. Shall comply to specifications in the Schedule of Particulars and Guarantees.

5.9 Optical Fibre transmission interface

The Optical Fibre transmission interface shall connect to the single mode optical fibre infrastructure of Pretoria Electricity. Specifications as per Schedule of Particulars and Guarantees.

5.10 G.703 2Mbits/s transmission interface

The 2Mbit/s transmission interface shall be an integral part of the Optical Fibre transmission interface and specifications shall be as per Schedule of Particulars and Guarantees.

5.11 Accessories and Options (Clause 4 and 5)

A complete installation kit with all the connecting cables and connectors including patch leads shall be supplied with each unit.

A complete set of configuration / setup / network monitor software and firmware shall be included and/or supplied with each unit, whichever is necessary. If only one item of the latter is needed for a complete network, it shall be supplied as such.

Blanking plates shall be supplied for the front cover to cover open slots.

The tenderer shall list all accessories and options not listed that are of importance to the user and that are essential to the successful installation, commissioning and operation thereof.

An extra power supply shall be available for redundancy, the power supply shall slot into a open slot in the main chassis.

PART 17.2 : MARSHALLING KIOSKS & TERMINATION BOXES

SPECIFICATION NO: TB09/00

1. EXTENT OF WORK

The single, free-standing 132 kV bay yard marshalling kiosks shall be omitted by terminating the multi-core cables from the control panels directly onto the primary equipment or to small collection boxes mounted directly on the primary equipment support structures.

The collection boxes shall be weatherproof, manufactured of galvanised steel and suitably equipped, meeting the general requirements of Part 1.4. Contractors shall submit detailed general arrangement drawings for approval by the Engineer.

PART 18.1 : SCADA INTERFACE

SPECIFICATION No : SC.03/0-97

CONTENTS

1. INTRODUCTION

This specification specifies the Supervisory Control and Data Acquisition (SCADA) interface for a substation.

The City of Tshwane Metropolitan Municipality control centre are situated at Capital Park, from where fifty substations are monitored and controlled via SCADA links

The Scada Protocol at the Control Centre of the City of Tshwane is DNP 3 level 3. The Tenderer shall submit the following documents

) A document stating that the tenderer complies to IEC 60870-5-103

ii) A document explaining the protocol that the tenderer will be using in the substation.

iii) A document stating that the protocol being used by the tenderer can be converted to DNP3 level 3.

The conversion of the substation protocol to DNP 3 level 3 can de done by the tenderer, by doing the conversion in the substation MMI or by doing the conversion in a Harris D20++ Processor board. The tenderer must be able to prove both conditions. The implementation of the protocol conversion at the substation will be the responsibility of the tenderer. The tenderer will supply the City of Tshwane with an IO list indicating Digital Inputs, Digital Outputs, Analogs and DNP mapping.

The Tenderer will give training to personnel of the City of Tshwane on fault finding, populating of the database in the MMI and the substation protocol

2. STANDARDS

The following documents are referred to in this specification:

a) The DNP Basic 4 Document set which includes the complete description of all the facilities available in DNP together with their usage; and

b) the DNP V3.00 Subset Definitions which explains the minimum functionality that is expected in the three officially recognised subsets of DNP.

Both of these documents are available from the DNP users group and from Pretoria Electricity.

3. OVERVIEW

Harris Distributed Network Protocol (DNP) has been developed by Harris Canada Inc. for application in both SCADA and distributed automation systems. The DNP protocol are being used by CCP to interface the front end processor at Capital Park with different substations.

4. COMMUNICATION MEDIUM

The communication medium consists of optical fibre with multi-plexers, twisted copper pilot wire with modems and micro wave radio links. The baud rates vary between 300 baud and 19 200 kilo baud.

5. SUBSTATION SCADA INTERFACE

The preferred option will be for the Tenderer to make use of a standard D20 ++ processor card from Harris to convert the protocol inside the substation to interface to the Control Centre at Capital Park talking DNP protocol on the SCADA link.

Harris support protocols such as ABB SPA-BUS, GEC Courier K-bus, Modbus, etc.

The configuration for the substation will be programmed on NV Ram situated on the D20 ++ card.

The Council will provide a suitable cubicle to house the 19 inch rack.

An option for the Tenderer to make use of an intelligent device (Gateway) to convert the protocol inside the substation to interface to the Control Centre at Capital Park talking DNP protocol on the SCADA link would also be considered by the Council.

The Tenderer should quote on both the above options.

6. BUSBAR COLOURING

a) Powered : 275 kV Busbar : Blue
b) 132 kV Busbar : Orange
c) 33 kV Busbar : Magenta
d) 11 kV Busbar : Cyan
e) Without power : All busbars white
f) Earthed : All busbars green
g) Invalid : All busbars yellow
h) Background : Black

7. SYMBOLS LIST

For further details see Part 12.

7.1 Breaker

Use a square symbol with the following conditions:

a) Breaker closed : a square solid red;
b) breaker open : a square solid green; and
c) breaker disturbed : a square yellow with a line running from top left to bottom right.

7.2 Isolator

Use a circle with the following conditions:

a) Isolator closed : a circle solid red
b) isolator open : a circle solid green
c) isolator disturbed : a hollow circle in yellow with a 45 degree line running from top left to bottom right.

7.3 Earth

The conventional 3 horizontal lines arranged within the outline of a triangle.

When earthed the green symbol should show, when not earthed no symbol should show.

8. DATA POINT NUMBERING

For the purposes of maximum efficiency of the communications system and data entry into the SCADA system the following are recommended for any equipment to be connected to the control centre via DNP.

a) All point numbers for all types of data should start from zero (0);

b) all point numbers should be contiguous, with no gaps or spares within the point mapping. This is recommended because on start-up and at pre-set intervals the FEP will ask for all data (integrity poll) and gaps in data will make the response inefficient as the real data and the spare points are all transmitted together;

c) the two points associated with status of a device (e.g. open-closed status of a circuit breaker) shall be adjacent to each other in the point map and located at an even boundary. The Open and Close indications should be in the same order as for the RTU s that have already been installed (Closed Indication first, Open indication second). If this procedure is followed the SCADA system data entry and FEP mapping will be easier; and

d) control output bits should follow the same procedure in that the associated output should be next to each other and at an even boundary. The sequence should be Trip first and then Close.

Digital Inputs (time tagged or not) should be allocated to Class 1, Analogue Inputs should be allocated to Class 2 and Counter values to Class 3

9. OFFICIAL DNP SUBSETS

Three official subsets of DNP have been defined by the DNP Users group. These are as follows:

a) Level 1 Implementation (DNP-L1)

b) level 2 Implementation (DNP-L2)

c) level 3 Implementation (DNP-L3)

Level 1 is the minimum subset that should be implemented and is typically used between a master station and an IED. The requests for the following data objects from the slave must be accepted

a) Reads of Class Data Objects;

b) Reads of Binary Outputs and Analogue Output Objects only if these objects exist in the slave;

c) Control Operations;

d) Writes to the RESTART Internal Indication;

e) Cold Restarts; and

f) Time Synchronisation.

The Level 2 implementation consists of all the Level 1 features plus additional data objects as defined in the subsets document.

The Level 3 implementation consists of all Level 2 plus additional data objects as defined in the subsets document. This is the level which is required and specified by the Council.

10. CLASS DATA

DNP has the facility to send changed (event), data to the master station. The master station thus polls for changed data rather than for data of a specific type e.g. the poll is for all Class 1 data rather than all Analogue.

DNP has 4 different classes of data, each of which can contain different types of data, but which have different event queues and priorities :

a) Class 0 Data is the exception in the that data is static data rather than changed data. Class 0 consists of all data and is called an integrity poll because it returns the status of all the I/O points in the RTU; and

b) Class 1, 2 and 3 data there are different priorities of data and the master station can be set up to poll more frequently for Class 1 data than for Class 2 data and Class 3 data.

Class Data requests are the basis for the communications in the Pretoria Electricity SCADA network. This is due to the necessity to most efficiently use the bandwidth available for communications, as DNP is a relatively high overhead protocol.

11. MODES OF OPERATIONS

DNP provides several different means of operation:

a) **Quiescent Operation;**

where the master never polls the slave. All communications are unsolicited report by exception. This mechanism is generally used for systems using radio communications and pole top RTU s to keep communications to a minimum. The integrity of the data is never verified and is thus not recommended for Pretoria Electricity;

b) **Unsolicited Report by Exception;**

in which most communications is unsolicited, but the master occasionally send integrity polls for Class 0 Data (all data) to verify its database. This option is not acceptable to the Council.

c) **Polled Report by Exception Operation;** and

in which the master polls frequently for event data and occasionally for Class 0 Data. Polling is generally quick because only significantly changed data objects are reported to the master station. This is the mechanism that is used by the Pretoria Electricity system at this moment, due to the combination of high efficiency, good integrity, and control by the master. The slave never sends data unless polled by the master and the master is thus controlling the system. This is the recommended implementation needed by the Council.

d) **Polled Static Operation.**

where the master always polls for all data. This is very inefficient and not acceptable to the Council.

12. GPS CLOCK

The Tenderer shall supply and install a GPS clock for the time tagging of events at the substation and also for time synchronisation with the front end processor at Capital Park with an accuracy of 1 ms or better.

13. FUNCTIONALITY OF THE SCADA

The SCADA shall be able to control the substation in the same way and with the same detail as the MMI or substation control system. All controls, status indication, analogue indications, event recording and alarms shall be provided.

When any of the elements of the substation is in local mode it shall not be possible to control that element by the SCADA.

It is not necessary for the SCADA to be able to communicate with the relays

In addition intruder detection and alarms shall be supplied, as well as battery status alarms and charger control (e.g. battery boost charge).

14. TESTING

The Contractor shall be responsible to test all the Substation SCADA alarms, analogues, tap positions and indications to the front end processor at Capital Park

15. DOCUMENTATION

The following drawings shall be supplied by the Tenderer :

a) Single line diagrams showing the basic layout of the busbars, breakers, isolators, bus couplers, bus sections etc.

b) a document showing the numbering of addresses for all the different 1 bits, 2 bits, analogues, tap positions, controls and alarms

c) a drawing of the element types (circuit breakers, transformers, isolators etc.

d) transducer outputs (0-5 mA or 4-20 mA etc.) and voltage- and current transformers ratios.

The following documentation will be supplied by CCP to the Contractor:

a) DNP documents mentioned above

b) protocols supported by Harris

c) a hardware manual on the Harris D20 ++ processor card

d) a name and telephone list of contact persons at CCP.

PART 19.1 : 132KV POWER LINES

SPECIFICATION No : PL.60/0-93

Contents

1. SCOPE

TECHNICAL SPECIFICATION FOR THE CONSTRUCTION OF DOUBLE CIRCUIT OVERHEAD 132KV POWER LINES AND COMPOSITE EARTH WIRES:

This Specification covers the design, manufacture, supply, delivery, installation, erection, stringing, commissioning and handing over in a complete and proper working condition of three-phase double circuit overhead 132kV power lines having "BEAR" A.C.S.R. phase conductors and tow overhead earth wires erected on single lattice steel towers, complete with foundations, supplementary earthing, Tee-off, cross-over or terminal gantry structures and gantry spans as required, down droppers, insulators, all line fittings and accessories as required, and all other items, components and incidental work as detailed in the Specification, the Schedules of Particulars and Guarantees and the contract drawings. Alternatives designs of towers shall be discussed with the Engineer, and the compliance with or deviation from the provisions of this specification shall be submitted in writing. The following two types of power line are covered by this Specification:

150MVA three-phase double circuit overhead 132kV power line using a single "BEAR" A.C.S.R. conductor per phase with steel or fibre-optic earth wire and supported on towers as depicted on drawings Nos B-500, B-501 and B-502.

300MVA three-phase double circuit overhead 132kV power line using twin "BEAR" A.C.S.R. conductors per phase with steel or fibre-optic earthwire and supported on towers as depicted on drawings Nos B-500, B-501 and B-502.

This Specification also covers alterations to, or deviations of similar existing overhead power lines in accordance with the provisions of the Specification and the Schedules of Particulars and Guarantees and as depicted on contract drawings if so called for in the enquiry.

Except where specifically stated to the contrary, the contract work to be carried out under this Specification includes the provision and installation of all the equipment required, including all matters and details to provide a complete power transmission system and includes negotiations with and/or giving notice to other Municipal Departments, other Authorities where necessary, landowners where necessary, and the carrying out of all aspects of the Work necessary to complete the contract commitments. Assistance will be given by the Electricity Department of the City Council of Pretoria as specifically provided for in the contract and at the discretion of the General Manager, Electricity.

2. STANDARDS

Power lines to be constructed to this Specification and all equipment to be supplied and work to be carried out under this Specification, shall comply with the requirements of this Specification, shall comply with the requirements of this Specification, the particulars and guarantees stated by the tenderer in the Schedule(s) of Particulars and Guarantees and the relevant requirements in the latest revisions of the following standard specifications and codes of practice:

<u>Power line in general</u>

The design and construction of the complete power line shall be in accordance with South African Institute of Electrical Engineers' code of practice for overhead power lines for conditions prevailing in South Africa.

<u>Concrete work and foundations</u>

SABS 471:	Portland cement and rapid-hardening Portland cement
SABS 718:	Aggregates for concrete
SABS 878:	Ready-mixed concrete
CKS 53:	Sand for concrete
SABS 920:	Steel bars for concrete reinforcement

SABS 82: Bending dimensions of bars for concrete reinforcement
SABS 088: Pile foundations

Structural steel
SABS 222: Dimensions and properties of rolled carbon steel structural sections;
Or alternatively

BS.4848: Hot-rolled structural steel sections together with BS.4360: Weldable structural steels

SABS 763: Hot-dipped (galvanized) zinc coatings (other than on sheet and wire)

Or alternatively

BS.729; Hot dipped galvanized coatings on iron and steel articles

SABS 094: Bolted friction grip joints in structural steelwork:

Or alternatively

BS.4604: The use of high strength friction grip bolts in structural steelwork

BS.5135: Metal-arc welding of carbon and carbon manganese steels

Conductor and earth wire
SABS 182: Conductors for overhead electrical transmission lines: Part III: Aluminium conductors, steel reinforced:

Or alternatively

BS.215: Part 2: Aluminium conductors, steel reinforced, for overhead power transmission together with
BS.4565: Galvanized steel wire for aluminium conductors, steel reinforced.

BS.183: General purpose galvanized steel wire strand

BS.443: Galvanized coatings on wire;

Or alternatively

SABS.935: Hot-dip (galvanized0 zinc coatings on steel wire.

Insulators
SABS.177: Ceramic and glass insulators for overhead lines of nominal voltage greater than 1 000 V;

Or alternatively

BS.137: insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000V

BS.3288: Insulators and conductor fittings for overhead power lines

Incidental work

CKS.146: Gates, steel with tubular frames (for farm and domestic use)

CKS.82: Steel posts, stays, standards and droppers for strained wire fences

SABS 935: Hot-dip (galvanized) zinc coatings on steel wire.

Except where otherwise specified or implied, the Contract Works shall comply with the standards of the British Standards Institution current at the contract commencement date (such standards being herein referred to as "BS.") or the standards of the South African Bureau of Standards (herin referred to as "SABS"), as applicable.

3. QUALITY OF MATERIAL AND WORKMANSHIP

The Plant shall be manufactured and constructed to the highest standards and all materials used under this Contract shall be new and of approved qualities and of the class most suitable for working under the conditions specified, and shall withstand the variations of temperature and atmospheric conditions arising under working conditions without distortion or deterioration or the setting up of undue stresses in any part, such as to affect the efficiency, suitability and reliability of the installation.

Workmanship shall be of the highest standard and shall in all respects be subject to approval by the Engineer.

The design shall incorporate every reasonable precaution and provision for the safety of all those concerned in the operation and maintenance of the Work.

The general arrangement of all plant supplied under this Contract, the arrangement of all towers, gantry structures and earthing including any special arrangements which may be necessary, shall be to approval.

4. STATUTORY REQUIREMENTS

With regard to power line design and construction and with regard to his own operations when working on site, the Contractor shall comply in all respects with the requirements of the Machinery and Occupational Safety Act (Act No 6 of 1983) and the Regulations issued there under which shall take precedence over other statutory requirements.

Should a power line route cross the route of a national road the Contractor shall, in the execution of the contract, comply with the requirements of the Act on National Roads (Act No 54 of 1971) and such requirements as may be laid down by the Department of Transport.

In the execution of the contract, the Contractor shall comply with the Transvaal Road Ordinance and Regulations (No 22 of 1957) and such requirements as the Transvaal Roads Department may lay down for power lines crossing provincial roads.

Should the power line route cross any railway line, the Contractor shall, in the execution of the contract, comply with the requirements laid down by the South African Transport Services.

Should the power line route cross any telegraph or telephone line, the Contractor shall, in the execution of the contract, comply with the requirements of the Post Office Act (Act No 44 of 1958) and such requirements as laid down by the Department of Post and Telecommunications.

Copies of way leave conditions for certain specific power line crossings as laid down by other Authorities in correspondence with the Electricity Department, can be obtain by the Contractor from the Electricity Department.

The Engineer shall have the power to instruct the Contractor to alter, replace, rectify, or otherwise provide for any item which is necessary to comply with any statutory requirement applicable to the contract. No extra payment will be considered for any provision which the Contractor may have to make to comply with any act or statutory requirement as all such costs will be taken as having been provided for in the prices quoted in the tender.

5. SERVICE CONDITIONS

The power line shall be suitable for continuous outdoor operating under the varying atmospheric and climatic conditions occurring at all seasons in Pretoria and shall operate satisfactorily under the following conditions:

Altitude above sea-level …………………………… 1 530 m
Maximum ambient temperature (summer) ……….. 40°C
Average daily maximum ambient temperature
(summer) ………………………………………….. 30°C
Minimum ambient temperature (winter) ………….. minus 5 °C
Average daily minimum ambient temperature
(winter) …………………………………………….. 2 °C
Minimum relative humidity ………………………….. 20%
Maximum relative humidity …………………… At times up to 94%
Maximum wind speeds:
Steady conditions ………………………………….. 25 m/s
Gusty conditions …………………………………… 45 m/s
Lightning area ……………………………………… Yes
Average thunderstorms days per annum ± 75
Approximate ground flash density per square km per
Square annum ……………………………………….. 7
Median value of peak discharge current …………….. 41 kA
Mean duration of strokes …………………….. les than 200 microsecond
Number of multiple stroke flashes as a percentage
Of total number of strokes …………………………… 40%
Polution conditions …………………………………. Normal to heavy
(dust and smog)
Other climatic conditions …… ..…………………. At times dry and dusty
Gravity constant for Pretoria ………………………….. 9,786 m/s

6. SYSTEM PARTICULARS

The transmission line will be connected to a power distribution system in which electrical energy is generated at interconnected power stations as three-phase current at a frequency of 50 Hz and transmitted by means of overhead lines and underground cables.

The load on the system will consist of all or any of the following: Static transformers, induction and synchronous motors, motor generators, rotary converters and rectifiers for the supply of motive power, traction, lighting, heating and electromechanical work.

Further particulars of the three-phase distribution system are as follows:

Nominal system voltage (r.m.s. line to line) ……… 132 kV
Highest system voltage (r.m.s. line to line) ……… 145 kV
System frequency ………………………………….. 50Hz
Maximum symmetrical fault current capacity

(1,0 second rating) ………………………………… 31,5 kA (r.m.s.)
System BIL at sea-level …………………………... 650 kV
System insulation level at Pretoria altitude ……… 550kV
Phase colour identification ……………………….. A – Red
B – Yellow
C – Blue
Phase rotation …………………………………….. R – Y – B
Anti-clockwise
Details of system neutral earthing ……………… Neutral points of transformers solidly earthed

7. POWER LINE PARAMETERS

In addition to other requirements specified alesewhere in the enquiry document, the power lines to be erected under this Specification shall be designed and constructed in compliance with the basic parameters specified in the Schedule of Basi Parameters for the design and construction of power lines at the end of this Specification.

8. WORKING LOADS

The complete power line including all towers, supporting structures, cross-arms, line fittings, conductor and foundations shall be designed, manufactured and constructed to operate safely under the specified in the Schedule of Basic Parameters for the design and construction of the power lines.

The assumed maximum simultaneous working loads on towers and supporting structures shall not be less than that specified in the clauses hereafter.

Simultaneous working loads under normal balanced load conditions

Vertical load
The weight of all insulator sets complete with all fittings attached to the structure; plus
The weight of all phase conductors and earth wires (including the weight of spacers and dampers) of twice the normal span length (to allow for towers at different levels); plus
The weight of all phase conductors and earth wire jumpers including the weight of jumper spacers and jumper terminals supported by the structure;

Together with

Longitudinal load (tension towers only)
The horizontal longitudinal components of the maximum tensions in the phase conductors and earth wires under minimum temperature and maximum wind loading conditions;

Together with

Transverse lodad
A wind pressure of 700 Pa on 1,5 times the projected area of all members on one face of the supporting structure; plus

A wind pressure of 700 Pa on 0,6 times the projected area of all phase conductors and earth wires in the maximum windspan length as stated in schedule B (Items 2.5. and 3.5); plus

The horizontal transverse components of the maximum working tensions in all phase conductors and earth wires operating at minus 5°C in still air and assuming the maximum power line deviation angle permissible for the structure under consideration.

Uplift consideration

On all types of angle tension towers the tower shall also be designed to safely withstand the loads specified in clauses 8.3.1, 8.3.2 and 8.3.3 but with the vertical load specified in clause 8.3.1.2 for the down hill span applied on the down hill side of the tower and a maximum nett total uplift equal to one-third of the respective maximum conductor working tensions applied at each attachement point on the other side of the tower.

Safety factor : balanced load condition

Based on the type-tested failing load or based on the calculated failing load (elastic limit for tension members and crippling load for compression members), the minimum factor of safety under the above assumed maximum simultaneous normal balanced loading conditions shall not be less than 2,5 for all support structures including any extensions up to maximum extension height.

Each tower together with any combination of base and tower leg extensions shall be designed such that no failure or permanent distortion shall occur in any part or component when tested with applied forces equal rto 2,5 times the maxisimultaneous working loads specified in clause 8.3 above.

Simultaneous working loads under unbalanced load conditions (Broken conductors)

For suspension type towers the maximum unbalanced load condition shall be the worst case of tower loading with any one phase conductor and any one earth wire broken (remote side of span) with either one or both circuits strung assuming both earth wires strung in both cases before conductor breakage. The assumed simultaneous maximum working loads on attachements carrying unbroken conductors shall be the same as that specified in clauses 8.3.1, 8.3.2, 8.3.3 and 8.3.4 above. The simultaneous working loads on attachements carrying broken conductors shall be assumed to be altered as follows:

A vertical load (conductor weight) equal to 75% of the conductor weight as specified in clause 8.3.1.2.

On the cross-arm carrying the broken conductor a longitudinal load equal to 70% of the maximum working tension in the case of a phase conductor and 100% in the case of an earth wire

A horizontal transverse load (wind load) equal to 75% of the conductor wind load specified in clause 8.3.3.2

All other loads remain as specified in clause 8.3

For strain angle towers (tension towers) the maximum unbalance load condition shall be the worst case of tower loading with any two phase conductors and any one earth wire broken (remote side of span) with either one or both circuits strung but assumning both earth wires strung in both cases before conductor breakage. The assumed simultaneous maximum working loads on attachements carrying unbroken conductors shall be the same as that specified in clauses 8.3.1, 8.3.2, 8.3.3 and 8.3.4. The simultanerous working loads on the corss-arms carrying broken conductors shall be assumed to be altered as follows:

The vertical load due to conductor weight reduces to 75% of that specified in clause 8.3.1.2.

An unbalanced longitudinal load equal to the conductor maximum working tension is imposed on the other side of the cross-arm.

The conductor wind load on the cross-arm reduces to 75% of that specified in clause 8.3.3.2.

All other loads remaining as specified in clause 8.3.

Safety factor : Unbalanced load condition

Based on the type-tested failing load or based on the calculated failing load (elastic limit for tension members and crippling load for compression members), the minimum factor of safety under the above assumed maximum unbalanced loading conditions shall not be less that 1,5 for all types of towers including any extensions up to the maximum simultaneous working loadings specified in clause 8.4 above.

The gravitational acceleration constant to be used for calculating the above loads in newtons shall be 9,786 m/s (for Pretoria)

9. SUPPORTING STRUCTURES

Towers general

The powr line shall be supported on galvanized steel towers of bolted lattice construction which shall be of the self-supporting brad-based type designed to accommodate double circuit transmission lines: one three-phase circuit on each side of the tower. The towers shall have concrete foundations. Where the right of way is exceptionally narrow, the Engineer may allow the use of a support of the tubular steel or concrete pole type for straight-line suspension supports only.

All towers shall be so designed that the two circuits are arranged symmetrically with the three-phase conductors of each circuit vertically disposed and with the two earth wires in the uppermost positions. Each conductor and earth wire shall be carrie dby iets own cross-arm.

The towers shall be of standard design and all members of towers of the same type shall be fully interchangeable. The dimensions, dispositions and methods of connections fo all tower members and accessories shall be to approval

The Standard tower heights shall be designed for a ground clearance of 7,5 m to the bottom conductor at an operating temperature of 75°C for a normal span (or standard span) length of 300 m over level ground; the span length being measured horizontally between supports. All standard towers shall be designed so that where favourable grounds contours exist the sum of two adjacent spans may total the maximum length stated in the Schedule of Basic Parameters provided that no single span shall exceed the maximum permissible single span length stated in the Schedule of Basic parameters provided that the specified factors of safety are maintained.

To increase the height of support where necessary, it shall be possible to extend the height of towers by the addition of standard base extension of lattice construction in steps of nominally 3m without affecting the specified maximum working load or fator of safety of the tower.

To facilitate the erection of tower bases on very steep slopes, standard individual tower leg extensions in steps of nominally one metre within the range minus one metre op to plus 2 m shall be available. Tower leg extensions shall be designed such that the maximum working load rating and safety factors for the tower is not affected by the use of leg extensions.

Towers shall be designed with standard cross-arm lengths but alternative cross-arm lengths shall be available, if required, especially on terminal towers for special take-off purposes.

The cross-arm designs shall facilitate the separate attachment of earth wire clamps (on earth wire cross-arms) and disc insulator strings (on phase conductor corss-arms) by means of suitable shackles, as well as all other accessories and equipment for the erection of conductors and maintenance equipment.

All tower and tower components, including special cross-arms, base extensions, tower leg extensions etc, shall be sesigned to carry the phase conductors and earth wires together with all insulator strings and fittings under the working load conditions and with the minimum safety factors specified in clause 8. The towers shall also be designed to comply with the parameters specified in the Schedule of Basic Parameters for the design and construction of the power line at the end of this Specification.

Tower designs based upon strength calculations only will not be accepted. Towers shall be type-testd to determine their simultaneously acting failing loads as specified in clause 18 and Tenderers shall quote prices and delay times for type-testing of towers not previously type-tested. Where acceptable type-test reports and certificates on type testing of towers similar to those specified can be provided, and the designs of the towers offered are certified by an independent professional Structural engineer, the required type-testing may be waived by the Engineer. Type-testing may also be waived by the Engineer in the case of towers previously accepted and proved satisfactory for use on the Council's 132kV overhead line system.

The maximum unit stresses in the various members of towers, extensions and base steelwork shall not exceed the figures stated in the Schedule of Particulars and Guarantees and the Contractor shall submit such drawings, stress diagrams and calculations of tower and extension design to the Engineer as the Engineer may require.

Types of towers: application and designation

For the purpose of standardization, towers for double circuit transmission lines shall nominally have the dimensions shown on the drawings issued with the Specification and shall have the following type designation for the specified applications:

TOWER TYPE DESIGNATION		**TOWER DESCRIPTION APPLIATION**	**LIMITS OF LINE DEVIATION ANGLE**
150 MVA SINGLE CONDUCTOR LINES	**300 MVA TWIN CONDUCTOR LINES**		
1D	2D	Straight line suspension tower	0° to 2°
1D30	2D30	Strain angle tower for line deviations up to 30°	2° to 30°
1D60	2D60	Strain angle tower for line deviations above 30° up to 60°	30° to 60°
		Right angle strain tower for line deviations above 60° up to 90°	
1D90	2D90	Terminal strain tower with angle between normal of landing gantry and line approach between 0° and 45°	60° to 90°
1DT	2DT	Terminal strain tower with angle between line approach and normal of landing gantry above 45° up to 90°	
1DT90	2DT90		
NOTE: *The prefix "D" designates "Double circuit" transmission line towers			

Suspension insulator sets shall be used on type 1D or 2D towers whilst tension insulator sets shall be used on all other tower types.

Type 1DT and 2DT towers shall be sesigned to allow the conductors of the line to be terminated on the tower at any angle up to 45° from the normal to the cross-arms, assuming the tension on the other side of such a tower to be zero as the down-droppers from the tower will be installed with greatly reduced tensions and insulated by means of light duty tension insulator sets.

Type 1DT90 and 2DT90 towers are intended for use where the angle between the approaching line and the normal of the landing gantry exceeds 45° but not 90°. In these cases the terminal tower is normally placed such that the vertical plane through the tower corss-arms bisects the supplementary angle (larger angle) between the downdroppers to the landing gantry and the centre line of the power line. Type 1DT90 and 2DT90 towers shall be designed to allow the line conductors to be terminated on the tower at any angle up to 45° from the normal to the cross-arms assuming zero tension on the take-off side.

Should it prove economical the duties of one or more towers may be combined in a single tower in which case tower designation shall be agreed with the Engineer.

A tower extended by means of the addition of a base extension shall be designated by the standard designation followed by the letter E and a figure indicating the height of the base extension as follows:=-

TOWER TYPE	POSSIBLE EXTENSION DESIGN	MAXIMUM EXTENSION HEIGHT
1D and 2D	E3, E6, E9, E12, E15 and E18	18 m
1D30 and 2D30	E3, E6, E9, E12, and E15	15 m
1D60 and 2D60	E3, E6, E9, and E12	12 m
1D90 and 2D90	E3, E6, E9, and E12	12 m
1DT and 2DT	E3, E6, and E9	9 m
1DT90 and 2DT90	E3, E6 and E9	9 m

Special parts for any standard tower as well as special towers, foundations or special extensions shall be of an approved design and shall be provided where required.

The type of tower and extension to be used in each position along the route shall be approved by the Engineer.

Gantry structures

Should gantry structures be required under the contract, all cross- over gantries, tee-off gantries and landing gantries shall be of bolted lattice steelwork construction of the self-supporting portal type mounted on block type concrete foundations:

Two types of gantries are defined as follows:

“Single gantry” or H-gantry consisting of two column supports and a horizontal strain beam suitable for carrying one three-phase circuits.

“Double gantry” or M-gantry consisting of three column supports and two horizontal strain beams suitable for accommodating two parallel running three-phase circuits

Gantry types shall be designated as follows:

A single gantry for a single conductor circuit shall be designated type 1HG.
A double gantry for a single conductor circuit shall be designated type 1 MG

A single gantry for a twin conductor circuit shall be designated type 2HG

A double gantry for a twin conductor circuit shall be designated type 2MG.

Gantries shall be designed to carry the three-phase conductors of each circuit in horizontal formantio

Gantry spans and phas-to-phase spacing shall be designed such that at maximum sag at a conductor temperature of 75° and assuming two adjacent conductors swinging through 90° towards each other for example under external fault conditions, the phase-to-phase clearance shall not be less than the value specified in the Schedule of Basic Parameters.

Subject to the requirements of clause 9.3.5 above, the minimum phase spacing (centre line to centre line) of gantry span conductors shall be as follows:

GANTRY TYPE	SPAN LENGTH	MIN. PHASE SPACING
1H and 1M	Up to 36 m	3,0
1H and 1M	Above 36 m up to 45 m	3,5
2H and 2M	Up to 30 m	3,0
2H and 2M	Above 30 m up to 38 M	3,5

Ganry designs shall be such that the phase-to-earth (steelwork) clearances laid down in the Schedule of Basic Parameters are complied with.

Steelwork

In the case of lattice type towers and structures all members shall be of standard metricated rolled steel sections (manufactured from structural steel to the requirements of BSS 4360 and /or SABS 222) bolted together. All such members shall be cut to jig and all bolt holes shall be drilled or punched to jig prior to galvanizing.

All members shall be clearly stamped with a distinguishing code corresponding to an approved code provided on approved drawings or material lists to be submitted by the Contractor. Such code shall be stamped prior to galvanizing and shall be clearly legible after galvanizing.

Bolted friction-grip joints shall comply with th requirements of SABS Code of Practice 064.

No Bolt holes shall be more than 1,5 mm larger than the corresponding bolt diameter and drifting and reaming of holes will not be allowed.

All bolts, nuts and other fittings shall be galvanized unless otherwise approved and all bolts shall as far as conveniently possible, be fitted with the bolt head on the outer face of the structure, rather than the nut. The minimum diameter of bolts used to fix members shall be:

Stressed members	-	16 mm
Other steelwork	-	12 mm

The length of bolts shall be such that when fitted the maximum projection through the nut shall be 15 mm and the minimym 6 mm. Under no circumstances shall the screwed portion of any bolt fall withing ht eshearing plane between members.

The centres of all bolt holes in plate members shall not be less than one bolt diameter from the edge of such a member.

A hole to clear a 16 mm bolt drilled approximately 200 mm above the concrete encasement, necessary for bolting of the earthing counterpoise shall be provided in each leg of every tower or extension and gantry column.

All steelwork below ground level shall be completely encased in concrete of not less than 80 mm thickness from a position 200 mm above ground level down to the main foundation. Details shall be given of the method and type of concrete to be used as well as the preventative measures against ingress of water between the steelwork and foundation concrete.

All exposed steelwork shall be hot-dipped galvanized as specified elsewhere.

Galvanizing

Galvanizing shall be in accordance with SABS 763 or BS 729.

Tenderers shall include in their supply prices, for the complete test and approval of the galvanizing by the SABS at the factory of the galvanizing by the SABS at the factory of the galvanizing company. Steel members will be unacceptable without the stamp of the SABS or their written approval.

The hot-dip process shall apply galvanizing. Sheradising or other similar processes shall not be used.

All welding, drilling, punching, cutting and bending of parts shall be completed and all scale, flux, rust and burrs removed and fabrication completed before the galvanizing process is applied.

The minimum weight of zinc coating on structural steelwork and other fittings shall not be less than 763 grams per square metre.

The threads of bolts and screwed rods shall be cleared by spinning or brushing; a die shall not be used. In the case of nuts the threaded portion shall be cleared after galvanizing by the passing through of a tap. Immediately after tapping to clear the threads the ungalvanized portions shall be coated by dipping in hot grease. The grease used shall be to approval.

The zinc coating shall be adherent, smooth and continuous. The coating shall be free of such imperfections as lumps, thin patches, blisters, fritty areas, uncoated spots, acid and black spots and flux. The zinc coating shall not be so loosely adherent as to be removable by any reasonable process of handling during transport and erection. Light blows with a hammer shall not cause peeling of the coating adjacent to the area deformed by the hammer blows.

Globular and extra heavy deposits of zinc which will interfere with the intended use of material will not be permitted.

Faulty areas of galvanized steelwork may only be repaired by re-dipping in molten zinc before the sample cools or oxidizes.

Tower accessories

Anti-climbing devices
An anti-climbing device shall be provided on each tower and tee-off or cross-over gantry column at a height of not less than 3 m and not more than 6 m above ground level.

Climbing bolts (step bolts)
Climbing bolts to approval shall be provided on two diagonally opposite legs of the tower commencing immediately above the anti-climbing devices at a maximum spacing of 400 mm up to the earthwire cross-arm.

No climbing bolts or ladders are required on gantry columns.

Tower identification and danger plates
General:
1) Each tower erected under this specifiation shall be fitted with a danger and property plate, a tower number and route identification plate with two circuit identification discs.

2) The plates shall be fixed to the tower insuch postions that they cannot be tampered with and are clearly legible to any observer, either from the ground or the air, underneath the lines with the front facing the source (as discussed with customer), at a height of 6 m from groundlevel.

3) All tower plates and discs shall be durable and robust. The plates shall be of approved design and sizes and the layout, wording and numbering shall be approved by the Engineer. The inscription on all plates shall be on a contrasting background and shall be clearly distinguishable.

Substrate:
1) The substrate shall be nonfading and resistant to ultra violet rays.

2) All tower, route identification, danger and property plates shall have black inscriptions on a yellow background.

3) The colours to be used on the tower plates shall comply with the colour requirements of SABS 1091 – 1975 as follows:

COLOUR	**SABS 1091 – 1975**	
	COLOUR NUMBER	**COLOUR NAME**
Black	-	-
Yellow	G.61	Canary yellow

4) Unless specifically otherwise approved, the substrate shall be manufactured of cold rolled enamelling quality steel plates, (like chromadeck), with the background as well as the inscription in vitreous baked enamel.
The vitreous baked enamelling shall properly cover the whole surface of the plate including the edges and back to prevent corrosion.

Legend:
1) The material of the legend shall be non fading and resitant to ultra violet rays. The colour shall be black and the lettering shall be style ARIAL.

2) The letters on the line designation labels shall have a minimum height of 75 mm.

3) The letters on the tower designation labels shall have a minimum height of 150 mm.

4) The lettering used on danger and property plates shall be of minimum height of 50 mm.

5) The circuit identification discs shall be yellow lettering on black circular background. The background circle shall be of minimum diametr of 125 mm. The lettering inside the black circle shall be of minimum height of 100 mm, and of style ARIAL.

Identification

1) Each label shall be marked with the uppliers name. The identification marking shall be of the same quality and standard as the rest of the tower plates and the legend shall be legible with a maximum height of 15 mm.

Size of plates:

1) The size of the identification plate shall be of dimensions 500 (w) x 500 (h) mm. The layout of the lettering and symbols required will be as illustrated in figure …………………..

2) The size of the danger plate shall be of dimensions 500 (w) x 450 (h) mm. The layout of the lettering and symbols required will be as illustrated in figure ………………….

Affixing methods:

1) Both the danger and identification plates, shall be affixed as follows:
   - For steel lattice towers, at the crossing of the second horizontal cross beam and connecting lattices, see figure ………….
   - For concrete and other poles, at a distance of 9 m from gound level.

2) The plates shall be mounted on a 50 x 50 x 3 mm angle-iron regtangular frame, in a robust way, provided with adjustable connection points for connection on the lattice frame of the tower, (or relevant part of pole, if poles are to be used).

3) Assurance must be given for the design's ability to withstand atmospheric and temperature conditions, without failure.

Naming of towers :

1) Tower route numbers and identification will be provided by the customer.

Bird Guards

Guards of approved design to prevent birds perching above insulator sets shall be provided on all suspension type towers.

10. FOUNDATIONS

Standard foundations and design

Concrete block or frustum type foundations shall be regarded as standard foundations and shall be used in all cases where suitable ground conditions exist.

Rock anchor foundations of approved design will only be permitted in solid fresh rock or massively bedded fresh rock and then only with the specific approval of the Engineer for each instance. Tock anchors in shale, "ouklip", boulders or other loose or fragmented or decomposed rock strata will not be accepted. Should rock be encountered during excavations, and the Contractor propose to install rock anchors, he shall employ the services of a Geological Engineering Consultant (Geotechnical Consultant) approved by the Engineer to investigate and report on the suitability of the rock for the type of rock anchor proposed by the Contractor. The Contractor shall submit a copy of the geotechnical report with his request for approval for using a rock anchor foundation. The cost of the geotechnical investigation and report shall be included in the price to be quoted for rock anchor foundations.

No drilled or root pile type foundation will be allowed without the specific approval of the Engineer. If piled foundations for special purposes are approved by the Engineer they shall comply with SABS Code of Practice 088 and full details of piling and foundation design shall be submitted to the Engineer for approval beforehand.

Where poor subsoil conditions are encounterd, i.e. excavations below water table level, or in soils of which the bearing pressures are to be determined by test as specified in the Schedule of Basic Parameters, or in soils of which the maximum safe bearing pressure could possibly become less than the minimum safe bearing pressure used for the design of standard foundations, the Contractor shall employ the services of a Geotechnical Consultant approved by the Engineer to carry out subsurface geotechnical investigations, and if necessary, soil tests, to determine soil parameters for the selection of foundation type and report on the suitablility of employing standard foundations. Should standard foundations not be suitable, specially designed foundations, the type(s) and details of which are approved by the Engineer, shall be provided by the Contractor at jprices to be agreed. Unit rate(s) for geotechnical investigations required in terms of this clause shall be quoted in the Form of Tender. The Engineer shall nevertheless be entitled to instruct the Contractor to appoint a Geotechnical Consultant to carry out geotechnical subsoil investigations, including soil tests if required, at sites to be selected by the Engineer at the unit rate(s) quoted for geotechnical investigations.

For each site so investigated, the Contractor shall submit a copy of the Geotechnical Consultant's detailed report on the investigation to the Engineer for approval of foundation type before installation of the foundation is commenced with.

In dolomite areas percussion drilling or other approved means shall be used for investigating sub-soil conditions and exploring subsurface cavities at proposed tower positions before starting foundation excavations.

In the design and application of standard and special foundations. The Contractor shall be responsible for ensuring that the subsoil at each foundation is suitable to withstand the maximum design load which will be imposed upon it by the foundation under maximum simultaneous tower working load conditions specified in clause 8 and according to the parameters specified in the Schedule of Basic Parameters.

The Contractor shall be responsible for any subsidence or failure of foundations due to insufficient care having been taken in the examination of the soil or the installation of the foundations. In such an event the foundation shall be replaced by the Contractor at his own expense.

Foundations design(s) shall comply with the parameters specified in the schedule of Basic Parameters for the Design and construction of the power line and the minimum safety factors specified therein.

The type of foundation to be used at each tower and gantry position shall be approved by the Engineer and the Contractor shall submit full particulars and design details of each type of foundation to be used before installation thereof.

Contrete block foundations

Concrete block foundations shall have stubs of galvanized steel sections embedded in the concrete. The stubs shall be firmly keyed into the concrete by means of suitable attachments or cleats. The adhesion between galvanized steel and concrete shall not be relied on to transmit the load to the foundations.

Each tower leg or base shall be bolted to a foundation stub with the top end of the joint approximately 300 mm below groundlevel. The concrete encasement shall however be continued to a level approximately 200 mm above finished ground level where it shall be finished off smoothly and neatly. The upper surface of this encasement or cap shall be sloped inan approved manner to prevent the accumulation of water.

All steelwork below ground and part of the tower shall be galvanized. Steel shall be completely covered by concrete not less than 80 mm thick. Care shall be taken to ensure that no crack can developm between the encasing and th main foundation block.

All members projecting above the concrete section at the lower leg bases as well as the concrete encasement cap shall be thorough\hly coated with black bitumastic paint to a point approximately 1 m above ground.

Rock anchor foundation

The holes in rock for rock anchors shall be made in such a way that the possibility of cracking the rock is eliminated.

The dispositions and dimensions of holes for rock anchors shall be to approval. The actual depth of an anchor bolt grouted into the rock shall in no case be less than one metre.

Rock anchor bolts shall be completely galvanized. The adhesion between galvanized steel and grouting shall not be relied upon to transmit the load to the rock. The anchor bolt shall be firmly keyed to the rock by means of taper heads of split ends with taper wedges properly and completely grouted.

If solid rock is encountered below the surface, the tower leg or footing shall be supported on a concrete base or cap extending down to the rock surface in which the rock anchors shall project at least 200 mm above finished ground level and shall be grouted off around the baseplate with the upper surfaces sloping in an approved manner to shed water.

The design of rock anchor foundations shall be to approval and shall comply with the parameters specified in the Schedule of Basic Parameters.

Concrete work for foundations

Unless otherwise approved, the concrete mix for all foundations shall consist of one part Portland Cement, two parts of sand and four parts of 18 mm crushed stone aggregate whilst the concrete required for encasing of tower steelwork above ground line shall consist of one part Portland Cement, two parts of sand and four parts of 6 mm stone chipping

In the case of excavations required beyond the normal foundation depth in order to establish suitable sub-soil, such sub-foundations shall be filled with a mixture of one part Portland cement and 10 parts of approved soil/sand well tamped down.

Broken stone and sand shall be clean and free from earthy or organic matter and salt. Seashore sand, unwashed pit sand or unwashed gravel shall not be used. All gravel or broken stone shall be of approved grading, and able to pass through a mesh of not more than 18 mm diameter. All sand shall be screened through a mesh not exceeding 5 mm square in the clear. All sand shall be coarse, sharp, clean and free from dust, salt, clay, vegetable matter or other impurities. Fine sand of a uniform grain size shall not be used, but all sand shall be a well graded mixture of coarse and fine grains.

Stone aggregte for concrete shall comply with SABS 718 and concrete sand with CKS 53. Fresh Portland cement complying with SABS 471 shall be used.

Water shall be clean and free from all earthy vegetation or organic matter, acids and alkali substances in solution or suspension.

The aggregates and cement shall first be mixed dry, then after addition of the minimum water consistent with proactical workability, mixing shall be carried on until the concrete is of even colour and consistency throughout. No concrete shall be poured, or mixed, when the ambient temperature, or the temperature of the ingredients, is less than 2°C.

Ready-mixed concrete, if used shall comply with SABS 878.

All concrete shall be mechanically vibrated during installation so as to form a well consolidated mass presenting a smooth surface upon removal of the shuttering.

Where required, the Contractor shall supply all re-inforcing steel required for foundations. All reinforcing steel shall comply with SABS 920 and bending dimensions shall conform to SABS 82. The concrete cover over steel reinforcement shall not be less than 50 mm.

Joints in concrete are to be avoided. Where the construction requirements are such that joints are unavoidable, adequate bond between old and new concrete shall be ensured by chipping the old concrete to a rough and clean surface. Before casting the frewsh concrete, the old concrete shall be sprinkle and dusted over with dry cement.

The Contractor shall provide all shuttering and foundation templates required for concrete work. Tunless otherwise approved shuttering or templates used for foundations shall not be struck within 24 hours after casting and towers or other structures shall not be erected on any foundation within fourteen days of casting.

11. EARTHING OF STRUCTURES

All towers and steel structures shall be earthed to a resistance level not exceeding 10 ohms. Buried foundation earths as specified below shall be installed under each tower leg and gantry column foundation. Structure earth resistances shall be measured before stringing and supplementary buried earthing or driven earth rods shall be installed to lower the earth resistance in cases where the footing resistance exceeds 10 ohms.

Buried foundation earths shall consists of a galvanized steel tape of dimensions 38 mm by 3 mm and 7 m long coiled at the bottom of each foundation excavation and covered with a layer of at least 80 mm of good riddled soil, which shall be well tamped down prior to the casting of the foundation. If the steel tape is not one continuous length, the joint(s) shall be bolted and soldered to approval. One end of the coil shall be brought up outside the foundation and be bolted to the structure leg at a position clearly visible for inspection. The cost of supply and installation of the steel tapes shall be included in the price for the erection of the foundation. The Contractor shall arrange with the Engineer for the inspection of foundation earths before casting the foundation concrete.

As provided for in clause 9.4.8, in addition to provision for the above earthing coils, provision shall be made on each leg of all structures for the connection of a buried supplementary earthing system whre required by the Engineer. The conductor to be used for the supplementary earthing system shall be as specified in the Schedule of Particulars and Guarantees.

One week prior to stringing of the earth conductors, the Contractor shall advise the Engineer of the proposed stringing date, in order that the Engineer may make timely arrangements for the measuring of tower earthing resistances by the Council, (if required) after which the Contractor will be advised of the extent of the counterpoise earthing system to be installed by the Contractor.

The supplementary earthing shall be buried in a 700 mm deep trench along a route to be directed by the Engineer. The cost of excavation shall be included in the installation rate for supplementary earthing. No extra price will be paid to the Contractor due to variations in the ground conditions.

Terminal towers shall be bonded to the overhead earth wires and to the station earthing system. The earthing of the earth peaks on gantry structures shall be to approval of the Engineer.

The overhead earth wires shall be continuous between terminal towers and all intermidiate towers and structures shall be conded to the earth wires except for the following exclusions:

For the control of electrolysis, all towers within 800 m of electrified railway lines or within 800 m of major pipe lineswith cathodic protection, shall be insulated from the earth wires using standard earth wire insulators with spark gaps.

12. CONDUCTORS

Phase conductors

Phse conductors shall be of the stranded aluminium conductor steel reinforced type with the code reference specified in the Schedule of Basic Parameters. The conductor shall comply in all respects with the requirements of BS 215 Part 2 and/or SABS 182 part IIIand shall have the characteristics detailed in the Schedule of Particulars and Guarantees.

The steel core of the conductor shall comply with BS 4565 and shall be uniformly covered with an approved grease of applied mass not less than 16 kg per kilometre of conductor.

The number of conductors per phase conductor for the different line ratings shall be as specified in the Schedule of Basic Parameters.

The conductors of twin conductor lines shall be disposed horizontally throughout the entire span at the centre line spacing specified in the Schedule of Basic Parameters.

At tension points, phase conductors shall be terminated by means of approved clamps of the compression type (dead ends). On strain angle towers, terminal towers and gantries, phase conductors shall be connected through by means of removable (bolt-on) jumper loops made up of accurately cut lengths of the same conductor fitted with compression type jumper terminals at each end. Twin jumper loops shall be used for connecting through twin conductor lines. Removable jumpers shall also be used for connections between down-droppers and lines or jumper loops,

Phase conductors, including jumpers and droppers, shall comply with the conductor clearances specified in the Schedule of Basic Parameters. Jumper swing shall not be limited by the installation of additional insulator sets. Where approved by the Engineer, jumper weights of jumper stiffeners of aluminium tube may, if necessary, be installed to obtain the specified clearances. On twin conductor lines the centre line spacing on twin down-droppers and over the centre section of twin jumper loops may be reduced as stated in the Schedule of Basic Parameters.

Earth conductors (Ground Wire

The two aerial earth wires used as overhead earth conductors shall be of the stranded galvanized steel wire type. Where specified, optical Fibre Ground Wire (OPGW) as detailed in Clause 15 shall be used. The size and othr parameters are specified in the Schedule of Basic Parameters

The earth conductor shall comply with the requirements of BS 183 and/or SABS 182 and shall have the characteristics stated in the Schedule of Particulars and Guarantees. Galvanizing of the earth wires shall comply with BS 443 and/or SABS 935.

At tension points earth wires shall be clamped in suitable bolted earth wire strain clamps. The tails of the earth wires shall be taken through and bonded to the structures where required by means of compression type earth wire lugs bolted to the steel structures. Where called for, earth wires shall be insulated from the towers by using approved earth wire suspension and tension assemblies.

Conductor general

All conductors on the power line shall be applied with the factor of safety specified in the Schedule of Basic Parameters under maximum working load conditions and in compliance with the other relevant parameters laid down in the Schedule of Basic Parameters.

Factory drum lengths of conductor shall be supplied without joints in individual strands of conductor.

On site, joints for jointing successive conductor lengths shall be of approved types. Midspan joints (tension joints) shall be avoided as far as possible. Unless otherwise approved conductor joints shall be located at tower positions. No Joints will be permitted in spans crossing proclaimed roads, railway lines, other power lines, important communication lines or buildings. Joints will also net be permitted in gantry spans or down-droppers.

Vibration dampers shall be fitted to all conductors to damp vibration, oscillation and galloping of the conductors to damp vibration, oscillation and galloping of the conductors.

Drumming of conductor

All conductors to be installed on this contract shall be supplied on new wooden drums of substantial construction, suitable in every way for the safe handling and transport thereof. All drums shall be clearly marked to indicate the drum number, the length of conductor on the drum and the correct direction of rolling shall be indicated by an arrow.

Any spare conductor required on this contract shall be supplied to the Council's Stores on approved steel drums. These steel drums shall be suitable for ratation on a 120 mm diameter spindle with at least 20 mm wide bearing surface at each point of contact with the spindle. Both flanges and the barrel of the drum shall be of material of approved guage which shall be braced to the approval of the Engineer and the entire drum shall be either galvanized or painted with approved anti-rust paint and clearly marked as specified above.

13. BASIC REQUIREMENTS STIPULATED FOR COMPOSITEINSULATORS FOR 132 KV POWERLINES:

Phase conductors shall be insulated from towers and supporting structures by means of string insulators

Relevent standards

All insulatorstrings and fittings shall comply with the following relevant standards unless otherwise specified:

- NRS 041:1995
- IEC 815

Sesvice conditions

The insulators shall be suitable for continuous outdoor operation under the varying atmospheric and climatic conditions occurring at all seasons in Pretoria and shall operate satisfactory under the following conditions:

Altitude above sea level	1700 m
Maximum ambient temperature (summer)	45°C
Average daily maximum ambient temperature (winter)	30°C
Minimum ambient temperature (winter)	-5°C
Average dailly minimum ambient temperature (winter)	2°C
Minimum relative humidity	20%
Maximum relative humidity	94%
Maximum wind speeds	

• Steady conditions • Gusty conditions	25 m/s 45 m/s
Lightning area	Yes (high)
Average thunderstorms days per annum	± 75
Approximate ground flash density per square km per annum	7
Median value of peak discharge current	41kA
Mean duration of strokes	<200µs
Number of multiple stroke flashes as a percentage of total number of strokes	40%
Pollution conditions	Normal to Heavy (industrial dust, smog & mist)
Gravity constant for Pretoria	9.786m/s²
Design wind pressure (DWP)	1170 Pa

System particulars

The insulators will be used on transmission lines and gantry structures, which are connected to a 132kV power distribution system in which electrical energy is generated at interconnected power stations as three-phase current at a frequency of 50 Hz, and transmitted by means of overhead powerlines and underground cables.

The load on the system will consist of all or any of the following: Static transformers, induction and synchronous motors, motor generators, rotary converters, rectifiers for the supply of motive power, traction, lighting, heating and electromechanical work.

Further particulars of the three-phase distribution system are as follows:

Nominal system voltage (r.m.s. line to line)	132kV
Highest system voltage (r.m.s. line to line)	145kV
System frequency	50Hz
Maximum symmetrical fault current capacity (1 second rating)	31,5kA (r.m.s.)
System BIL at sea level	650kV
System insulation level at Pretoria altitude	550kV

Electrical requirements

All components used in insulator assembly sets shall be designed such that the voltage stress anywhere on the metal surface of such fittings shall not exceed a value equivalent to a voltage gradient of 0,65 MV/m at sea level with the fittings energised at the specified maximum system voltage (line to line)

There shall be no audible or visible corona on the fittings when in use on site and energised to the maximum system voltage.

Insulator assembly sets shall not cause unacceptable levels of radio or television interference when energised to maximum system voltage.

Required creepage:	
Light pollution Medium pollution Heavy pollution Very heavy pollution	16 mm/kV 20 mm/kV 25 mm/kV 31 mm/kV

Mechanical

The insulator string as a whole shall be designed, manufactured and constructed to operate safely under the specified service conditions under the maximum simultaneous working loads to which it may be exposed with the minimum factors of safety as in NRS 041:1995 (table 1)

The assumed maximum simultaneous balanced and unbalanced working loads, as well as the maximum loads during broken conductor conditions, on the insulator string and fittings shall not be less than that specified in the NRS 041:1995.

A 16 mm ball and socket connection will be provided on all new suspension and tension insulator strings, to provide a 120 kN mechanical load strength on suspension insulator strings.

On all tenders where replacement of existing glass or pordelain insulators are called for, the following will be provided:

- 20 mm ball and socket connection for tension insulator strings
- 16 mm ball and socket connection for suspension insulator strings

On suspension towers, a single suspension string shall be used for both single and twin concuctor lines.

Strain insulator strings shall be used on all strain towers. On single conductor lines, a single tension string shall be used. On twin conductor lines, double tension strings shall be used.

Other requirements

The insulator sheds shall be self-cleaning
The insulator sheds shall be hydrophobic
The insulator sheds profile will be designed so that:

- The insulator surfaces are sufficiently aerodynamic to minimise the deposition of pollution;
- Rain washing will be effective; and
- Bridging of adjacent sheds will not take place under heavy rain conditions

:The material rod shall be a well pultruded fibreglass reinforced resin rod. A test sample of the rod shall be supplied.
The sleeve shall cover the whole fibreglass rod, up to the end fittings, and shall be of uniform thickness. The sleeve shall be High Temperature Vulcanized to the rod to form a seamless protective covering.
The sleeve shall hermetically seal the rod and provide resistance to hydrolysis, ultraviolet radiation, corona and ozone degradation.
The sheds shall be installed over the sleeved rod and High Temperature Vulcanized to insure a track resistant, bonded composite insulator.
The sheds shall also be resistant to hydrolysis, ultraviolet radiation, corona and ozone degradation.
The preferred material used for the composite shall be silicone rubber, free of all EPDM and EPM alloy polymers.
The required lifespan of the insulator string and fittings is 30 years, during this time no degrading in the insulator string and fittings is 30 years, during this time no degrading in the insulator's ability of hydrophobic action, mechanical strength, or any other requirements will take place.
Insulator sheds must be able to withstand the amount of reasonable pressure generated during washing, without loss of bonding to the sleev.
All insulatorstring and fittings must be accompied by the following tests:
Flashover test
Type test
Sample test
Breaking strength test (*to be arranged with tenderer)*
The insulator shall be provided with a arcing control lip to provide a termination point for 50 Hz power follow current during an insulator flashover. The lip shall be designed to divert the heat generated from flashover currents away from the crimped portion of the end fitting.
The insulator shall be vandal proof.
The manufacturer shall have at least 10 years field experience in composite insulators.
Proof of adequqte service and support must be supplied by the tenderer.
The manufacturer shall comply with ISO 9000 standars in Quality Control.

Profile parameters

To be specified in the Schedule of basic parameters as follows:

Definitions

C - Shed clearance – the length of perpendicular to the shced surface to the outer rib of the shed above.
S - Shed spacing – the vertical distance between two similar points on successive sheds
P - Shed protection – the maximum shed overhang
_ - The straight air distance between any two points on the shed surface
I_ - The creepage distance measured between the two points that define _
Is - The creepage distance measured between the two points that define S.
L - The total creepage distance of the insulator
A - The arcing distance of the insulator
CF - Creepage factor = L/A
Pf - Profile factor = (2P+S)/Is or (2P1 + 2P2 + S)/Is (P1 and P2 is the respective maximum shed overhangs for sheds on an alternating shed insulator)

Recommended profile parameter limits:

C	>	20mm (shed clearance the length of perpendicular to the shed surface to the outer rib of the shed above
S/p	>	0.8 for ribbed sheds
S/P	>	0.65 for plain sheds
I_/_	<	5
P1-P2	>	15mm
_	>	5°
ß	>	2°
CF	<	4
PF	>	0.7

14. POWER LINE FITTINGS AND HARDWARE

Fittings general

All powr line fittings shall be of approved design and shall comply with the relevant requirements of SABS 178 and/or BS.3288.

All fittings made of ferrous materials shall be hot-dipped galvanized to SABS 763 and/or BS 729 after comlplete manufacturing.

All fittings shall be supplied complete with all nuts, bolts, washers, pins, clips and locking devices as required. Bolts and pins shall be fitted with approved locking devices such as split pins. Spring wasahers on galvanized surfaces will not be permitted. All split pins shall be backed by flat washers and shall be either of phosphor bronze or stainless steel.

All bolt threds shall be greased before erection.

Standard ball-ended links or fittings shall be used for attachement to the cap side of disc insulators, and links or fittings used for attachment to the pin side of the disc insulators shall have standard socket connections. These links or fittings shall have facilities to accommodate arcing horns if required.

All ball and socket joint shall be effectively locked by means of W-security clips or retaining pins or other approved locking device.

Retaining pins or locking devices shall be of phosphor bronze or stainless steel and shall be so formed that when set and under any conditions nothing but extreme deformation of the retaining pin or locking device shall allow separation of the insulator units or fittings, or shall permit accidental displacement of the retaining pins or locking devices. Their design shall be such as to allow for easy removal or replacement of insulator units or fittings without removal of the insulator sets from the structures. Retaining pins or locking devices shall be incapable of rotationwhen in position.

All ball and socket couplings shall be lightly coated with an approved grease immediately before erection on site.

Standard pin type shackles and clevis couplings shall be used for attachement of insulator assemblied to conductor clamps or yoke plates. Under no circumstances will hooks be allowed.

All fittings and components in tension and suspension assemblies shall be of sufficient mechanical rating of the set is met and applied with a minimum factor of safety under maximum working load conditions as specified in the Schedule of Basic Parameters.

All clamps to be used shall have the minimum mass consistent with good design and adequate mechanical strength. Clamps shall bomply with the relevant requirements of SABS 178 and/or BS 3288. Clamps intended for stranded conductor shall be designed to avoid any possiblility of deforming the stranded conductor or separating of the individual strands.

Tension insulator assemblies (sets) for phase conductor

The fittings of tension insulator set assemblies shall be arranged to provide a minimum clearance of 150mm between the rim of the live end insulator disc and the jumper conductor or arcing horn.

For single conductor lines a single tension insulator assembly shall be used and be referred to as a normal tension set. Each normal tension set shall be provided with an approved sag adjusting plate or links for sag adjustment where necessary. No device employing screw threads shall be used for sag adjustment on Norman tension sets.

In the case of twin conductor lines, a separate insulator string assembly for each conductor shall be used which shall be separately attached to the cross-arm. These tension sets shall be referred to as double normal tension sets and shall be fitted with approved sag adjustment links to provide a total adjustment range of 300 mm in approved steps. Devices using screw threads for sag adjustment will not be acceptable on double normal tension sets.

For low duty applications, on down droppers and gantry spans, low duty tension sets employing disc insulators and fittings with a lower assigned safe load rating, may be used. These tension sets shall be reffered to as low duty tension sets and reverse low duty tension sets where the insulators have to be reversed to shed water. A single insulator string shall be used for both single and twin conductor low duty tension sets, but the low duty tension set for twin conductor construction shall incorporate a yoke plate to equalise conductor tensions. Separate means shall be provided for sag, adjustment on each conductor on twin sets. On low duty tension sets, approved turn-buckels with suitable lock nuts will be allowed for sag adjustment.

Suspension insulator assemblies (sets) for phase conductor

For both single and twin conductor lines, phase conductor suspension sets shall consist of a single insulator string assembly with the necessary links and fittings. Suspension sets intended for supporting twin conductor lines shall incorporate a yoke plate to equalise conductor loads.

Arcing horns

Acing horns of approved types, capable of safely withstanding a force of 500 N applied to the tip of the horn and designed to minimise the damage to conductors or insulatort assemblies under all flash-over conditions, shall be attached to the fittings of the assembly in an approved menner and not to the clamps or insulator caps.

All suspension and normal tension insulator sets throughout the line shall be fitted with arcing horns on the live end only. Arcing horns shall only be fitted on the outer strings of double tension insulator sets.

Low duty and reverse low duty tension sets, shall be fitted with arcing horns on the live as well as on the earthed side.

Phase conductor strain clamps

All tension clamps for phase conductors shall be of the current carrying compression type.

Compression type strain clamps shall have a mechanical strength of not less than 100% of the ultimate strength of the conductor when tested in accordance with BS 3288 Part I.

Compression type strain clamps for steel reinforced aluminium conductor shall comprise two compression sleeves, an inner steel compression sleeve for transmitting the mechanical strain from the steel core of the conductor to the attachment fitting and an outer aluminium compression sleeve mainly for current transfer.

Compression type strain clamps shall be supplied complete with jumper flags (jumper lugs) for bolting on jumper terminals. Where required strain clamp sleeves shall have double flags opposite each other for making two connections. The bolt-on surface of the flag shall be machined to proved a flat and reasonable smooth contract surface which shall be protected against oxidation by approved means.

Compression type strain clamps shall comply with the relevant requirements for current carrying clamps.

Phase conductor suspension clamps

Suspension clamps for phase conductors shall be of the trunnion type fixed in position by means of two M12 U-bolts and a keeper piece. The clamp shall be designed to support the conductor even if both U-Bolts are removed.

The conductor supporting groove of suspension clamps shall be flared out in a vertical plane to allow the conductor to leave the groove tangentially at any angle of declination encountered in service. In addition the groove shall be bell-mouthed to a minimum radius of 25 mm.

The mechanical clamping of the conductor shall be designed so as not to cause mechanical damage to the conductor of deforming it or separating the individual strands. The clamp shall permit conductor slip before conductor failure.

On conductor suspension clamps pivoting shall be provided about a horizontal axis transverse to, and through the centre line of the conductor.

Suspension clamps shall be of galvanized malleable cast iron. Ferrous suspension clamps shall be provided with sorft pure aluminium liners to protect the conductors.

Suspension clamps shall comply with SABS 178.

Earth wire strain clamps

Earth wire strain clamps shall be of the straight bolted type strain clamps and shall comply with the relevant requirements of SABS 178.

The clamp shall be forged from steel and shall comprise a clampt body with integral pulling eye and keeper plate(s). At least six M12 bolts shall be used for clamping the conductor in the groove. The clamp shall be reasonably smooth and all parts shall be hot-dipped galvanized.

The clamp shall be supplied compete with all necessary bolts, nuts and washers.

Earth wire suspension clamps

Suspension clamps for earth wires shall be of the trunnion type and shall be fixed in position by means of two M12 U-Bolts bolting down onto a preformed keeper plate to clamp the conductor.

Earth wire suspension clamps shall comply with similar requirements as laid down for the phase conductor suspension clamps.

Current carrying clamps, joints and and accessories

All current carrying parts of compression type clamps, joints and accessories (e.g. conductor repair sleeves) for aluminium conductor shall be manufactured of aluminium of at least 99,5%purity.

The conductivity and current carrying capacity of compression type clamps and joints shall not be less thatn that of the conductor.

The clamps shall clamp the stranded conductor effectively under all conditions including repeated cyclic heating resulting in clamp remperatures varying between minus 5°C and plus 95°C.

Phase conductor jumper terminals

Jumper terminals shall be of the compression/bolt type arranged for compression jointing to the conductor and bolt-on to other clamps as for instance strain clamp flags.

The connection between jumper terminals and strain clamps shall be arranged such that the jumper conductor approaches the extended centre line of the line conductor at an angle of between 60°C and 75°C.

The bolt-on surface or palm of jumper terminals shall be machined to provede a flat and reasonable smooth contact surface which shall be protected against oxidation by approved means.

Jumper terminals shall be bolted to strain clamps by means of at least two M12 bolts. All jumper terminals shall be supplied complete with all necessary bolts, washers, spring washers and nuts as required.

Jumper terminals shall comply with the requirements for current carrying clamps.

Tension joints (Midspan joints)

If the use of a midspan joint is approved by the Engineer midspan tension joints shall be of the compression current carrying type and shall be of approved design.

Tension joints shall not allow any slip of the conductor and shall have a mechanical strength not less than 100% of the ultimate strength of the conductor when tested in accordance with BS 3288 Part I.

Compression type tension joints for steel reinforced aluminium conductor shall comprise of compression sleeves; an inner steel sleeve to transmit mechanical tension from steel core to steel core of the conductor, and an outer aluminium compression sleeve mainly for current transfer.

Steel compression sleeves shall be used for midspan jointing of earth wires, if approved.

Compression type joints shall comply with the requirements for current carrying clamps and joints specified elsewhere in this Specification.

Conductor repair sleeves

Should isolated strands of the conductor be damaged during erection, repair sleeves may be permitted at the discretion of the Engineer. The type and manner of fitting shall be to approval.

Coductor repair sleeves shall not be used on stranded conductor which has been kinked.

Phase conductor spacers

On twin conductor lines, the two conductors in each phase conductor shall be disposed horizontallyt and spaced throughout the entire span at the centre line spacing specified in the Schedule of Basic Parameters by means of suitable spacers of approved design.

Spacers shall be fitted at regular intervals not exceeding 75 m along each span with the first spacer in each span fitted at 10 m from the tower centre line.

Line spacers shall be of the flexible ring type allowing limited relative longitudinal movement between conductors as well as limited torsional movement of each conductor.

Rigid spacers shall be used ontwin jumper connections as well as ontwin down droppers and twin ganry spans. At least three spacers shall be fitted at intervals not exceeding 3 m.

All spacers shall be light and of robust construction.

Spacer clamps shall be designed so as to avoid any possibility of deforming the stranded aluminium conductor or separating the individual strands.

Spacer clamps shall be designed with an adequate radius of curvature at the clamp mouth to prevent the clamp “biting” into the conductor.

U-bolts employed on spacer clamps shall not clamp directly onto the conductor. Conductor keeper plates of suitable design shall be used to clamp down onto the conductor. Unless otherwise approved the spacer clamp body and keeper plate(s) shall be made of aluminium.

All bolts, nuts and washers and other ferrous part of spacers shall be galvanized to SABS 763. All nuts on spacers shall be locked in an approved manner.

Spacers shall comply with the test requirements of SABS 178 and/or BS 3288 Part I.

Vibration dampers

Stockbridge pattern vibration dampers shall be fitted to all phase conductors and to both earth wires on all spans exceeding 50 m to damp conductor vibrations.

The mass of vibration dampers on phase conductors shall be approximately 6 kg and that of earth wire dampers approximately 1,5 kg.

On all conductors the bivration damper shall be fitted at a distance of 1,25 m from the conductor support point or conductor attachment point. On spans exceeding 360 m a second damper shall be fitted on each conductor in a position 1,25 m out from the first damper.

All dampers shall be of approved design and construction.

15. OPTICAL FIRBRE MATERIAL

Optical fibre ground wire (OPGW)

A composite earthwire with forty-eight (48) individually identified optical fibres shall be supplied and installed where specified.

The composite earthwire characteristics shall be similar or better thatn the conventional earth wire in operation.

The optical fibre earthwire will be used for the vital protection and control functions of the terminal substations where reliability and proven integrity under Pretoria service conditions are essential.

Full details of service experience giving type of system, lenth of line, location and years in service and the direct effect of lightning on the optical fibre shall be provided. Full Type Test information shall be provide.

The optical system will operate at 1 300Nm. The average maximum attenuation shall not exceed 0.15 dB per km.

The OPGW shall be in drum lengths commensurate with tension tower spacing in order to minimise the number of joints in the line.

The optical fibre contained within the OPGW shall be of the loose buffered type with fibres housed in individual grooves in a helically grooved extruded aluminium alloy former within an extruded aluminium tube. The earthwire itself shall consist of aluminium clad steel wire.

Optical fibre cable

Normal underground optical fibre cable for connection between the tower and the substation will be enquired and shall be non-armoured with 48 individually identified optical fibre cores with a strength member and orange colourd outer PVC sheath.

The optical characteristics shall be the same as the OPGW.

The non-armoured cable shall be installed in a 32 mm high density polythene pipe.

16. SETTING OUT AND NOTIFICATION

General

The power line(s) is/are to be erected along the route(s) shown on the route plan(s) to be provided by the Council. Unless otherwise specified or directed by the Engineer, the power line is to be erectedon the centre line of the route shown on the route plan.

The necessary wayleaves and right of access will be obtained by the Council. Obstructions, which in the opinion of the Engineer have to be cleared, and certain trees on the route will be cleared by the Council to enable the Contractor to carry out the erection of the line. The Contractor will have to make his own arrangements and provide the necessary scaffolding or other means to cross over the remaining obstacles such as fences, structures, roads, railway lines, telephone lines, etc.

Access to the line route I available at several positions along the route, therefore no special access will be provided by the Council, Tenderers shall acquaint themselves fully as to the access required on site and provide in the contract price for any special access to be built, as no extra claims will be entertained by the Council at a later date.

Particulars of ground contours along the route on which the power line is to be erected are shown on the profile drawings. The necessary surveyed profile drawings will be provided by the Council on which side-slope information is indicated in positions where side-slopes in excess of 1:10 are encountered. The Contractor shall show the following information on such profile drawings all of which shall be approved by the Engineer before the Contractor commences setting out foundations:

Tower positions.

Tower type number and if applicable tower base extensiontype number at each tower position.

The sag curve of the bottom phase conductor at maimum operating temperature between towers.

The 7,5 m clearance curve from bottom phase conductor at maximum temperature.

Sag curve(s) of bottom phase conductor in spans crossing railway lines or proclaimed roads under broken line (adjacent span) conditions.

Minimum weight span length on every tower.

Maximum weight span length on every tower showing the contribution from each span adjacent to tower.

Windspan length on each tower showing contribution from each span adjacent to tower.
Position of maximum sag at macimum conductor operating temperature.
Position of maximum sag at minimum conductor temperature.
Equivalent span length of strain section.
Actual length of each span.

Prior to the stage of crossing any overhead services, public roads, railway lines or pipe lines with the stringing of conductors, or installation of counterpoise earth conductor, the contractor shall give adequate notice to the appropriate authority of the date and time of the proposed work and make the necessary arrangements for the protection of the services and the safety of the public at his own cost.

The contractor shall give adequate notice of the commencement of work to occupiers of all properties to be traversed and shall at his own expense make good any damage caused to crops, fences, gates, gardens, walls, roads, or other property.

At all crossings of public roads, railways, telephone, telegraph and other power lines the provisions of the Factories, Machinery and Building Wrok Act, 1941, as amended, shall be complied with to the approval of the Engineer.

Prior to erection, the Representative of the Contractor shall ascertain from the Engineer which part of the work, and at what stage, he wishes to inspect and approve contract work from time to time. Adequate notice shall be given to the Engineer to enable him t carry out such inspections.

As each part of the Contract Works is erected the Engineer shall approve it. This particularly applies to the setting out, installation of buried earths, foundation construction, the levelling, aligning and adjusting of the various parts. No approval given by the Engineer will exonerate the Contractor from his contractual obligations or his guarantees under the contract.

Tenderer to inform himself fully

The onus is on the tenderer to inform himself fully as to details of the Work involved and Plant and Equipment required for carrying out the contract. Tenderers shall visit the sites to familiarize themselves with all conditions on site before Tenderers are submitted. Tenderers shall allow for all conditions on site. No claims for extras will be allowed whatsoever if Tenderers failed to allow for all costs and any conditions peculiar to the site.

17. INSTALLATION, ERECTIONAND SITE WORK

Excavations

Prior to tendering, Tenderers are to inform themselves fuilly as to the nature of the ground to be excavated throughout the route, as the cost of excavation shall be included in the unit price for the installation of foundations and structure earthing regardless of the type of material which will be encountered. It shall be distingctly understood that the Council will not be responsible for any variations in the strata and tyope of material and under no circumstances will be Contractor be paid an extra price due to such variations.

Any additional excavation in excess of the excavation required for the standard foundation, in order to establish suitable subsoil or bearing area, shall be approved by the Engineer, and shall be paid for at the unit rates for such excavations to be quoted in the Price Schedules.

The Contractor shall at his own expense provide means for maintaining the excavations for foundations in a dry state free from storm-water, seepage water or any other water.

The excavated material shall be stacked as compactly as possible, consistant with safety of workmen and the Works and the Contractor will be held responsible for making good at his own expense any damage caused by the excavation of such stacked material.

As soon as possible after the shuttering has been struck the foundation shall be back-filled in even layers of not more than 300 mm thick, each of which shall be well rammed down.

The foundations shall in all respects comply with the requirements of clause 10 of the specification.

Erection of towers and structures

No tower or structure shall be erected on any foundation within 14 days after being cast.

Prior to the erection of any conductors all towers and other structure shall be vertical within a tolerance of 0,3 per cent the total structure heidht measured at the top of the structure.

Earthing resistance shall be measured on all foundations prior stringing as described under clause 11 of the specification.

All bolts and nuts below 3 m above ground level shall be locked by punching with a heavy centre punch to make the removal thereof without special tools impractical.

After back-filling the concrete encasement cap and the base steelwork shall be treated as detailed under clause 10.2.4.

Stringing and sagging of conductors

The method of stringing, the utilization of conductor lengths to minimize the number of joints and the type of equipment to be used for erection shall be to approval. Come-along clamps used for stringing shall be of the proper size, especially on the OPGW. No joints will be allowed in the crossing spans over roads, railways, buildings, other power lines or important communications lines or in any strain section of three spans or less.

The Contractor shallsatisfy the Council that he has wide experience in the erection of power lines of this nature. If in the opinion of the Engineer, the work I carried out in an inefficient and unsatisfactory manner, the Engineer shall have the power to onrder the Contractor to employ additional plant, tools, labour or anything he may see fit in order that the work may thereafter be executed ina proper and efficient manner at no extra cost to the Council.

The Contractor shall take all precautions to prevent excessive loading of towers during erection and shall provide any temporary staying of towers where necessary.

Rubber faced snatch blocks, scaffolding and/or other approved devices shall be employed during stringing to avoid any contract between the conductor and the ground or other obstructions. No extra charges for providing such equipment or manhandling of materials during abnormal stringing and sagging operations over buildings, other overhead services, roads, railways and communication circuits or other obstructions will be allowed.

The cut ends of all conductors shall be tied by wire binders and painted or treated in an approved manner to prevent oxidation and the ingress of moisture.

Vibration dampers and conductor spacers shall be installed as soon as possible after the erection of the conductors.

Suitable dynamometers, sag scopes, sighting rods or other approved devices shall be provided by the Contractor for the proper checking of the work.

The sagging of conductors shall be done on the equivalent span method, whereby the tension of the strain section will be calculated for the equivalent span and the equivalent span length is calculated from the formula:

$$Le = \sqrt{\frac{L_1^3 + L_2^3 + \ldots\ldots\ldots\ldots\ldots\ldots L_n^3}{L_1 + L_2 + \ldots\ldots\ldots\ldots\ldots\ldots L_n}}$$

Where Le = Equivalent (or ruling) span length
L_1 = Length of first span in strain section
L_2 = Length of second span in strain section
L_n = Length of nth span in strain section

Phase conductors and earth wires shall be erected with such sags in still air that, at a conductor temperature of minus5°C and under maximum wind loading conditionsand with the assumed maximum simultaneous work loads specified in clause 8, the failing strength of the conductor and failing loads of the tower, tower foundaton, insulator sets or fittings are not exceeded whilst maintaining the minimum factors of safety specified in the Schedule of Basic Parameters, The everyday-stress in the conductor shall also not exceed 25% of the ultimate strength. The design maximum working tension in phase conductors and earth wires shall be stated in the Schedule of Particulars and Guarantees.

In calculating the sags and tensions for the different spans at erection temperature, due allowance shall be made for the elasticity and coefficients of expansion of the conductor materials.

In order to allow for any permanent settlement of the conductors after erection, the conductors shall be over-tensioned to approved curves and sag charts clearly indicating the intial and final sags and tensions at defferent temperatures of the line and earth conductors.

The Contractor shall submit for approval curves or tables showing the correct initial and final sags and tensions of the line and earth conductors at various temperatures and spans, the former making allowance for such permanent stretch as might take place in service.

The actual sag of any conductor shall not differ more than 3 per cent from the calculated sag for that span, and shall not differ by more than 100 mm from the mean of the sag of all the conductors in that span. For twin conductor lines the difference in sag of the conductors of a pair shall not exceed 30 mm. Any adjustments required to comply with these requirements shall be carried out by the Contractor at the end of the maintenance period at no extra charge to the Council.

The appropriate ambient temperature shall be determined by means of a thermometer inserted in the end of a 1,5 m section of conductor from which a 150 mm length of centre strands have been removed. The conductor with the thermometer inserted shall be hung at cress-arm level for at least two hours before the temperature is read.

The Contractor shall also be responsible to ensure that the mass carried by any suspension insulator string under the above tensions at minus 5°C in still air, be not less that the minimum weight span specified in the Schedule of Basic Parameters. If required, the Contractor shall prove this to the Engineer and shall be responsible for any alterations which may be required in order to comply with the above specified requirements.

The Contractor shall satisfy himself as to the correctness of all connections made between plant and apparatus supplied under this Contract and Plant and apparatus supplied under any other contract before any of the former is put into operation.

The carrying out of all work included inthis contract shall be supervised throughout by a sufficient number of qualified representatives of the Contractor who have had thorough experience in the erection and operation of apparatus similar to that to be supplied.

Stringing of the optical fibre earth wire shall be done by the main contractor under the supervision of the OPGW supplier. The maximum permissible pulling tension for the offered OPGW and the pulley diameter for stringing shall be specified with the tender.

Optical fibre work

Joint boxes shall be mounted on the inside of the tower immediately above the anti-climbing device on a horizontal beam. The earth wire shall be properly clamped on the inside of the tower leg at 1,5 m intervals or less.

Where earth wires are specified to be insulated, the joint boxes shall be mounted on top of the earth wire tower cross arm.

All stringing clamps shall be installed with armour rods, to prevent damage on the inner aluminium tube. Bolts on all tension and suspension clamps shall be tightened with a torque wrench to the specified torque of the OPGW supplier.

The Contractor shall be responsible for jointing and shall, therefore be equipped with all the necessary specialised tools and test equipment and shall have staff capable of performing such a function.

The Tenderer shall describe the jointing method to be employed both on the optical fibre ground wire and the underground optical fibre cable.

The Contractor shall have a full after service facility so that the Council may call on these services with immediate response available to perform jointing and testing at the request of the council should this be necessary once the line is in service.

Where applicable each fibre optic splice shall have a loss of less than 0,15 dB/joint.

The OPGW shall be terminated at each end in a tower mounted joint box. From this joint box, all optical fibres shall be extended into the respective substation or control room, as the case may be, by means of the required length of underground type optical fibre cable, laid from the outdoor termination box, through the substation yard in high density polythene pipes. The pipes shall be laid in the ground at a depth of 0,9m, where no ducts exist. The trench shall be backfilled and compacted in layers of 300 mm up to ground level. In the substation, or control room, the underground optical fibre in the indoor cubicle shall be spliced into a 5 m length of reinforced fibre pigtail, and where applicable, the fibre optic cores shall be terminated in an approved manner using type ST connectors.

Incidental work

If directed by the Engineer, the Contractor shall install access gates in fences on the power line servitude at the unit prices quoted in the Form of Tender.

Steel gates with tubular frames complying with the requirements of CKS 146 shall be installed on steel posts with stays complying with the requirements of CKS 82. All fencing wire used shall be galvanized in accordance with SABS 935.

Facilities for locking the gate by means of a length of 10 mm chain and a padlock shall be provided. The padlocks will be supplied by the Electricity Department and the Contractor shall fit them. The chain shall be fixed to the gate post.

All posts and stays shall be set in concrete.

Working in live yards

Site work in energised (live) yards will only be permitted under cover of a Permit to Work, issued by the Chief Distribution Engineer (Operations) or his duly authorized representative and then only under such conditions as may be laid down in the said Work Permit. Work in live yards shall be carried out under the constant, direct and strict supervision of a competent responsible person so appointed in writing by the Contractor. In the above context "competent person" shall have the meaning as defined in Chapter I of the Regulations appertaining to the Machinery and Occupational Safety Act.

The contractor shall apply in writing for the necessary Work Permit(s) and shall submit with his application the following particulars:

Full name, designation and other particulars of the responsible person appointed by the Contractor together with a copy of his letter of appointment.

The date, time, period and detailed purpose for which access is required to each site or yard.

The names or identity numbers of all persons (including sub-contractor employees, if any) for whom access is required under the responsibility of the Contractor's responsible person.

In order that the Council may make the necessary arrangements, each application for a Work Permit shall be submitted to the Engineer, together with all the required particulars, at least three full working days before access to the site or yard is required.

The Work Permit hall be made out to the contractor's responsible person who shall have the responsibilities and duties stipulated in Regulation C.1(6) issued under the Machinery and Occupational Safety Act who shall be responsible to see to it that the conditions laid down in the Work Permit are fully complied with by himself and all persons under his control.

When working in live yards the contractor shall ensure that all his workmen, employees and sub-contractors obey the Council's Safety Rules, a copy of which may be obtained from the Chief Distribution Engineer (Works).

With regard to safety, the Council in its own discretion may appoint one of its own employees to supervise safety aspects on a full or part time basis while work is carried out in live yards or in the vicinity of live equipment. The contractor's responsible person shall comply with, and shall see to it that safety instructions issued by the Council's supervisor, are complied with by all persons working under the responsibility of the responsible person.

On completion of the work in live yards the responsible person shall sign off the Work Permit and shall not leave the site without signing off the Work Permit and returning it to the issuer. Should the contractor fail to have this requirement strictly observed, he shall render himself liable to pay all direct and indirect costs which the Council may incur in having the Work Permit signed off, which cost may include the loss of revenue in respect of equipment remaining switched out or the purpose of giving the contractor access.

In the case of work to be carried out on existing power lines or equipment in operation or work to be carried out so close to existing live equipment that switching out is required, the contractor shall prepare a proposed programme of the work for discussion with the Council's Operation Staff, which programme shall be submitted for approval to the Engineer at least three weeks prior to the proposed access date. If required, the contractor of his duly authorized representative shall be present to discuss the proposed programme with the operation staff.

With regard to switching out of equipment to facilitate contract work to be carried out, it shall be distinctly understood that switch out dates, times and periods are subject to load and operational requirements. Operational and/or load requirements may dictate that contract work on the existing network be carried out over weekends or outside normal working hours, and the contractor shall therefore quote as an extra to contract for alterations to existing power lines to be carried out outside normal working hours.

For stringing new lines parallel and close to existing power lines, the contractor may apply for the nearest circuit on the existing line to be switched out to reduce induced voltages in the conductors to be erected. Should load and operational conditions permit it, the circuit will be switched out for such period(s) as it may be feasible but the Council reserves the right to switch back the circuit on very short notice to the contractor. Should it not be possible to switch out the nearest parallel circuit as contemplated above, the contractor shall take such safety precautions as may be required and provide such measures as the Engineer may direct to prevent damage to the existing line at no extra cost to the Council.

Security measures

Work inside electrical yards are subject to the Council's security measures and the contractor shall contact the Council's Chief Security Officer at telephone number 313-7480 prior to the commencement of any work under the contract to make the required security arrangements. The cost of security measures shall be included in the rates for site work.

If so required by the Council, all employees of the contractor his subcontractors employed with regard to the execution of the contract, shall be security cleared on such conditions as laid down by the Council.

Should any employee of the contractor or his subcontractor, for whatever security reasons, be declared unfit, the contractor or the subcontractor shall have the right to appoint any person in lieu of the employer who had been disqualified for security reasons, subject to the Council's security clearance.

The contractor undertakes –

To treat all information regarding the contract and the execution thereof as strictly confidential;
That he himself, his subcontractors and all employees concerned, will sign the Council's Declaration of Secrecy;
In the execution of the contract, to report to the Council's Chief Security Officer, without delay and donfidentially, any information regarding:

1) Any suspected espionage in respect of the lay-out of the site where the work is being executed, or in respect of sites where protective measures are applied;
2) Actions which may be interpreted as sabotage, or any planning in this regard;
3) Any suspected subversive activities among these employees
4) The loss of any classified documents which came into his possession as a result of the contract

5) The contravening of any security measure by an employee
6) Housebreaking, theft, arson, vandalism, loss of identity documents, security keys or lock combinations
7) Corruption, blackmail, intimidation, striking or inciting or unauthorized access to an office or premises;
8) Any employee who has ties with a person who has recently come from a Communistic country, or who has relations with a person sympathizing with Communism; and
9) Any employee who is involved with the contract and who is suspected of bringing drugs, intoxicating liquor, a weapon, ammunition or explosives on the site of the Council.

The Council shall have the right to inspect, al all reasonable times, and through its Security Sub department, the contractor's and subcontractor's premises and offices where work in connection with the contract is executed or where documents in that connection are kept, in order to prescribe suitable security measures, and to determine whether the prescribed security measures are being implemented satisfactorily.

Storage of Materials

The contractor shall be solely responsible for all security arrangements for the safe storage of materials on site and the arrangements for the safe storage of materials on site and the arrangements for safe storage positions along the route. The Council will not be liable for any loss or damage of any materials or equipment whatsoever.

Prices for supply and delivery of materials shall allow for all railage, transport, handling, loading and offloading on site.

The receiving on site of all materials and the handling thereafter is the responsibility of the contractor.

Working hours

Site work carried out for the execution of this contract, shall be confined, as far as possible, to normal working hours on normal working days (i.e. 07:00 – 17:00 on Mondays to Fridays) excluding Public Holidays.

Work to be done outside normal working hours shall be approved by the Engineer who shall be notified of the reasons in writing at least three working days in advance of any work to be done outside normal working hours.

Clearing site

On completion of the contract the contractor shall clear the site of all temporary offices, sheds, temporary structures and of all stumps, boulders, debris, surplus excavated material, waste material and rubbish. The contractor shall level off all ground on the site and shall reasonably prior to the commencement of such works, except where otherwise provided for, and shall leave the site in a clean and tidy order, to the satisfaction of the Engineer. Waste, rubble, rubbish and surplus excavated material shall be dumped at one of the Council's official dumping sites.

The cost of clearing the site shall be included in the various prices for work.

18. RECORDING

The contractor shall keep accurate records of the positions of all conductor joints, temperatures, sags and tensions for each strain section, the positions where counterpoise earthing is installed as well as tower types, extensions and positions of towers. On completion of the contract the contractor shall supply to the approval of the Engineer, fully marked-up transparencies of the profile drawings with all the complete schedules of particulars of all items used and installed on the line, for reference when repairs or modifications are to be made.

19. TESTS AND TESTING

Testing general

All materials and equipment supplied to this specification shall be tested in accordance with the requirements of the relevant Standard Specification referred to and in accordance with the requirements specified hereafter.

Notice of all testing shall be given to the Engineer in accordance with clause 69 of the Conditions of Contract.

All instruments required for testing shall be approved and if required, shall be calibrated at the expense of the contractor by the South African Bureau of Standards or such other body as may be approved.

Factory routine and sample tests shall be regarded as an integral part of the manufacturing of the various items and shall therefore be allowed for in the unit prices quoted for supplying.

Site and commissioning tests shall be regarded as an integral part of the installation of the various items and shall be allowed for in the unit prices quoted for installation.

Three copies of the manufacturer's records of all factory tests shall be furnished to the Engineer, immediately after such tests and before any material is shipped. No material shall be installed before these tests have been officially approved by the Engineer.

Three copies of the contractor's records of all site and commissioning tests shall be furnished directly to the city Electrical Engineer, P O Box 423, Pretoria, 0001, immediately after completion of such tests.

Type tests

The contractor shall satisfy the Engineer that the following equipment has been type-tested successfully, or is certified to have been type-tested successfully in accordance with the specified requirements laid down in the appropriate Standard Specification and if required by the Engineer, the Contractor shall furnish copies of the relevant type test certificates:

A.C.S.R. conductor to SABS 182 Part III or BS 215 Part 2.
Earth wire and supplementary earthing conductor to SABS 182 or BS 183.
Insulators to SABS 177 or BS 137
Line fittings and clamps to SABS 178 or BS 3288
Galvanizing to SABS 763 and 935 or BS 729 and BS 443 (as applicable)

Type-testing of towers and supporting structures shall be to approval and shall be fully detailed in type test certificates.

Existing type test certificates will be considered on their merits and Tenderers are requested to submit copies of existing type test certificates with their tenders. Should reasonable doubt arise as to the validity of test certificates submitted after acceptance by the Engineer in relation to the equipment actually to be supplied, for example by virtue of modifications to the equipment, the Engineer may direct that a further certificate(s) be obtained on a sample unit(s) manufactured under the contract at the expense of the successful tenderer. Such further testing shall be carried out by an independent recognised testing institute.

If type-testing is to be done specifically for the purpose of this contract, testing shall be carried out in accordance with the following specified requirements by an independent recognised testing institute approved of by the Engineer at the prices to be inserted in the Form of Tender.

Type-testing of supporting structures

If required by the Engineer, one tower of each standard type, with or without base extension as specified, shall be assembled and erected at the approved testing station. Such towers shall be erected on a rigid test foundation and the erection shall be done consistent with the practice used on site.

Each tower shall then be subjected to such test loads as the Engineer may specify in order to prove compliance with the factors of safety stated in clause 8 in an approved manner, without showing signs of failure or permanent distortion in any part.

If required by the Engineer, tests to destruction shall then be carried out in an approved manner on all or any of the towers submitted for test.

Unless specially approved, steel towers submitted for test shall be galvanized.

No parts of any tower which has been submitted to test loads shall be used on the Contract Works.

Gantries shall be tested in a similar way.

Corona tests

If required by the Engineer, one suspension insulator set and one tension insulator set of each type (to be selected by the Engineer), complete with all fittings as in service and with insulator strings approved by the Engineer, shall be tested when clean and dry as follows:

19.2.6.1.1 A length of not less than 5 m of the specified conductor (or aluminium tubing with equivalent diameter; at the discretion of the Engineer) shall be fixed to the conductor clamp in the manner adopted in service. The tension set shall be supported vertically under a nominal tension of 1 000 N parallel to and at a distance of 1 400 mm from an earthed vertical “wall”. The “dead” end of the et shall be earthed.

19.2.6.1.2 The test voltage shall be applied between the conductor and earth for not less than 10 minutes during which time the room shall be in complete darkness.

19.2.6.1.3 The voltage of any visible corona shall be noted with the aid of binoculars having 50 mm x 8 objectives.

19.2.6.1.4 No corona shall be visible on the fittings at any voltage below an applied voltage of 1,2 times nominal phase to neutral (earth) voltage.

Routine and sample tests

All routine and sample tests as laid down in the appropriate Standard Specification shall be carried out in accordance with the requirements of such Standard Specifications by the manufacturer at his factor (or at an alternative place of testing as specified or approved).

Samples of the materials for the towers and fittings shall be sample tested in accordance with the latest issue of BS 4360.

Fibre optic testing

A certificate giving the optical characteristics for each drum shall be submitted to the Engineer on delivery to site and thereafter the following tests on the fibre shall be performed.

<u>TEST 1:</u> Testing of the fibre per drum prior to stringing (continuity test).

<u>TEST 2</u>: Testing of the fibre after stringing (continuity test)

<u>TEST 3</u>: During jointing each connector loss (splice loss) shall be measured in dB using an optical time domain reflectometer (OTDR). The result shall be printed out and the corresponding distance and attenuation measurement determined from the plot.

<u>TEST 4</u>: A total test from both ends of the line including all joints. The object of the test is to measure the attenuation of each fibre from both ends including all fibre splices.

Site and commissioning tests

After erection of the towers but before any stringing operations, the contractor shall accurately measure and record the tower footing resistance of every tower and gantry installed under the contract.

The contractor shall carry out such site testing as the Engineer may reasonably call for to determine compliance with the specification, which testing shall be carried out in the present of the Engineer.

If so required by the Engineer, the contractor shall be available on site and shall render such assistance as the Engineer may reasonably require from him during commissioning of the equipment.

20. PAYMENTS, MEASUREMENTS AND RATES

Payment general

No invoices will be authorized for payment without the necessary substantiating documents to prove measurements or actual quantities of work done as certified by the Engineer.

All payments shall be subjected to the “Terms of Payment” and shall be made in accordance with the Conditions of Contract. (See also clauses 12,17,75,76,77 and 78 of the Conditions of Contract)

Payments for conductors, towers and fittings will be adjusted for the actual measured and true quantities after completion of the work. Likewise progress payments will be made on application by the contractor (refer to clause 75 of the Conditions of Contract) for total quantities measured.

Payment of clerk of Works

The Council may appoint and pay a Clerk of Works for the specified period of the contract, as stated in clause 50 of the Conditions of Contract.

Sum for plant and establishment

The sum provided in the Price Schedule for plant, shall include for the supply, delivery, erection, maintenance and removal on completion, of all plant of every description together with all tools required for the complete carrying out of all work under this contract.

The Contractor’s claim for the sum for plant and equipment will only be considered on completion of the contract provided no plant, equipment or labour has been withdrawn (without the Engineer’s consent) from the contract, whereby completion of any part of the contract has been delayed.

Measurement of work

The measurements of lengths for the purpose of payment for conductors shall be to the nearest metre and shall be made by the contractor in the presence of the Engineer. These measurements shall normally be made along the centre line of the completed power line measured on ground level if suitably even or calculate as the straight line length between the centre lines of towers and no allowance shall be made for any sag. Measuring-up shall be subject to the provisions of clause 74 of the Conditions of Contract.

After inspection of any trenches required for supplementary earthing, (specified under clause 11) payment will be made on a basis of lineal metres of completed trench measured by the contractor in the presence of te Engineer after installation of the counterpoise cable but prior to back-filling. This payment for trenching shall include excavation, back-filling and reinstatement of the trench and shall be paid for as the installation of counterpoise as specified under clause 11.

Measurements of the mass of extra steel required shall be calculated from approved working drawings to the nearest kilogram, assuming a density for steel of 7,843 g/cc. These calculations shall be jointly made by the contractor and the Engineer.

Payment for foundations

The payment for foundations shall be at the unit prices for the applicable type of foundations quoted in the price schedules. These prices shall include the cost of soil investigations, excavations, drilling, provision and installaton of earthing tapes (refer to clause 11.2), foundations steelwork and reinforcement, shuttering and/or templates as well as the dismantling thereof, the provision and installation of concrete and the proper back-filling and reinstatement of the excavations.

As specified under clause 17.1.1, no extra prices will be considered for foundation excavations due to changes in the types of materials to be excavated and no consideration shall be given to any claims for shuttering to be placed, as the Contractor is required to inform himself fully as to the nature of the materials to be excavated prior to tendering.

Excavation required in excess of that of the applicable standard foundation, in order to establish suitable subsoil, or bearing area, shall be measured and approved by the Engineer and shall be paid for at the appropriate unit rates for such additional excavations quoted in the price schedule.

The actual measured and approved quantities of all sub foundation filling as specified under clause 10.4.2 shall be paid for at the unit rate provided in the Schedule of Prices.

Payment for towers and fittings

All standard towers shall be paid for at the appropriate unit prices for towers quoted in the Schedule of Prices. The unit price for each type of tower shall include the following in accordance with the specified requirements:

Tower steelwork for standard towers including foundation steel and earth tape.

Bolts, nuts and washers.

Anti-climbing devices, climbing bolts, bird anti-perching guards, danger, property, number and phase plates and other tower accessories.

All line hardware such as the required number of insulator assemblies complete with insulator strings, shackles, links, sag adjusters, yokes and live-end arching horns, the required number of suspension clamps or strain clamps (compression dead ends), vibration dampers, jumper terminals, jumper loops, jumper spacers and all other conductor fittings for six phase conductors (single or twin as applicable) and two earth conductor suspension sets complete with suspension clamps or the required number of earth wire tension sets complete with earth wire tension clamps, bonding loops, earth wire terminals, and the required number of earth wire vibration dampers, all as required for the particular type of tower.

The above prices shall be based on the following:
Phase conductor insulator strings …………………..…. 10 discs only
Arching horns …………………………………………… Live end only
Earth wire assemblies ………………… without earth wire insulators
Vibration dampers ……. 1(one) per conductor on each side of tower

The unit rate for tower erection shall include the cost of measuring the tower footing resistance before stringing.

Should any additional items be required to a tower or its fittings, these quantities shall be approved by the Engineer and shall be paid for at the appropriate rate in the Schedule of Prices.

No payments will be made for any tower and its accessories prior to satisfactory completion by the contractor and inspection by the Electricity Department.

Where individual tower leg extensions are required on sloping ground, such extensions shall be measured in accordance with clause 20.4.3 and will be paid for at the rate for such steelwork in the Schedule of Prices.

Any special towers, major modifications to the main structure of standard towers or special foundations shall be approved by the Engineer and shall be paid for at the appropriate rates in the Schedule of Prices. Should provision not be made in the Schedules, the Tenderers shall advise and agree such rates with the Engineer beforehand, since failing to do so will result in the costs being taken as included in the normal prices and rates.

Payment for time and material work

Extra work which is ordered by the Engineer in writing and which is not covered by the contract, shall be undertaken by the contractor on a day-work basis. Such day labour as may be required for such work shall be provided by the contractor at the rate(s) of wages inserted by the tenderer in the appropriate price schedule in the Form of Tender.

Where the contractor is required to supply material(s) in connection with such day-work as may be ordered, and no provision has been made in the price schedule(s) for the supply of such materials, the tendere shall state in the Form of Tender the percentage over actual cost price on which the contractor agrees to supply such materials as may be required.

The contractor shall, when required by the Engineer, produce all variation orders, correspondence, quotations, invoices, vouchers and receipted bills, time sheets and any other particulars necessary to enable the Engineer to certify as to the correctness of claims for payment made in terms of this clause.

Vouchers specifying the time spent and materials used shall be delivered to the Engineer before the end of the week following that in which the work is carried out. Failure to comply with the requirement may render the claims liable to rejection.

21. DRAWINGS ISSUED WITH ENQUIRY

The drawings will be issued with the enquiry document for tender purpose.

22. DRAWINGS & DESCRIPTIVE LITERATURE TO BE SUPPLIED BY TENDERERS

All Tenderers shall supply with their tenders paper copies of the following drawings relating to the equipment offered:

Dimensioned general outline and arrangement drawings for:
Each type of tower offered.
Available base and leg extensions for each type of tower offered.
Alternative cross-arm lengths available for each type of tower offered with alternative cross-arm lengths.
Each type and size of portal gantry offered.

Dimensioned and to scale clearance diagram clearly showing cross-arm arrangement, conductor to ground clearance and conductor to steelwork clearances in still air and under specified maximum conductor swing conditions for each type of tower and gantry structure offered.

Dimensioned drawings showing foundation lay-out and full details of foundations and foundation excavations for:

Standard block type foundations for each type of tower offered without and with base extensions up to the maximum height offered.
Block type foundations for each type and size of gantry column offered.
Special non-standard foundations offered (e.g. rock anchor foundations).

Dimensioned general arrangement drawing showing details, catalogue reference number and mass of each component, part or fitting in:

Double tension insulator assembly (set) for twin conductor line.

Tension insulator assembly (set) for single conductor line.

Suspension insulator assembly (set) for twin conductor line.

Suspension insulator assembly (set) for single conductor line.

Low duty tension set for twin conductor line.

Low duty tension set for single conductor line.

Reverse low duty tension set for twin conductor line.

Reverse low duty tension set for single conductor line.

Earth wire tension assembly (set).

Earth wire insulated tension assembly (set).

Earth wire suspension assembly (set).

Earth wire insulated suspension assembly (set)

Earth wire tension assembly (set) for OPGW.

Earth wire insulated tension assembly (set) for OPGW

Earth wire suspension assembly (set) for OPGW.

Earth wire insulated suspension assembly (set) for OPGW

Drawings showing the voltage gradient across each disc insulator unit in tension and suspension strings with arcing horn fitted to live end only and operating at system voltage.

Detailed drawings of:

Phase conductor tension clamp (compression type dead end).

Phase conductor suspension clamp

Earth wire strain clamp

Earth wire suspension clamp

Twin conductor line spacer.

Twin conductor jumper spacer.

Phase conductor midspan joint.

Phase conductor repair sleeve.

Phase conductor jumper terminal.

Earth wire midspan joint.

Earth wire terminal.

Counterpoise earth conductor terminal.

Phase conductor vibrat5ion damper.

Earth wire vibration damper.

Anti-perching guard.

Tower OPGW joint box.

Tower OPGW joint box with insulated gland plate.

Each Tenderer shall return with his tnderer one set of enquiry profile drawings on which his provisional power line design shall be shown with the positions and types of towers and types of extensions offered. The position and magnitude of maximum and minimum weight spans and windspan for both phase conductor and earth wire in respect of each span and individual tower shall be clearly shown for the provisional design.

Tenderers shall also return with their tenders one set of route plans on which the tower positions and types of towers with provisional tower numbers corresponding to his provisional design are clearly marked up.

Tenderers are invited to furnish such other drawings and descriptive literature as they may think fit with their tenders in amplification thereof.

Tenderers shall submit with their tenders the type test certificates and/or certified design certificates specified under Clause 9.1.10.

23. DRAWINGS AND LITERATURE TO BE SUPPLIED BY CONTRACTOR

The successful tenderer shall submit duplicate prints of the following drawings for approval to the Engineer, after which approval a durable set of transparencies of the said drawings, as approved, shall be supplied by the contractor for the permanent recodes of the Electricity Department not later than the delivery to site date of the equipment.

All drawings specified under clause 22.1 which drawings shall be to scale, fully detailed and show metric dimensions.

Fully detailed drawings to scale and showing metric dimensions of the following

Tower leg extensions to be used on the contract.

Arrangement of anti-climbing device on towers.

Arrangement of anti-climbing device on gantry columns.

Danger and property plate.

Town number and route identification plate.

Circuit identification plates or discs.

Phase identification plates or discs.

Full constructional details in respect of each type of tower and structure to be supplied showing the part and member reference codes or numbers called for in clause 9.4.2.

Erection information and drawings complete with structure lists detailing materials required for each tower or structure.

Special foundations or structures required under the contract.

Such other items of which the Engineer may require drawings.

Stress diagrams for all types of structures to be supplied.

Within two months of the contract being awarded, the contractor shall submit for approval a duplicate set of prints of profile drawings on which his proposed power line design together with all the relevant information called for in clauses 16.1.4 and 21.2 is shown. For this purpose a set of transparent surveyed ground profile drawings will be provided by the Council to the contractor. Within two months of completion of each separate section of line, the contractor shall supply a complete et of "as installed" profile drawings on durable plastic film for that section as approved by the Engineer.

The contractor shall also mark up on a set of route plans to be supplied by the Council the "as installed" final positions of towers.

The contractor shall also supply the other information to be recorded in terms of clause 18 in such form as the Engineer may approve. Counterpoise earthing installed by the contractor shall be shown in the strip plan on the profile drawings. A table listing the structure footing resistances shall be supplied.

The contractor shall supply two complete sets of profile templates to the Engineer before completion of the transmission line. The design and scales of the templates shall be to approval. If different templates are used for twin and single conductor lines, two sets for each type of line shall be supplied.

Before stringing the lines, the contractor shall supply the sag/tension curves/tables called for under clause 17.3.

Drawings: general requirements

All drawings, diagrams, sketches and plans to be supplied by the Contractor shall be clear, well laid out, of a high standard and in all respects subject to the approval of the Engineer. Legends, notes and descriptions shall be incorporated in each drawing or diagram or plan. Separate loose legend sheets or descriptions or other leaflets will not be acceptable.

The wording of drawing titles shall be to approval. The name of the manufacturer, supplier and/or contractor and the contract number shall appear prominently on all drawings, plans and diagrams.

Preference is given to drawing sheet sizes complying with the International A series within and including sizes A4 to A0.

All lay-out, constructional and detail drawings and all plans shall be to scale.

All drawings, diagrams or plans shall use S.I. metric units and the English or Afrikaans language.

Transparency drawings (sepias) shall be on durable transparency polyester film and shall render uncluttered prints.

The approval of drawings by the Engineer shall not relieve the contractor of his responsibility regarding the correctness thereof, or of any subsequent failures as a result of faults or omissions by the contractor.

The cost of all drawings, diagrams and plans to be supplied on this contract shall be included in the tender price of equipment to be supplied. <u>The equipment will not be considered to be “delivered complete” if the drawings and certificates called for have not been supplied, which may result in payment being withheld.</u>

CITY OF TSHWANE METROPOLITAN MUNICIPALITY
ENERGY AND ELECTRICITY DIVISION
SCHEDULE OF BASIC PARAMETERS FOR 300 /150 MVA POWER LINE
SPECIFICATION NO PL.60/0-93

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.1	**General power line design requirements**	
24.1.1	Nominal rated voltage (line-to-line) .... kV	132
24.1.2	Highest operating voltage (line-to-line) ………........ kV	145
24.1.3	Rated operating frequency……………….................Hz	50
24.1.4	Power line insulation level at Pretoria altitude (1 530 m) ……………………………. kV (peak)	550
24.1.5	Number of three-phase circuits per tower …………..	Two
24.1.6	Disposition of conductors on tower (per circuit) …….	Vertical
24.1.7	Vertical arrangement of conductors:	
24.1.7.1	Uppermost position ……………………………. wire	Earth

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.1.7.2	Top phase conductor ……………………………….	Red or blue phase
24.1.7.3	Middle phase conductor ………………………..	Yellow phase
24.1.7.4	Bottom phase conductor ………………………..	Blue or red phase
24.1.8	Conductor material and type of conductor to be used for phase conductors ……………………………...	A.C.S.R.
24.1.9	Code name of conductor ………………………...	"BEAR"
24.1.10	Number of conductors per phase conductor for circuit rating of	
	a) 300 MVA ……………………………….	Twin "BEAR"
	b) 150 MVA ……………………………….	Single "BEAR"
24.1.11	Disposition of twin conductors …………… horizontal	Horizontal
24.1.12	Centre line to centre line spacing of twin conductors:	
24.1.12.1	Tower to tower …………………………… mm	380
24.1.12.2	Gantry spans …………………………… mm	380
24.1.12.3	Down droppers …………………………… mm	May be reduced to 330
24.1.12.4	Jumpers and jumper loops ………………….. m	May be reduced to 330
24.1.13	Number of aerial earth-wires per tower …………….	Two
24.1.14	Position of earth-wires on tower …………………….	Above phase conductor
24.1.15.1	Stranded galvanized high tensile strength steel wire of number and diameter ……………. No / diameter mm	7/3, 251
24.1.15.2	Tensile strength of steel used in earthwire ………MPa	1 060
24.1.16	Lightning protection angle:	
24.1.16.1	Outside shielding angle with no conductors swing (to vertical plane through earth-wire) ……………………	0° or negative
24.1.16.2	Outside shielding angle with maximum outward swing of top phase conductor ………………………………..	less than 30°
24.2	**Optical fibre**	

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.2.1	Number of fibres ……………………………………….	48
24.2.2	Material of the tube …………………………………….	Aluminium
24.2.3	Type of fibre ……………………………………………	Single mode
24.2.4	Optimum wave length of fibre …………………….. mm	1 300
24.2.5	Maximum average attenuation level ……….. dB/km	0,5
24.2.6	Glass fibre core diameter error ……….. micro meter	+/-1
24.2.7	Glass fibre cladding diameter error ……. Micro meter	+/-3
24.2.8	Core concentricity error ………………… Micro meter	1
24.3	**Design spans**	
24.3.1	Normal (or standard) span length …………...….…. m	300
24.3.2	Ruling (or equivalent) span length ……….………….. m	Varies
24.3.3	Maximum permissible single span length (unless specifically approved otherwise by Engineer) …..........................m	510
24.3.4	Maximum wind span length ……………….....…….. m	330
24.3.5	Maximum weight span length …………….....……... m	600
24.3.6	Minimum weight span length on suspension towers with all conductors and earth-wires at minus 5°C in still air ………………………………………………. m	100
24.3.7	Maximum of sum of any two adjacent span lengths (unless specifically sanctioned otherwise by Engineer) without any line deviation at straight line towers …. m	600
24.4	**Operating temperatures**	
24.4.1	Minimum operating temperature of phase conductors ……………………………………………………… °C	Minus 5
24.1.2	Minimum operating temperature of earth-wires °C minus 5	
24.4.3	Maximum normal operating temperature of phase conductor …………………………………………….. °C	75
24.4.4	Maximum normal operating temperature of earth-wire ……………………………………………………… °C	4
24.5	**Wind pressures**	
24.5.1	Maximum wind pressure on each phase (horizontally at right	

CLAUSE	PARAMETER	VALUE / REQUIREMENT
	angles to conductor centre line) ………………	700 Pa on 0,6 of project conductor area
24.5.2	Maximum wind pressure on each earth wire (horizontally at right angles to conductor centre line) ..	700 Pa on 0,6 of project conductor area
24.5.3	Maximum wind pressure on steel lattice structure (including cross-arms or gantry times projected area of beam as applicable) (horizontally at right angles to centre line of power line) ……………………………….	700 Pa on 1,5 times projected area of all members on one face of structure exposed to wing
24.6	**Tower loading**	
24.6.1	Assumed maximum simultaneous working on to er under normal balanced load conditions ……………..	See clause 8.3 of specification
24.6.2	Assumed maximum simultaneous working load on tower under unbalanced (broken conductor) conditions………………………………………………..	See clause 8.3 of specification
24.7	**Safety factors : tower and supporting structures**	
24.7.1	Minimum factor of safety under balanced maximum simultaneous working load on supporting structure based on type tested failing load of structure ……….	2,5 (See clause 8.3.5 of specification)
24.7.2	Minimum factor of safety under unbalanced maximum simultaneous working load on structure based on type tested failing load of structure ………….. specification	1,5 (See clause 8.4.4 of specification)
24.8	**Safety factor : foundations**	
24.8.1	Minimum factor of safety against overturning or uprooting under maximum simultaneous working load under normal balanced loading condtions …………..	2,5
24.8.2	Minimum factor of safety overturning or uprooting under maximum simultaneous working load under maximum unbalanced loading conditions ……………	1,5
24.9	**Safety factor : insulators and line fittings**	
24.9.1	Minimum factor of safety for insulators and fittings for phase conductors and earth-wires under maximum working load (worst case) based on type tested failing load of insulator or fittings as applicable ……………	3,0
24.10	Minimum factor of safety with phase conductor operating at maximum tension (at minus 5°C and simultaneously subjected to maximum wind pressure of 700 Pa on 0,6 project area) based on rated ultimate tensile strength of phase conductor …………………..	2,5

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.10.1	Minimum factor of safety with phase conductor operating at maximum tension (at minus 5°C and simultaneously subjected to maximum wind pressure of 700 Pa on 0,6 projected ares) based on rated ultimate tensile strength of phase conductor ………..	2,5
24.10.2	Minimum factor of safety with earth wire operating at maximum tension (at minus 5°C and simultaneously subjected to a maximum wind pressure of 700 Pa on 0,6 projected area) based on rated ultimate tensile strength of earth wire conductor ……………………..	2,5
24.11	**Conductor clearances to ground and other structures**	
24.11.1	Minimum conductor clearance under conditions of maximum sag at a conductor temperature of 75°C in still air with conductor swinging through any angle from zero degrees to 45°C from vertical	
24.11.1.1	To normal ground level within and outside townships and at all road crossings …………………………….. m	7,5
24.11.1.2	To road level at road crossings under broken conductor conditions (broken in adjacent span) … m	4,5
24.11.2	To railway formation level in spans crossing non-electrified railway lines ……………………………… m	11,2
24.11.3	To railway formation level in spans crossing electrified railway lines ………………………………………….. m	13,0
24.11.4	To conductors on railway electrification structures .. m	3,3
24.11.5	To buildings and other structures on which a person can stand unsupported ……………………………… m	4,5
24.11.6	To communication lines, other power lines of a lower voltage or between power lines and cradles ……… m	2,2
24.12	**Minimum live metal to steelwork clearance**	
24.12.1	Live metal to tower steelwork measured in any direction on suspension towers with insulator string hanging vertically (i.e. no swing) …………………. mm	1 500
24.12.2	Live metal to tower steelwork measured in any direction on tension towers with any line deviation angle up to maximum deviation angle with jumper loops haning vertically (ie no swing) ……………. mm	1 500
24.12.3	Live metal to tower steelwork on suspension towers under maximum inward (transverse) insulator swing of 40° from the	

CLAUSE	PARAMETER	VALUE / REQUIREMENT
	vertical ……………………………. mm	1 500
24.12.4	Live metal to tower steelwork measured horizontally on outside arms of angle towers erected at maximum line deviation angle under conditions of maximum inward jumper loop swing of 20° from vertical …. mm	1 300
24.12.5	Live metal to earthed steelwork or metal for all jumper loops other than line to line jumpers under no swing conditions ………………………………………….. mm	1 5--
24.12.6	Live metal to earth for all jumper loops other than line to line jumpers under conditions of maximum swing (assume 20° swing from position of equilibrium) mm	1 450
24.12.7	Minimum clearance between top phase conductor and earth wire ……………………………………. mm	4 000
24.13	**Minimum phase-to-phase clearance**	
24.13.1	Minimum clearance between live metal of different phases …………………………………………….. mm	1 650
24.13.2	Minimum vertical clearance between phase conductors of same circuit ……………………….. mm	3 500
24.13.3	Minimum horizontal clearance in still air between phase conductors of opposite circuits on tower … mm	6 500
24.14	**Insulator parameters**	
24.14.1	Insulator material ……………………………. glass	Toughened
24.14.2	Reference type number of disc insulator unit used in:	
24.14.2.1	Phase conductor normal tension strings (twin conductor) …………………………………………..	U120BS/20
24.14.2.2	Phase conductor normal tension tension strings (single conductor) ………………………………….	U120BS/20
24.14.2.3	Phase conductor low duty and reverse low-duty tension strings (single and twin conductor)	U70BL
24.14.2.4	Phase conductor suspension strings (single and twin conductor)	U70BL
24.14.2.5	Earth-wire insulated tension set ……………………..	U90-EWS
24.14.2.6	Earth-wire insulated suspension set …………………	U90-EWS
24.14.3	Arcing horn gap setting on earth-wire insulator …. mm	10 1
24.14.4	Number of disc insulator units in insulator strings:	

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.14.4.1	Phase conductor normal tension string for single conductor ………………………………………………	10
24.14.4.2	Phase conductor normal tension string for twin conductor ……………………………………………….	2 x 10
24.14.4.3	Phase conductor low duty and reverse low-duty tension string (single and twin conductor) …………..	10
24.14.4.4	Phase conductor suspension string (single and twin conductor) …………………………………………….	10
24.14.4.5	Earth-wire insulated tension set ………………………	1
24.14.4.6	Earth-wire insulated suspension set ………………….	1
24.15	**Foundation parameters**	
24.15.1	Assumed maximum density of earth ……….. kg/mm^3	1 600
24.15.2	Assumed maximum density of concrete …… kg/mm^3	2 200
24.15.3	Assumed maximum safe bearing pressure for sub soils under foundations for:	
24.15.3.1	Massively bedded fresh rock, igneous, metamorphic or sedimentary rock requiring blasting to remove ..kPa	5 000
24.15.3.2	Fresh rock (fractured or jointed) and hard shale excavated with difficulty using pneumatic picks … kPa	1 000
24.15.3.3	Compact well graded gravels permanently above water table ………………………………………….. kPa	400
24.15.3.4	Compact well graded gravels and soft shale from time to time below water table …………………………. kPa	200
24.15.3.5	Compact but poorly graded gravels, sands or mixtures thereof permanently above water table .. kPa	200
24.15.3.6	Firm clays, sandy clays, sandy silts and silty sands permanently above the water table ……………….kPa	By test only
24.15.3.7	Soft clays, sandy clays, sandy silts and silty sands ……………………………………………………… kPa	By test only
24.15.3.8	Loose sand and other poor non-cohesive soils	By test only
24.15.3.9	Make-up ground, waste dumps and the like	By test only
24.15.4	Assumed angle to the vertical of sides of inverted earth frustum resisting uplift for:	
24.15.4.1	Virgin cohesive soils …………………………. degrees	30°

CLAUSE	PARAMETER	VALUE / REQUIREMENT
24.15.4.2	Back-filled soil, loose sand, make-up ground and the like ……………………………………………… degrees	0°
24.15.5	Maximum ultimate stresses allowable in concrete for foundation design under assumed maximum simultaneous tower loading conditions with a factor of safety of 2,5:	
24.15.5.1	Tensile stress in concrete due to bending ……… MPa	2,0°
24.15.5.2	Bond stress: galvanized steel to concrete ……. MPa	1,0°
24.15.5.3	Bearing stress of concrete made with ordinary Portland Cement ………………………………….. MPa	20
24.15.5.4	Punching shear stress …………………………… MPa	6
24.15.5.5	Diagonal shear stress ……………………………. MPa	4
24.15.6	Minimum proportion of stub load to be provided for with cleats in concrete foundation ……………………	50%

PART 19.1B : CONCRETE POLES

SPECIFICATION No : PL.61/0-97-A

CONTENTS

1. SCOPE

This specification covers reinforced, partially pre-stressed and pre-stressed concrete poles, spun or gravity cast.

Note : The titles of standards referred to by number in the specification are given in Appendix A.

2. DEFINITIONS

For the purpose of this specification the following definitions shall apply :

a)	Acceptable and	:	The product shall be acceptable according to the tests physical properties as specified in this document.;
b)	Defective the	:	A pole that fails in one or more respects to comply with requirements of this specification;
c)	Failure	:	The inability of a pole under test to support further load, unacceptable cracking or deflection;
d)	Load factor	:	The ratio of the ultimate load to the working load (safety factor);
e)	Partially pre-stressed poles	:	Poles that utilise pre-stressed and other reinforcing to withstand the ultimate loading;
f)	Permanent set due	:	The deflection of the pole tip from the initial position after removal of a specific proof load. The apparent deflection to movement of the pole butt in the test rig must not be included in this measurement;
g)	Planting depth planted 1 or	:	The recommended depth to which the pole should be in the ground. This depth should be calculated as in Fig according to the attached drawings;
h)	Pole strength	:	The required ultimate load capacity of the pole;
i)	Pre-stressed poles resist the	:	Poles which utilise only pressurised wires or bars to ultimate loading;
j)	Proof load of	:	A test load, equivalent to the 10% above the working load the pole;
k)	Reinforced poles the	:	Poles which utilise only normal reinforcing to withstand ultimate loading;
l)	Ultimate load which is factor. failure;	:	The test load (when tested as described in clause 5.5.) numerically equal to the working load times the load The pole must be capable of resisting this load without
m)	Ultimate torsional load when	:	The tensional load which the pole is required to carry tested as described in clause 5.5; and
n)	Working load which cause	:	The test load (when tested as described in clause 5.3) bending moments at least equal to those occurring during service conditions.

3. PHYSICAL REQUIREMENTS

Each pole is defined by two axes which cross through its centre of gravity: The major axis and the minor axis

The major axis is designated as the direction with the greatest moment of inertia.

3.1 Types

The pole shall be one of the following types, as specified:

a) Reinforced concrete pole;

b) partially pre-stressed concrete pole; or

c) Pre-stressed concrete pole.

3.2 Dimensions

3.2.1 Length

The overall length of the pole shall be as specified by the purchaser and shall be preferably one of the following: 4,0 m, 7,0 m, 9,0 m, 10,0 m, 11,0 m, 12,0 m, 15,0 m, 18,0 m, 21,0 m, and 24,0 m.

When determined in accordance with clause 5.3, the actual length (see Fig 1) of a pole shall not differ from the stated length (see above), by more than 50 mm.

3.2.2 Cover to Reinforce

When determined in accordance with clause 5.7, the minimum thickness of the cover over all reinforcement in the case of centrifugally spun poles shall be not less than 15 mm over the entire length of the pole. In the case of poles made by any other process, the cover shall be not less than 20 mm

For coastal Regions this cover shall be increased to 25 mm for both the above. (Less than 20 km from the coast line).

3.2.3 Straightness

When determined in accordance with clause 5.4, any deviation from straightness shall not exceed 0,5% of the total length of the pole.

3.2.4 Cross-sectional Dimensions

When determined in accordance with clause 5.3.2, the tolerance on cross-sectional dimensions shall be 3mm.

3.3 Finish

The finished product shall have a smooth external surface free from honeycombing. The pole to be soft grey in colour. All arises shall be clean and true and shall present a neat appearance. All sharp corners shall be rounded (minimum 5 mm radius).

3.4 Holes and/or Recesses

If so required, holes or recesses shall be provided in the poles during the manufacturing of the poles. The holes/recesses may be used for the attachment of cross-arms and other equipment.

3.5 Length Combinations

Poles may also be manufactured by joining together single pole segments with suitable connecting pieces in such a manner that the jointed pole acts as one unit.

FIG. 1

F = Proof Load (kN)

L = Pole length (m)

D = Planted depth

H = Height of pole above theoretical ground level (m), calculated as shown below

C = Clamped length of pole during test (m), calculated as shown below

D = 0,1 L + 0,6 (m) (for 4 m, 7 m and 9 m poles)

D = 0,1 L + 0,8(m) (for 10 m, 11 m and 12 m poles)

H = L - D (m)

C = D - 0,3 (m)

Actual planting depth will be determined by soil conditions and soil resistance.

3.6 Resistance to Proof Load

When a pole is tested in accordance with clause 5.5 to the proof load it shall pass all the acceptance criteria specified.

3.7 Ultimate Load

When a pole is tested in accordance with clause 5.5, the ultimate load shall be 2,0 times the appropriate working load.

3.8 Torsional Test

When a pole is tested in accordance with clause 3.8, it shall resist the required torsional load without any failure.

4. MANUFACTURE AND DESIGN OF POLES

4.1 Details Required

The finished poles shall be clearly and indelibly marked with the following particulars: (Preferred to be indented in the concrete 10 mm x 2 mm thick x 2 mm deep).

a) Manufacturer's name, trade name or trade mark;

b) overall length of the pole in (m);

c) ultimate load designation;

d) type of pole RC for reinforced concrete
PPC for partially pre-stressed concrete
PC for pre-stressed concrete

e) Date of manufacture (week/year)

f) Datum line 75 mm long, 5 mm wide and 2 mm deep 1.5 m from the designated ground line.

4.2 Marking and Location

The marking shall be legibly impressed in the concrete or on a corrosion-resistant tag that is anchored into the pole in such a way that it does not extend beyond the pole's surface, at a position 1,5 m above the designated ground level (DGL).

4.3 Holes

The marking of holes as indicated on the attached drawings and those agreed too shall be accurately located perpendicular to the pole axis unless otherwise stated. Holes may be drilled or performed using a PVC pipe liner, this shall not affect the strength design of the pole in any way. These holes are to be perpendicular to the axis with a maximum deviation of 10° to the horizontal.

For spun poles the holes shall all lie in the same plane as indicated on the appropriate drawings.

4.4 Embedded Items

Embedded items shall be accurately set in moulds and secured to prevent movement during concrete placement, spinning or vibrating of poles.

4.5 Finish Product

After the pole is removed from the form, all small cavities caused by air bubbles, honey comb spots or other small voids shall be cleaned, saturated with water and then carefully pointed with mortar. A small cavity is defined as exceeding 10 mm but less than 20 mm. Larger cavities not exceeding 40 mm shall be repaired by opening the cavity sides with a mechanical grinder, cleaning thoroughly and patching with a fast set cement. Patching the poles is not to affect in any way the integrity of the designed pole and it's capabilities in this document.

For holes greater than 40 mm the pole is to be rejected.

4.6 End of Poles

The end of each pole shall have no pre-stressed wire protruding, or any other reinforcing, the ends shall be cleaned of debris and sealed with an epoxy paint of black in colour.

All transformer poles shall be marked with a large T at the tip of the pole white colour, the thickness of the lines shall be 30 mm wide of the marked T.

Spun concrete poles are to be capped at the top of the pole with concrete or a glass fibre cap.

4.7 Lifting Points

Design of poles shall include for both multiple and one point lifting on the pole.

4.8 Second Order Analysis

Design shall consider secondary moments induced by deflection (2^{nd} order analysis).

5. INSPECTION AND METHODS OF TEST

5.1 Inspection

Inspect all poles in the sample for compliance with the requirements of 3.3.

5.2 Sequence of Tests

Subject all poles in the sample to the tests given in clauses 5.3, 5.4, 5.5, 5.6, 5.7 and 5.8. Carry out the tests in the order given

Sample size : For tests 5.3 and 5.4 - 1/20

For tests 5.5 and 5.7 - 1/200

For tests 5.6 and 5.8 - 1/500 or once a month

5.3 Dimensions

5.3.1 Length

Measure, to the nearest 2 mm, the length of the pole.

5.3.2 Cross-sectional Dimensions

Measure, to the nearest 1mm the tip dimensions of the pole.

5.4 Straightness Test

Measure to the nearest 5 mm, the deviation from straightness. This deviation is taken as the maximum distance measured between the centre line of the two faces of the pole at any point along the length of the pole, to a line drawn from the centre of the tip of the pole to the centre of the butt of the pole. The measurements should be done on at least two faces of the pole which are at 90 degrees apart.

5.5 Proof Load Test

Tests must be carried out on both planes of rectangular poles.

5.5.1 General

The pole must be tested in a horizontal position. To minimise vertical movement at the point of load application and to reduce stresses due to the dead weight of the pole, a low-friction support (e.g. a trolley) must be provided near the pole tip or throughout the strength of the pole. The frictional resistance of the supporting trolleys should be as low as is practically possible.

5.5.2 Testing Equipment

A schematic drawing of the testing equipment and full layout for conducting tests is shown in Fig 2. The butt end of the pole shall be rigidly clamped by steel or concrete cribs or similar rigid devices over a length 'C' with rubber inserts to protect crushing of the pole. (See Fig 1). The bearing block faces shall be of such dimension and construction that no injury is caused to the butt section. The crib must be able to resist all longitudinal and rotational motions of the clamped portion of the pole.

5.5.3 Loading

The load shall be applied at a point 300 mm from the top of the pole by means of a suitable device, such as a wire cable and winch placed in a direction normal to the direction of the length of the pole. To make the angle between the initial and final positions of the pulling line small, the loading device must be set sufficiently far away from the pole. The load shall be applied as gradually as possible. The pulling device shall be secured around the pole at the load point. Load measuring device shall be placed in such a way as to accurately measure the tension in the pulling cable between the pole and the loading equipment (winch). This test could also be done using a ram.

5.5.4 Load Measurements

A load cell or any other satisfactory method of load measurement may be adopted. The load measuring device shall be calibrated at regular intervals. It shall be supported in such a way that the force required to pull it shall not add materially to the measured load on the pole and that no damage is caused to the instrument if the pole and that no damage is caused to the instrument if the pole suddenly breaks under the test.

5.5.5 Procedure

a) The lest load shall be applied 300 mm from the top of the pole in the direction of the load.

b) The load shall be applied in increments of 10% of the designed ultimate load of the pole, up the proof load. The deflection shall be recorded for each of the increments. The load shall then be reduced to zero and the permanent set, (i.e. the irrecoverable deflection) measured and recorded. The crack width at the theoretical ground level must be checked at proof load and recorded.

c) Each time a load is applied it should be held for a minimum of two minutes.

5.5.6 Recording of Data and Measurement

a) Deflections

i. General. The measurement of the pole tip deflection shall be made perpendicular to the direction of the original unloaded pole axis. The arrangement for measuring deflections is given in Fig 2. All deflection measurements shall be made correct to the nearest 5 mm.

ii. Maximum Deflection. During each loading cycle the permanent set shall be recorded.

NOTE A laser or telescope fixed to the butt end of the pole may be used to eliminate this apparent movement.

b) Cracks

i. General. Certain specified crack widths, (i.e. 0,1 or 0,25 mm) are used as an indication as to whether the serviceability limit of a pole is exceeded or not. These crack widths are measured during the proof load cycle of the pole test.

ii. Crack measuring Gauge. A gauge made from a steel leaf, of width 10mm and thickness corresponding to the specified crack width, should be used. The gauge must be tapered to a rounded point of width 2 mm. The taper shall be 1 in 4. See Fig 3 below.

iii. Measurement. A crack shall be considered of 0,25 mm (or 0,1 mm) size if the 0,25 mm (or 0,25 mm) thick gauge will enter it to a depth of 2 mm at a closely spaced intervals (±25 mm) over a continuos length of about one quarter of the pole circumference at that point.

c) Loads. Record the load applied to pole at the time of failure as accurately as possible.

5.6 Ultimate Load Test

Successive loads in further in further increments of 10% up to 90% of the pole strength and thereafter in increments of 5% of the ultimate strength, shall be applied and released, until failure. The deflection crack width and permanent set shall be measured and recorded for each loading.

5.7 Cover to Reinforcement

Using a SABS acceptable method, measure, to the nearest 2 mm, the thickness of the cover over the reinforcement. Three sets of measurements should be taken; one near the tip end, one near the middle and one near the butt end of the pole. The cover should be measured to exposed faces of the concrete.

5.8 Torsional Test

Clamp the butt end of the test pole as described in clause 5.5.2. (See Figure 4) and apply torque by any suitable means at a point 600 mm from the top of the pole (or at such a distance which coincides with the position where the maximum torsion will occur). Measure and record the torque at failure of the pole to the nearest 10 Nm.

6. ACCEPTABLE CRITERIA

CRITERIA For Proof Loads	RC	PPC	PC	TEST METHOD
1. Deflection	7,5% of H	7,5% of H	5% of H	5.5.6(a)
2. Crack width	0,25 mm	0,1 mm	Zero	5.5.6(b)
Permanent set	1,5% of H	1,125% of H	0,5% of H	5.5.6(a)
Crack closure	100%	100%	N.A.	

Transformer poles deflection must not exceed 150 mm with a tip load of kN acting on the minor Axis. In the case of spun concrete transformer poles, the maximum deflection must not exceed 150 mm with a tip load of 1 kN acting in any direction.

7. APPENDIX A APPLICABLE STANDARDS

Reference is made to the latest issues of the following standards :

SABS 471 Portland cement (ordinary, rapid-hardening and sulphate resisting);

SABS 626	Portland blast furnace cement;
SABS 831	Portland cement 15 (ordinary and rapid-hardening);
SABS 1083	Aggregates from natural sources;
SABS 920	Steel bars for concrete reinforcement.;
BS 4482	Cold reduced steel wire for the reinforcement;
BS 5896	High tensile steel wire strand for the pre-stressed of concrete;
BSI 1881:V	Water absorption test (part 201); and
SABS 0100	The structural use of concrete.

The information in the appendix is additional to that in the specification and has been included purely for amplification and guidance.

8. APPENDIX B

TYPICAL MATERIALS RECOMMENDED FOR USE IN THE MANUFACTURE OF CONCRETE POLES

C-1 General

Materials for the concrete shall be so selected as to produce a high density, low porosity concrete. Poles that are intended to be resistant to chemical attack shall have an acceptably low content of material insoluble in hydrochloric acid. The use of Calcium Chloride, other salts or materials releasing chloride is prohibited.

C-2 Cement

The cement used in the manufacture of poles shall comply in all respects with the requirements of SABS 471, SABS 626 or SABS 831.

C-2 Aggregate

The aggregate shall consist of natural sand, or crashed or uncrushed gravel, stone or rock, or a combination of any of these.

C-4 Water

The water used in the manufacture of the concrete shall be clean and free from injurious amounts of acids, alkalis, organic matter and other substances that may impair the strength or durability (or both) of the concrete and the embedded steel. (Refer to SABS 0100).

C-5 Reinforcement

This should comply with the requirements of SABS 920, BS 4482 or BS 5896, or any other high tensile steel wire that has been agreed upon between the manufacturer and the purchaser.

Reinforcing bars and wires shall be free from loose or heavy rust, scale, oil and grease, or any material which might interfere with the bond between the bar and the concrete. Slight rust may, however, be permitted.

C-6 Admixtures

Admixtures used shall not have any harmful effects on the concrete properties or the embedded steel. Admixtures containing calcium chloride, accelerating admixtures or rust inhibiting admixtures or rust inhibiting admixtures shall not be used.

C-7 Additives

The use of additives to enhance the concrete properties will be allowed provided there is not detriment to the concrete or the embedded steel

Attention is drawn to the requirements of SABS 1083 and in particular to Subsections 3.2.1 and 3.3

9. APPENDIX C

Design

For the poles to meet the various requirements of the specification and have a long service life, it is essential that the concrete used in the manufacturing process be of good quality and sufficient strength. If ordinary Portland cement, Portland blast furnace cement, or Portland cement SL15 is used, the compressive strength of the concrete at 28 days should be not less than 30 MPA in the case of reinforced concrete poles and not less than 40 MPA in the case of pre-stressed poles. If rapid-hardening Portland cement is used, the respective values should be attained after 7 days.

The reinforcement should be in the form of a cage having continuos longitudinal rods extending the full length of the pole.

Provisioning for attachments to the poles may be made and may be in the form of suitably spaced transverse holes or of anchoring fittings embedded in the concrete.

Earthing

The earthing of the poles may be performed in various effective ways.

The earthing connection shall provide adequate electrical contact to at least one steel reinforcing bar of 10mm diameter (minimum). This bar should be continuos or welded (not lapped) throughout the length of the pole and metalically connected to all other reinforcing rods. The connection to this reinforcing bar shall be by means of M12 internally threaded stainless steel ferrules flush with the side of the pole.

10. APPENDIX D

POLE DIMENSIONS AND STRESSES

POLE LENTH (M)	ULTIMATE TIP LOAD kN		TORSIONAL LOAD kNm	TOP DIMENSION A x B		BOTTOM DIMENSION		NSN NO
	STRONG AXIS	WEAK AXIS		MIN (mm)	MAX (mm)	MIN (mm)	MAX (mm)	
4	1	0,3	NA	80 x 80	120 x 120	80 x 80	230 x 150	5690 70 009 1890
7	4	1,2	NA	100 x100	150 x 150	200 x 100	300 x 300	6580 70 009 1891
9	4	1,2	1,2	100 x 100	150 x 150	230 x 100	400 x 400	5680 70 009 1892
10	6	1,8	1,6	120 x 120	150 x 150	270 x 120	400 x 400	5680 70 009 8069
11	6	1,8	1,6	120 x 120	150 x 150	280 x 120	450 x 450	5680 70 009 1893
10 Cast pole Transformer	8	3,0	3,0	120 x 120	150 x 150	270 x 120	450 x 450	5680 70 010 5774
10 Spun pole Transformer	8	-	3,0	-	200 mm Diameter	-	15 mm/m Taper-	5680 70 010 5774

PART 19.2 : 33 kV Power Lines

SPECIFICATION No : PL.40/0-97

CONTENTS

1. SCOPE

This general quality specification describes the usual materials required for electrical installations and general methods of installing these materials. This general technical specification, drawings and the detailed technical specification forms part of this contract. Where the detailed technical specification and/or the drawings differ from this general quality specification, the detailed specification and the drawings shall take preference.

2. STATUTORY REQUIREMENTS

The installation of electrical equipment shall always comply with the requirements, stipulations and regulations contained in the following Act :

a) Occupational and Health Safety Act 85 of 1993;

b) the Post Office Act, No 85 of 1991 and the Postmaster General's Requirements issued in terms of the Act;

c) the Mines and Works Act, No 27 of 1956 and subsequent amendments and regulations issued thereunder;

d) the Electricity Act, No 41 of 1987;

e) the Forest Act, Article 34 of Act No 72 of 1968;

f) the Explosive Act, No 26 of 1956 as amended; and

g) the South African Transport Services Safety Regulations.

3. OVERHEAD ELECTRICAL TRANSMISSION LINES

3.1 General

This section covers the supply, delivery, erection and commissioning of overhead transmission line connections of up to 33 kV.

All materials and fittings shall be new and of high quality.

Overhead lines shall be erected in accordance with the "CODE OF PRACTICE FOR OVERHEAD POWER LINES FOR CONDITIONS PREVAILING IN SOUTH AFRICA", issued by the SA Institute of Electrical Engineers.

3.2 Standards

Unless otherwise specified all materials must comply with the SABS specifications as stipulated below. Where no applicable SABS specification exist all materials must :

a)	SABS 182	:	Conductors for overhead electrical transmission lines;
b)	PART 3	:	Aluminium Conductors, Steel reinforced;
c)	SABS 177 greater	:	Ceramic and glass insulators for overhead lines of nominal voltage than 1 000V;
d)	SABS 178	:	Non-current-carrying line fittings for overhead power lines;
e)	SABS 470	:	Concrete poles for telegraph, telephone, power and lighting purposes (reinforced and prestressed types); and
f)	SABS 171	:	Low voltage lightning arresters.

3.3 Clearances of Power Lines

3.3.1 The supplier of user shall cause -

a) The minimum clearances of electric conductors and other wires of power lines, excluding overhead service connections and line conductors having a voltage not exceeding 1,1 kV r m s consisting of insulated wire of a type which complies with a safety standard incorporated for this purpose in these regulations under section 36 of the Act, to be not less than the clearances indicated in the following table:

Maximum voltage for insulation is designed, kV rms phase-to-phase	36
Minimum safety clearance	0,43
Minimum clearance in meters	
Above ground outside townships	5,3
Above ground inside townships	5,5
Above roads in townships, proclaimed roads outside townships, railways and tramways	6,5
To communication lines, other power lines, or between power lines and cradles	1,0
To buildings, poles and structures not forming part of power lines	3,0

Provided that these figures are based on the assumption that clearances shall be determined for a minimum conductor temperature of 50° and a swing angle corresponding to a wind pressure of 500 Pa : Provided further that where under normal conditions power line conductors operate at a temperature above 50°C, the clearance at the higher temperature at which the conductors operate shall be in accordance with the clearance at the higher temperature at which the conductors operate shall be in accordance with the clearance indicated in the table:

b) the clearances of conductors and other wires over the normal high-water level of power lines crossing over water to be not less that the values of power lines above the ground outside townships : Provided that if the owner of the land on which the water is situated requires a greater clearance and no agreement van be reached, the dispute shall be referred to the chief inspector for a decision; and

c) the distance of any power line from an explosive magazine to comply with the requirements of the Explosives Act, 1956 (Act 26 of 1956).

d) No person shall construct any road, railway, tramway, communication line, other power line, building or structure or place any material or soil under or in the vicinity of a power line which will encroach on the appropriate minimum clearances prescribed in terms of subregulation a).

e) No person shall encroach in person or with objects on the minimum safety clearances prescribed in subregulation a) or require or permit any other person to do so except by permission of the supplier or user operating the power line.d) The supplier or user, of power lines shall control vegetation in order to prevent it from encroaching on the minimum safety clearance of the power lines and the owner of the vegetation shall permit such control.

3.4 Notices and Precausions

The contractor shall issue all notices and make the necessary arrangements with Supply Authorities, the postmaster General, SA Transport Services, Provincial or National Road Authorities and other authorities as may be required with respect to the installation of overhead lines.

The Contractor shall take all the necessary precautions and provide the necessary warning signs and/or lights to ensure that the public and/or employees are not endangered.

The Contractor will be held responsible for damage to any existing services and infrastructure prior to commencing the installation.

Lightning type danger notices shall be fitted to all structures with transformers, mechanically operated switchgear and fuses, as well as a notice indicating the nominal operating voltage.

3.5 Pegging the Route

The Contractor shall peg out the positions for the overhead line but shall maintain close liaison with the Engineer's representative shall be constructed and a ruling obtained.

The Engineer reserves the right to alter the line position at any time prior to the installation of the overhead wires. Payment in respect of any additional or wasted work involved shall be at the documented rates.

The removal of obstructions along the route shall be subject to the approval of the Engineer.

3.6 Line Impulse Level

The line Basic Impulse Level (BIL) shall be maintained at the full voltage recommended in the "Code of Practice for Overhead Power Lines", namely :

Line Voltage (kV)	Impulse Voltage withstand level (kV)
Up to 6,6	75
11	95
22	150
33	200

3.7 Poles

The line configuration and support structure shall be suitable for the proposed route.

Poles shall be LOOP TENSION banded at both ends.

Concrete poles where specified shall comply with SABS 470.

All poles shall be installed with the marking tags facing the roadside where applicable or shall face in the same direction where a road does not exist alongside the overhead line.

3.8 Insulators and Fittings

The insulators shall comply with Eskom Specification for composite insulators NWS 1612, IEC Publication No. 1109 and ANSI Specification C29-11.

The insulator shed material shall be of true silicon rubber type and will be completely free of all EPR, EPM and EPDM rubbers.

Curved pole washers shall be fitted between the collars of insulator pins and the cross-arm or pole and between the pin nut and the cross-arm or the pole.

3.9 Stay Insulators

Stay insulators shall be of brown glazed porcelain.

The minimum dry and wet flashover voltages shall be 35 kV and 30 kV respectively.

The ultimate breaking strength of the insulators shall be at least 110 kN.

The insulators shall be of "ELC" type 21-0521 manufacture or equal.

3.10 Conductors

Steel reinforced aluminium conductors to SABS 182, part 3 shall be used for overhead lines. Should copper conductors be specified, they shall comply with SABS 182, Part 1. The cross-sectional area shall comply with the Detail Technical Specification.

The spacing between phase conductors shall be increased by 20% over the spacing determined according to the formula in par …… of the "Code of Practice for Overhead Power Lines" to compensate for stay movement and other factors and to maintain the BIL as specified earlier herein.

The minimum conductor spacing are:

Pole Spacing	Conductor Spacing in mm at a specific Supply Voltage			
(m)	Up to 6,6kV	11kV	22 kV	33 kV
60	575	635	790	960
70	635	700	850	1 020
80	700	750	910	1 080
90	750	810	975	1 040

Manufacturer's stringing and tensioning charts shall be used to erect conductors. Conductors shall not be tensioned to more than 25% of the breaking strength of the conductor at -5,5°C with no wind.

Conductor running blocks shall be installed on all pole positions to run out the conductors. Conductors shall not be dragged along the ground. The three conductors shall be tensioned similtaneously using suitably rated chain-ratchet pullers and "come-alongs" specially designed for the particular conductor.

The minimum conductor to ground clearances as stipulated in the Machinery and Occupational Safety Act shall be closely observed as specified in Clause 1.4. Allowance shall be made for conductor creepage and subsequent increased sag after a period.

Conductors shall be prestressed for not less than one hour before binding in.

Conductor joints at non-tension points shall be made with two bolt parallel groove clamps of a type approved by the Engineer. The current carrying capacity of the clamps shall be at least equal to that of the conductor.

Non-oxidising conducting paste shall be liberally applied to the inside of these clamps.

Where aluminium to copper connections are made, suitable bi-metal clamps shall be used. ("Dulmison Preformed Line Products Type G" or equal).

3.11 Conductor Terminations

Cold compression, bolted snail clamps or preformed terminations shall be used. Suitable thimble clamps shall be used with the preformed terminations.

The conductor shall be bound in at pin insulators by a single stirrup and binding. A chafer tape of soft aluminium shall be wrapped around the conductor at the insulator contact area. The conductor shall be bound to the stirrup for a distance of 50mm on either side of the insulator. 5mm diameter hard drawn aluminium wire shall be used for binding.

Suitably sized preformed wrap lock ties with pads may be used as an alternative method to the process specified.

Trails and bridge wires must be neatly disposed and connected with clamps or line taps with a minimum of two per connection or by means of other approved mechanical connectors.

3.12 Stays

The position of stays may or may not be indicated in the instructions for the service, but it is the responsibility of the Contractor to provide staying adequate to maintain correct tension of the line and the vertically position of every pole in line, with or without the additional use of kicking blocks as he may decide.

Wind stays must also be provided for straight lines in exposed positions. Struts shall not be used if this can be avoided by the use of aerial stays and pillar stays.

Stay wires shall be spliced and bound in, in the accepted manner. Approved preformed materials may also be used.

The angle between the stay and the pole must be between 35° and 45°. The stay must be made off on the pole, as near as practicable to the point of resultant stress, with one and a half complete turns around the pole, supported by a suitable clamp.

For terminal poles of vertical line arrangements, at least two stays shall be used to prevent deformation of the pole, with the stay plates buried at least 1,5m apart.

Stay holes shall be vertical, not less than 1,5m deep and no wider than necessary to accommodate the baseplate, with a narrow side channel cut to embed the rod at the correct angle.

The baseplate and portion of rod within the stay hole shall be firmly packed with hard material or concrete where necessary.

Stay pillars shall be concreted into the ground with top and bottom kicking blocks where required by the nature of the soil.

Porcelain stay insulators shall be installed in the stay wire as high as possible above ground level but far enough away from the structure to ensure that the portion of the stay below the insulator does not become alive.

Stay wire shall be galvanised steel and the individual steel strands shall have a breaking stress of not less than 695 Mpa and shall comply with BS 183 or SABS 182, Part 5. Stay wire make-offs shall be painted with bitumastic paint on completion.

Stay rods shall comply with BS pattern 2 shall be of circular section with tubular type turn buckles. Heavy duty construction, deep contoured type thimbles shall be used.

Galvanised steel stay plates shall be used.

Stay guards are required in the vicinity of public paths and roadways.

3.13 Fuse Links

Fuse-links shall be a type approved by the Engineer.

Details of fixing methods and mounting shall be submitted to the Engineer for approval.

Fuse-links shall be installed at all transformers as specified in the Detailed Technical Specification.

3.14 Fittings

3.14.1 General

All fittings made of steel or malleable iron, including the threaded portions of bolts, shall be hot-dip galvanised in accordance with SABS 763 to prevent corrosion.

Bolts and nuts shall be of steel with hexagonal heads. Where metal parts are secured by bolts and nuts, single flat mild steel washers shall be used at both the bolt head and the nut sides.

Bolts shall be locked by means of locknuts or other methods.

All line, earth conductor and stay wire fittings shall not employ screw threads loaded in tension with the exception of cross-arm eye bolts and turnbuckle type stay rods.

Adequate bearing areas between fittings shall be provided. Point of line contacts shall be avoided where possible without adversely affecting the flexibility of the fittings.

All split pins shall be of phosphor bronze or stainless steel and shall be backed by flat steel washers.

The mechanical strength of insulators and fittings shall provide a factor of safety of at least 2,5 based on the guarantied minimum failing load when they are subjected to the maximum design tension in the conductor or earth wire to which they are attached. The ultimate breaking strength of insulators and fittings specified for tension applications shall in any event not be less than 70 kN.

3.14.2 Tension Clamps

Tension clamps shall be of the bolted type “snail” clamps.

The clamps shall be made of malleable cast iron to BS 310 and manufactured in compliance with SABS 178.

Tension clamps shall not permit slipping of or cause damage to or failure of the complete line conductor or any part thereof at a load less than 95% of the ultimate strength of the line conductor for which it is intended.

The tension clamps shall be designed so that relative movement between individual conductor layers shall not occur during assembly.

All bolts or U-bolts shall be provided with locknuts or an alternative locking manner approved by the Engineer. All nuts shall be backed with flat steel washers.

The clamps shall match the clevis and tongue string insulator units without additional adaptors and shall also be suitable for the specified conductor type and size.

3.14.3 Thimble clevises

Thimble clevises shall be used with performed dead-ends.

Thimble clevises shall be made of malleable cast iron to BS 310.

The radii of the thimble clevis shall be suitably designed to accept the preformed dead-ends.

The thimble clevises shall match the clevis and tongue string isolating units without any additional fittings.

3.14.4 Cross-arm and tower attachments, shackles, links, adaptors and yoke-plates

The fittings shall be made of malleable cast iron to BS 310 and manufactured in compliance with SABS 178 as amended.

The fittings shall match the specified immediate adjacent fitting or string insulator unit without the use of additional adaptors.

3.15 Lightning Arresters

3.15.1 General

Lightning arresters shall be placed on all the phase conductors at the following points in addition to those specified in the Detail Technical Specification:

As near as possible to the transformer terminals on the line side of the protection where applicable.

At each termination of a cable on the overhead line.

At every line sectionaliser or re-closer.

Lightning arresters shall be mounted below the overhead conductors in order to reduce the length of the discharge path.

The arresters shall be connected to the overhead conductors by 35mm^2 (minimum) copper conductors minimum and suitable parallel groove clamps.

On earth shall be supplied and installed at each point where lightning arresters are installed in accordance with the Section on Earthing.

3.15.2 High voltage lightning arresters

Surge diverters for installations with a rated voltage above 660 Volt shall conform to IEC 99-1 for "NON-LINEAR RESISTOR TYPE ARRESTERS FOR AC SYSTEMS" and shall be 10kA Series A arresters of the heavy duty type.

Lightning arresters must be of zinc oxide type (ZnO) which is built up from one or more hermetically sealed units, each containing valve resistor blocks fixed into a porcelain housing. The lightning arresters must be vertically mounted on a horizontal surface.

The line and earth connections shall consist of terminal lugs, complete with bolts, nuts, stainless steel washers and cable washers.

The mounting bracket which will be supplied with the lightning arrester shall be hot-tip galvanised steel brackets complete with damping band, bolts, nuts and washers. The mounting bracket shall have the dimensions of and comply with the NEMA bracket 1. All the bracket accessories shall be hot-dip galvanised.

Lightning arresters for system voltages up to 33 kV shall be of the 25 kA Class or equivalent.

3.16 Excavations

Excavations for poles, strays and trench earths shall remain open for as short a period as possible. The Contractor shall erect and maintain guards, warning notices and lights, if required by the Engineer, at open excavations and soil heaps.

Excavations shall be classified as follows:

Very hard rock - shall mean rock that can only be excavated by means of explosives.

Hard rock - shall mean granite, quartzitic sandstone, slate and rock of similar or greater hardness, solid shale and boulders in general requiring the use of jack hammers and other mechanical means of excavation eg compressor.

Soft rock - shall mean rock or hard material that can be loosened and removed, such as boulder with nominal diameters between 300 mm and 1 000 mm.

Earth - shall mean material more easily excavated by means of hand-picking or shovelling such as gravel, earth, turf, scale, sand, silt and clay.

After poles and stays have been planted, the holes shall be backfilled and well compacted. Compaction shall be executed in layers of not more than 300 mm to obtain a high compaction density.

PART 19.3 : 132kV UNDERGROUND CABLES.

SPECIFICATION No : EPPS0019

CONTENTS

1. SCOPE

1.1 This specification provides for the supply, delivery, installation, testing, commissioning and handing over of additions to the 132kV underground cable supply feeder system and the supply and delivery of spare equipment.

1.2 Except where specifically stated to the contrary, the Contract will include the provision and installation of all equipment required, including all matters and details to provide a complete installation; negotiations with other Municipal Departments or other Authorities where necessary, and the carrying out of all aspects of the Work necessary to complete the Contract commitments. Assistance will be given by the Electricity Department of the City of Tshwane Metropolitan Municipality as specifically provided for in the Contract and at the discretion of the Strategic Executive Officer.

2. STANDARDS

2.1 All material to be supplied, joints, terminations and work shall comply with all parts of this specification and with the relevant requirements of the latest revisions of the applicable NRS, SANS and IEC Specifications (Standards), and shall be designed, constructed, tested and installed strictly in accordance with the latest Standards.

2.2 If this Specification should conflict with the above Standards, the Standards shall govern.

2.3 Tenderers shall submit copies of all type tests done in accordance with IEC or other agreed standards for all cable and components offered.

2.4 See also Section 4 – Part 1.4 above.

3. QUALITY

3.1 Suppliers who have ISO 9001 accreditation will be preferred.

3.2 The cable, joints and terminations shall be manufactured and constructed to the highest standards and all materials used under this Contract shall be new and of approved quality and of the class most suitable for working under the conditions specified in Section 4 – Part 1.1 above, and shall withstand the variations of temperature and atmospheric conditions arising under working conditions without distortion or deterioration or the setting up of undue stresses in any part to affect the efficiency, suitability and reliability of the installation.

3.3 Workmanship shall be of the highest standard and shall in all respects be subject to the approval of the Engineer. The design shall incorporate every reasonable precaution and provision for the safety of all those concerned in the operation and maintenance of the Works.

3.4 See also Section 4 – Part 1.3 above.

4. STATUTORY REQUIREMENTS

4.1 With regard to his own operations when working on site, the Contractor shall comply in all respects with the requirements of the Occupational Health and Safety Act No.85 of 1993 and the Regulations (as amended) issued there under which shall take precedence over other statutory requirements.

4.2 With regard to his own operations when working on site, the Contractor shall comply in all respects with the requirements of Environmental Legislation, specifically complying with Environmental Management Program (EMP) resulting from the Environmental Impact Assessment (EIA) and indemnity stipulations embodied in the relevant legislation. (See Annexure 2 to this Technical Specification).

4.3 The Engineer shall have the power to instruct the Contractor to alter, replace, rectify, or otherwise provide for any item that is necessary to comply with any statutory requirements applicable to the Contract. No extra payment will be considered for any provision that the Contractor may have to make to comply with any Act or statutory requirements as all such costs will be taken as having been provided for in the prices quoted in the Tender.

4.4 Site work in energized (live) yards will only be permitted under cover of a Permit to Work issued by the Control Section of CTMM Power Management and then only under such conditions as may be laid down in the said Work Permit. Work in live yards shall be carried out under the direct and strict supervision of a competent responsible person so appointed in writing by the Contractor. In the above context "Competent Person" shall have the meaning as defined in Chapter I of the Regulations pertaining to the Occupational Health and Safety Act No.85 of 1993.

4.5 The Contractor shall apply in writing for the necessary Work Permit(s) and shall submit with his application particulars of the appointed responsible person together with a copy of his letter of appointment.

4.6 The application form for a Work Permit(s) shall be submitted at least three full working days before access to the yard is required.

4.7 On completion of the work in live yards the responsible person shall sign off the Work Permit and shall not leave the site without signing off the Work Permit and returning it to the issuer. Should the Contractor fail to have this requirement strictly observed, he shall render himself liable to pay all direct and indirect costs that the Council may incur in having the Work Permit signed off. This cost may include the estimated loss of revenue in respect of equipment remaining switched out for the purpose of giving the Contractor access.

4.8 When working in live yards, the Contractor shall ensure that all his workmen, employees and subcontractors obey the Council's safety rules, a copy of which may be obtained from the Control Section of CoT Power Management.

4.9 See also Section 4 – Part 1.1, 1.2 and 1.9 above

5. SERVICE CONDITIONS

5.1 The cable, joints and terminations shall be suitable for continuous trouble free operation under the following climatic conditions:

5.1.1	Altitude above sea-level	1 530m
5.1.2	Maximum ambient temperature	40ºC
5.1.3	Average daily maximum ambient temperature	30ºC
5.1.4	Minimum ambient temperature	Minus 5ºC
5.1.5	Average daily minimum ambient temperature	2ºC
5.1.6	Maximum ground temperature	25ºC
5.1.7	Minimum ground temperature	10ºC
5.1.8	Relative humidity	Up to 94%
5.1.9	Lightning conditions	Severe
5.1.10	Degree of pollution	Medium
5.1.11	Seismic condition	Normal
5.1.12	Soil thermal resistivity	1,2Km/W
5.1.13	Earth resistivity:	Varying between 50 and 1 000 ohm-meters at a depth of 1,5m.

5.2 The cable will be utilized on an electricity distribution system comprising high-voltage overhead transmission lines, underground cables, switchgear and transformers, all of which are energized from interconnected power- and infeed stations.

5.3 The cable on this Contract shall be laid in accordance with the route plans forming part of this enquiry. The route plans are subject to alterations by the Engineer, if found necessary.

6. SYSTEM PARTICULARS

6.1 Please refer to Section 4 – Part 1.1 above

7. MATERIAL REQUIREMENTS

7.1 General

7.1.1 All payments shall be subjected to the "Terms of Payment" and shall be made in accordance with the "Conditions of Contract". (See also Clauses 12, 17, 75, 76, 77 and 78 of the "Conditions of Contract".)

7.1.2 Payments for cable and auxiliary material will be adjusted for the measured and true quantities after completion of the work. Likewise progress payments will be made on application by the Contractor (see Clause 75) on measured quantities of excavation and back-fill, etc., completed and finally adjusted for the total quantity measured.

7.1.2 The material to be supplied and delivered shall comprise the main items as listed in the Annexures to the Specification, "Particulars and Guarantees" and "Schedule of Prices", and all ancillary material as is necessary to make the installation complete in every way.

7.1.3 Minor items not specifically mentioned in the Annexures to the Specification, "Particulars and Guarantees" and "Schedule of Prices" will be taken as having been included in the Contract Price.

7.1.4 A detailed quotation giving itemized prices shall be given in the "Schedule of Prices" for each item required.

7.1.5 When installed in the ground, the power cables shall be installed in trefoil formation with the continuous earth bonding just outside the associated power cable group in a touching position. Where applicable, the spacing between two power cable groups shall be 450mm. If required, the copper and fibre optic pilot cable (see separate specifications) shall be laid in the same trench as the power cable, on top of the concrete cable slabs, in suitable riddled earth.

7.1.5 Where installed in cable tunnels the cable shall be clamped onto racks in flat or trefoil formation with 450mm center line spacing, with the continuous earth bonding clamped with the power cable group. Where applicable, a second power cable group shall be installed on a separate rack when the formation is flat, or on the same rack in the case of trefoil, whilst the pilot cable shall be laid on a separate pilot cable and control cable rack. The fibre optic polyethylene pipes shall be clamped to the rack.

7.1.6 The power cable shall have a prospective through-fault capacity as stated in Items 2.30, 2.48.8.1 and 2.48.8.2 of the "Schedule of Particulars and Guarantees", form A, attached. Tenderers shall state the time rating assigned to each cable size and type under these fault conditions.

7.1.7 Based on the prevailing site and system conditions the power cable shall be designed to each be capable of an independent rating as stated in Items 1.4, 2.25, 2.26, 2.27, 2.28, 2.44.1 and 2.44.2 in the “Schedule of Particulars and Guarantees”, Form A, attached, when loaded singly. Under simultaneous loading conditions the feeders shall each have a continuous rating as stated.

7.1.8 All material supplied shall be to the approval of the Engineer. The Contractor shall furnish the insulation data and cable design criteria called for in Item 2 of the “Schedule of Particulars and Guarantees”, Form A. Design, production, and electrical test data is required to substantiate, verify, and support the research and development, processing techniques, and quality control method used in the manufacture of the cables and materials specified herein.

7.1.9 Preference will be given to designs limiting the number of cable joints to a minimum.

7.1.10 The design and construction of the cable shall be such that the cable will operate satisfactorily in wet or dry conditions at conductor temperatures not exceeding those stated in Items 2.30.1, 2.30.2 and 2.45 of the “Schedule of Particulars and Guarantees”, Form A, attached.

7.1.11 The Contractor shall be responsible for determining the final details of the drum lengths and quantities of incidental material to be ordered.

7.1.12 Sufficient length of cable shall be provided at the joints for jointing, and at the terminating positions for connecting the cable to sealing ends, as required.

7.1.13 Errors in the determination of the final lengths of cable or quantities of incidental materials ordered, shall be the Contractor’s responsibility, unless it can be shown that the error was caused by incorrect information or instructions in writing, or on the drawings supplied by the Council or the Engineer, or other authorized representatives of the Council.

7.1.14 Due to the cable route being mostly in a built-up residential area, blasting using explosives will not be permitted.

7.1.15 A triple extrusion process in applying the insulation to the conductor will be compulsory.

7.2 132kV Cable conductor

7.2.1 The stranded conductors in each core shall be composed of plain annealed copper wires or segmental strands having a conductivity of not less than 100% of the international standard and complying with the requirements of IEC 228.

7.2.2 A triple head extrusion process involving the extrusion of the semi-conducting inner screen, insulation and outer semi-conducting screen simultaneously is compulsory.

7.2.3 Unless approved otherwise, a non-hygroscopic semi-conducting tape shall be used between the conductor and the extruded semi-conducting shield material. The thickness of this non-hygroscopic semi-conducting tape shall not be considered as part of the minimum thickness of the extruded semi-conducting conductor shield specified in Item 2.2.6 of the "Schedule of Particulars and Guarantees", Form A, attached.

7.3 132kV Cable insulation

7.3.1 The insulation shall be non-filled, cross-linked polyethylene which has been screened or vacuumed and is free of contaminants larger than 10microns in its largest dimension.

7.3.2 The cross-linked polyethylene insulation shall have the conductor semi-conducting shielding layer, the XLPE- insulation and the semi-conducting outer insulation shield extruded simultaneously and continuously. The three layers shall then be cross-linked immediately and simultaneously by using a dry Nitrogen curing process in a vertical curing tower.

7.3.3 XLPE cables manufactured by the steam curing process shall be considered totally unacceptable.

7.3.4 The minimum thickness of insulation shall be stated in Item 2.3.2 of the "Schedule of Particulars and Guarantees", Form A, attached, and shall not include the conductor's semi-conducting shielding layer.

7.3.5 The physical and ageing requirements of the insulation shall comply with the requirements given in Item 2.5 of the "Schedule of Particulars and Guarantees", Form A, attached. It is preferred that the solvent extraction tests be performed in accordance with AEIC/ IPCEA standards.

7.4 132kV Cable insulation shielding

7.4.1 The insulation shielding shall be extruded simultaneously and continuously with the insulation, and shall consist of black, semi-conducting material fully compatible with the insulation.

7.4.2 The XLPE cable insulation shielding material shall have an allowable operating temperature equal to or higher than that of the insulation material. The inner surface of the extruded screen shall be bonded firmly, and continuously to the insulation, and shall under all conditions prevent the ingress of moisture between the insulation and the semi-conducting shield.

7.4.3 A semi-conductive, water swellable bedding tape may be helically applied to the cable over the extruded semi-conducting layer with a minimum lap of 6,35mm overlap on itself. The tape shall be free of significant creases or wrinkles.

7.4.4 The minimum thickness of the extruded semi-conducting insulation shield shall be as specified in Item 2.3.4.3 of the "Schedule of Particulars and Guarantees", Form A, attached.

7.5 132kV Cable metal tape screens

7.5.1 The electrostatic screening system of the cable shall consist of a soft aluminum or copper tape with suitable overlap and semi-conducting, water swellable bedding tape(s) applied under and over the metal tape screen.

7.6 132kV Cable metal sheath

7.6.1 The cable sheath shall be a continuous seamless aluminium extrusion of EC grade aluminium, concentrically corrugated, fully impervious, and formed around the cable core, extruded and corrugated in a continuous operation.

7.6.2 The cable sheath shall be adequately rated to safely carry the specified earth fault current of 31,5kA for 1 second.

7.6.3 The sheath shall be an impervious barrier to gases and fluids and shall be reasonably close fitting over the cable.

7.6.4 The Contractor shall submit with his Tender the maximum compression the cable sheath will withstand without damaging the sheath and cable when buried at depths of one, two or three meters as called for in Item 2.8.5 of the "Schedule of Particulars and Guarantees", Form A, attached.

7.6.5 The average thickness of the aluminium sheath shall not be less than the value specified in Item 2.8.3 of the "Schedule of Particulars and Guarantees", Form A, attached. The minimum thickness at any point shall be not less than 90% of the specified average value.

7.6.6 Immediately after the manufacturing tests, the ends of all cable lengths shall be sealed to prevent the ingress of moisture.

7.7 132kV Cable outer covering or serving

7.7.1 The anti-corrosion outer covering shall consist of a suitable waterproofing compound coating on the metallic cable sheath followed by a continuous extrusion of black polyethylene for the jacketing or serving purpose.

7.7.2 The polyethylene covering shall be continuously extruded over the corrugated aluminium sheath and shall fit tightly thereto.

7.7.3 The average thickness of the PE serving shall not be less than that specified in Item 2.9.2 of the "Schedule of Particulars and Guarantees", Form A, attached. The minimum thickness shall not be less than 70% of the values given.

7.7.4 The anti-corrosion outer protection covering shall form part of a fully insulated serving system. It shall be provided with a continuous conducting colloidal graphite layer on the outer surface so that it will possible to prove the integrity of the serving at any time after commissioning as well as immediately after laying each length of cable, by means of a DC pressure test to earth. The serving shall be suitable for the test voltage of 10kV DC applied between the metal sheath and the external cable surface for one minute.

7.7.5 The serving of the cable shall be tough and durable and suitable for direct laying in the ground.

7.7.6 The following information shall be embossed on the surface of the overall serving at approximately 300mm intervals: Manufacturer's name or trademark, voltage rating, conductor size and conductor material.

7.8 132kV Cable joints and terminations

7.8.1 All joints shall be complete with jointing material, bonding, concrete coffins, cradles, filling compounds, fiber glass boxes, etc. as required for use in the ground and in cable tunnels, or as spare repair kits.

7.8.2 All cable joint boxes, sealing ends or termination boxes shall be of approved type, water-tight, free from sharp points or ridges, thoroughly clean internally and shall be designed for an approved filling medium to suit the type of cable to be jointed or terminated.

7.8.3 The material required under terminations shall include all cable sealing ends complete with terminating materials. The cable sealing end structures and copper work for connections between the cable sealing ends and isolators is <u>not</u> included in this Contract. The successful Tenderer will be required to co-operate in the design of the flexible clamps to be used on the sealing ends. (Refer to Item 2.43.3 of the "Schedule of Particulars and Guarantees", Form A, attached.) Alternatively, the cable sealing ends shall be of the plug-in type, and the successful Tenderer shall co-operate with the switchgear supplier to ensure compatibility. (Refer to Item 2.43.4 of the "Schedule of Particulars and Guarantees", Form A, attached.)

7.8.4 The civil work for the sealing end structures shall not be part of this Contract and the successful Tenderer shall liaise with the switchgear supplier and civil building contractor to design and construct the structures. The design and construction shall be subject to the approval of the Engineer. Full detail on the requirements for the sealing end structures shall be provided with the Tender, together with constructional drawings.

7.8.5 Except where otherwise specified or approved the metal sheathing of the cable shall be a plumbed wipe to the cable box sleeve or gland.

7.8.6 All jointing and terminating accessories shall be suitable for use on a fully insulated serving system specified above. Suitable bonding and earthing straps, removable links and terminals shall be provided to facilitate testing from the terminal positions.

7.8.7 The Contractor appointed shall ensure that the installation offered is reliable and require a minimum maintenance. Therefore all joints, terminations and other required accessories shall be fully compatible with the cable offered, and where applicable the existing cable, to form a complete system. The required type test and ageing test certificates called for in Clause 11.2.5 shall therefore clearly indicate this compatibility.

7.8.8 Joints and terminations shall be to the approval of the Engineer and shall be fitted with suitable wiping type glands of approved materials.

7.8.9 Suitable connections shall be provided for draining, filling or pressure filling the joint or termination as may be required. Expansion of the insulating compound in the cable joint and termination shall be allowed for in an approved manner.

7.8.10 Where applicable the flanged joints of pressurized cable accessories shall be machined to accommodate approved seals.

7.8.11 Sealing ends shall be provided with all necessary fittings including filing holes, air vents and expansion domes of approved capacity. Drain plugs of ample size shall be provided to permit the filling medium to be quickly removed.

7.8.12 Arcing horns shall be provided on outdoor sealing ends. Sealing ends shall be provided with insulating mountings (preferably porcelain) so that the base of the bushing and gland can be separately earthed if desired. This insulation of glands and arcing rings or horns shall withstand a test voltage as specified in the Item 2.12 of the “Schedule of Particulars and Guarantees”, Form A, attached. Removable links or other suitable facilities for short-circuiting the insulation shall be provided.

7.8.13 The porcelain used for bushings, shall be sound, free from defects and thoroughly vitrified. The glaze shall not be depended upon for insulation. The glaze shall be smooth, hard, and of a uniform shade of brown and shall cover completely, all exposed parts of the insulator. Outdoor insulators and fittings shall be unaffected by atmospheric conditions due to the weather, fumes, ozone, acids, alkalis, dust or rapid changes of air temperature between the limits specified above.

7.8.14 All fixing materials used shall be of suitable quality and properly applied and shall not enter into chemical action with the metal parts, or cause fracture by expansion in service. Cement thickness shall be as small and even as possible, and proper care shall be taken to center and locate individual parts correctly during cementing.

7.8.15 Each bushing shall be marked by a method of imprinting which shall be clearly visible and legible after assembly. Each such marking shall clearly indicate the manufacturer’s indication, batch number and firing date.

7.8.16 All clamps and fittings made of steel or malleable iron shall be hot-dip galvanized to the relevant SANS Standards.

7.8.17 All bushings shall be suitably designed to withstand the specified minimum impulse withstand voltages as well as the specified wet and dry power frequency withstand voltages.

7.8.18 Bushings and its associated parts when mounted as in service, shall be able to withstand the following test, which shall be performed on the top H.V. terminal on at least 5% of the units:

7.8.18.1 A pull of 1000N shall be applied at right angles to the axis of the top terminal stem and at the tip of the stem without distortion or failure of the terminal stem or its associated parts.

7.8.18.2 There shall be no air, gas or oil leaks detectable by approved methods.

7.8.19 Tenderers shall submit one complete set of drawings of the relevant types of joints, boxes, terminations and terminating materials for the cable offered, as well as a complete list of the jointing materials required for each type of joint or termination

7.8.20 Tenderers shall submit full details of surface mounted facilities for testing the insulation of the serving of the cables, including manholes, manholes covers and locking facilities for manhole covers.

7.8.21 All Tenderers shall return one copy of the cable route drawing(s), with their Tender on which the proposed positions of all auxiliary equipment are indicated.

7.9 132kV Cable bonding and earthing materials

7.9.1 The supply and installation of all bonding and earthing material shall form part of this Contract.

7.9.2 A single point bonding system shall be used, where one end of each insulated sheath section is solidly bonded and earthed and the other is allowed to float and be protected against over voltages by a sheath voltage limiter (SVL) housed in an approved link box. Full details of the expected standing voltages as well as maximum over voltage and energy dissipation capability of the SVL shall be stated in Items 2.48 and 2.49 of the “Schedule of particulars and Guarantees”, Form A, attached.

7.9.3 All such SVL’s shall be suitable to safely retain the voltage for the full duration of a fault condition of 1 second.

7.9.4 If the cable terminates in gas insulated switchgear, the solid bonding shall be done at the switchgear, through solid removable links housed in an approved link box.

7.9.5 A cross-bonded system shall not be considered on this installation as the possibility exists of cutting future substations into this route.

7.9.6 Suitable and approved testing facilities hall be provided on the power cable system cable system for commissioning and subsequent serving testing, which includes removable links between the cable armouring and substation earth.

7.9.7 Where the continuity of the metal sheath is required by the bonding design, for example at the joints, a copper bonding strap having an adequate cross sectional area to safely carry the full specified earth fault current shall be provided to bridge over whatever material is in the gap.

7.9.8 The Contractor shall provide all bonding and earthing straps or earthing bars to run in the cable trench or ducts to agreed points on the earthing system.

7.9.9 All bonding and earthing employed on power cables shall be of copper having an adequate cross sectional area.

7.9.11 A full bonding and earthing design complying with the requirements of this Specification shall be submitted with the Tender.

7.10 132kV Cable protection system

7.10.1 The supply and installation of a protection system for the power cables does not form part of this Contract. In some cases involving sealing ends however, the ring type current transformers supplied shall be installed over the cable on the sealing end structure prior to the cable being terminated.

7.10.2 This Contract provides for the Contractor to collect these current transformers from the CTMM's stores, transport, installation, cabling up, termination as well as testing and commissioning.

7.10.3 The cables used on current transformer circuits shall be multi-strand, 4 sq mm per conductor, PVC/PVC/SWA/PVC, 7 core, and shall comply with SANS 1507-3, Edition 1 of 2002.

7.11 Steelwork and galvanising

7.11.1 All outdoor steelwork shall be galvanized in accordance with Clauses 7.11.2 to 7.11.11 on exterior surfaces only. All other steelwork shall be painted in accordance with Clauses 7.11.12 to 7.11.16. The treatment of underground steelwork shall be to the approval of the Engineer.

7.11.2 Galvanising shall be applied by the hot dip process.

7 11 3 Sherardising (vapour galvanizing) or other similar processes shall not be permissible.

7.11.4 All welding, drilling, punching, cutting and bending of parts shall be completed and all scale, flux, rust and burrs removed and fabrication completed before the galvanising process is applied.

7.11.5 Threads of bolts and screwed rods shall be cleared by spinning or brushing; a die shall not be used.

7.11.6 In the case of nuts the threaded portion shall be cleared after galvanising by the passing through of a tap. Immediately after tapping to clear the threads the un-galvanised portions shall be coated by dipping in hot grease. The grease used shall be to the approval of the Engineer.

7.11.7 The zinc coating shall be adherent, smooth and continuous. The coating shall be free of such imperfections as lumps, thin patches, blisters, gritty areas, uncoated spots, acid and black spots and flux. The zinc coating shall not be so loosely adherent as to be removable by any reasonable process or handling during transport and erection. Light blows with a hammer shall not cause peeling of the coating adjacent to the area deformed by the hammer blows.

7.11.8 Globular and extra heavy deposits of zinc that will interfere with the intended use of the material will not be permitted.

7.11.9 Repair of faulty areas of galvanised steelwork shall be by re-dipping in molten zinc before the sample cools or oxidises.

7.11.10 Surfaces that are in contact with oil shall not be galvanised or cadmium plated.

7.11.11 Before painting, all ungalvanised metal parts shall be free from rust, scale or grease, and be cleaned thoroughly by sand-blasting or acid pickling and degreasing, and all external rough surfaces shall be filed. Prior to the application of the priming coating of paint, ferrous material shall be given an acid phosphate treatment.

7.11.12 All ungalvanised external surfaces other than nuts, bolts and washers, which may have to be removed for maintenance purposes, shall receive a minimum of three coats of paint at the Works and a final coat after erection on site.

7.11.13 Each coat of paint shall be of a different colour and shall be applied to a surface that is clean and dry. With the agreement of the Engineer, approved aluminium paints may be used as an alternative to the final Works and Site coats specified above.

7.11.14 Damage to paintwork incurred during transport and erection shall be made good by thoroughly cleaning the damaged portion and applying the full amount of coats that had been applied before the damage was caused.

7.11.15 Exposed un-galvanised nuts, bolts and washers that may have to be removed for maintenance purposes shall be painted a minimum of one coat after erection.

7.12 Civil materials

7.12.1 All civil materials required on this Contract shall be supplied and installed to the approval of the Engineer, and shall in all respects fully comply with this Specification.

7.12.2 The material in this item includes all the material required for the laying and installation of the cables such as cable clamps, cleats, fixtures, fittings, concrete cable slabs, bricks, cement mortar, concrete, concrete stone, building sand, manhole covers, lockable lids, etc., to complete the Contract in every detail.

7.12.3 The successful Tenderer shall submit full particulars and detailed working drawings of joint bays, all manholes and manhole covers that may be required three months prior to commencing of site work. The positioning and construction of all such manholes, levels of manhole covers, etc., shall be to the approval of the Engineer.

7.12.4 Segregated itemized prices shall be quoted for clamping, cleating, racking and supporting of the cables per meter of cable run, in the “Schedule of Prices”.

7.12.5 Where concrete is required, the concrete shall be composed of Portland Cement, fine aggregate and coarse aggregate in the proportions specified, and water to give the required consistency.

7.12.6 The proportions by volume of the concrete in the various parts of the work will be specified and shall be accurately measured as follows:

7.12.6.1 Grade “A” – 1 cement, 2 sand, 4 of 18 mm nominal stone.

7.12.6.2 Grade “B” – 1 cement, 3 sand, 6 of 18 mm nominal stone

7.12.6.3 Grade “C” – 1 cement, 3 sand, 6 of 25 mm nominal stone.

7.12.7 The concrete materials shall be separately measured in approved separate gauge boxes.

7.12.8 The concrete aggregates and cement shall first be mixed dry, then after addition of the minimum water consistent with practical workability, mixing shall be carried on until the concrete is of even colour and consistency throughout.

7.12.9 Where cement mortar and plaster is required the cement and sand are to be thoroughly mixed before being wetted. Water is to be added in suitable quantity. No mortar is to be used after it has begun to set.

7.12.10 The cement mortar for brickwork and plaster shall be composed of 1 part Portland Cement and 5 parts of good quality aggregate of sand.

7.12.11 All bricks are to be supplied by the Contractor and shall be first grade, hard, wire-cut, bricks. The bricks shall have a regular shape, have even surfaces and shall have a clear ringing sound when struck together. The bricks shall be thoroughly burnt throughout their whole substance, free from cracks, flaws, stony and un-ground lumps of any materials, and especially free from lumps of lime, however small.

7.12.12 The percentage increase in weight of bricks when immersed in water for 24 hours shall not exceed 8% of the dry weight.

7.12.13 All joints shall be well flushed at every course and shall be entirely filled with mortar before the next course is laid in order to ensure water tightness. The joints of all walls not intended to be rendered shall be neatly finished with a struck joint cut along the bottom.

7.13 Spanners and special tools

7.13.1 All special tools required for the adjustment and maintenance of the equipment supplied under this Contract, shall be provided mounted in one or more cabinets, fitted with locks. A pressure gauge alarm setting knob is for instance regarded as a special tool.

7.13.2 Eye-bolts which have to be removed after use shall be accommodated in the cabinets.

7.13.3 Special spanners and other maintenance equipment provided under this Contract shall not be used for the purpose of erection of the Works.

7.14 Clamps, cleats and cable racks

7.14.1 Clamping, cleating and racking material shall be supplied and installed by the Contractor to the approval of the Engineer.

7.14.2 In tunnels the cables shall be installed in touching trefoil formation tied together at 0,5m intervals, or in flat formation, depending on the designed rating of the cable installation. The three phase cable groups shall individually be clamped to the cable racks at intervals not exceeding 3m.

7.14.3 The cable clamps for clamping the cable down onto the racks, shall consist of a hard wood clamp of either kiaat or meranti which shall be profiled to exactly suit the cable dimensions and laying arrangement. These cable clamps or cleats shall have a minimum thickness of 50mm and shall be clamped down to the cable rack by means of bolts having a minimum diameter of 12mm. The Engineer shall approve the constructional drawing of the proposed clamps.

7.14.4 Support legs for the cable rack arms, if required, shall be provided and included for in the "Schedule of Prices".

7.14.5 The cable "ties" to be used for strapping the trefoil groups together at 0,5m intervals shall consist of 3M type glass tapes or approved equivalent, which shall be applied for 10 layers. Stainless steel strapping, or similar, shall not be acceptable.

7.15 Permanent testing facilities, manholes and surface cubicles

7.15.1 Suitable rust and weather proof cubicles and links boxes shall be provided for the accommodation of testing facilities on the cables, high voltage testing facilities on the fully insulated serving system, and sheath voltage limiting devices where required.

7.15.2 Testing facilities shall be provided at both ends of cables, and at intermediate points necessitated by the design requirements of the cable system.

7.15.3 Sheath voltage limiting devices shall be housed at the ‘floating’ end of the cable in the suitable cubicles with suitable manholes, if the floating ends are on the cable run.

7.15.4 All enroute testing and voltage devices shall be housed in manholes approved by the Engineer.

7.15.5 The manholes shall be provided with approved steel or cast manhole covers designed to combine ease of opening with strength to carry a 5 ton load. To prevent unauthorized access to manholes, suitable locking facilities shall be provided for all manhole covers. An inner stainless steel lid hinged on heavy brass or stainless steel hinges with suitable locking lugs for padlocks is suggested inside the manhole just below the actual manhole cover. Manhole covers measuring in excess of 700mm are not favoured.

7.15.6 The position of manholes and cubicles shall be approved by the Engineer.

7.15.7 Tenderers shall submit full constructional details of such manholes and cubicles with their tenders with particular reference to weight, size and duty for which manhole covers are designed.

7.16 Erection marks and labels

7.16.1 Before leaving the Contractor’s Works all apparatus and fittings shall be painted or stamped in two places at least with a distinguishing number and/or letter corresponding to the distinguishing number and/or letter on an approved drawing and materials list. The erection marks on galvanized material shall be stamped before galvanising and shall be clearly legible after galvanising.

7.16.2 All markings shall be legible and weatherproof, and if tags are used, they shall be durable, securely attached and duplicated.

7.16.3 Phase colours (red, yellow and blue) shall be labeled or painted on cable boxes, tail ends and single-core cables, at all connecting points and/or positions the Engineer may determine. Cable boxes and/or cables shall be marked with approved labels indicating the purpose of the supply at each end of the run and at intermediate points where the Engineer may require.

7.16.4 Labels for mounting indoors or inside kiosks or boxes shall be of approved material to ensure permanency of the lettering. The surface of the labels shall have a matt or satin finish to avoid dazzle from reflected light. Labels mounted on black surfaces shall have white lettering.

7.16.5 All labels and plates for outdoor use shall be of stainless steel or other approved non-corrodable material and shall be fixed with stainless steel screws. Where the use of enameled iron plates is approved the whole surface including the back and edges shall be properly covered and resistant to corrosion. Protective washers of suitable material shall be provided front and back on the securing screws.

7.17 Cable markers and cable slabs

7.17.1 After the bedding soil has been back-filled, the cables shall be covered with 75mm thick, lightly reinforced concrete slabs arranged to have a mean overlap beyond the edges of the cable(s) of at least 120mm. (Joints not encased in concrete coffins shall be slabbed to approval). These slabs shall be manufactured from grade B type concrete, specified in Clause 7.12.6.2 of this specification, and shall be reinforced using brick-force. The slabs shall be vibrated during casting.

7.17.2 Cable slabs need not be interlocked but successive slabs along the cable run shall be closely butted. Details of proposed cable slabs shall be provided with the Tender.

7.17.3 Cable markers stamped with the relevant information shall be provided and erected by the Contractor in approved positions to show the position of all joints, or of cables where there is any abrupt deviation in the route. The cable markers shall be erected and stamped with the relevant information at the time the filling work is affected. The cable marker label shall be to the approval of the Engineer.

7.18 Imported bedding soil and sub-base

7.18.1 Where in the opinion of the Engineer, local excavation soil is not suitable for the bedding of the cable, suitable imported fine sifted bedding soil shall be provided by the Contractor. At road crossings approved imported sub-base material shall be used.

7.19 Spares

7.19.1 Additional material and spares will be required as detailed in the “Schedule of Prices”.

7.19.2 Tenderers are required to state their recommendations and prices at the time of tendering regarding the stocking of additional spares. The accepted tender prices and conditions shall apply to the acceptance of any spares at any time during the currency of the Contract.

7.19.3 The Council reserves the right to place an order for any portion of the spares provided for in the “Schedule of Prices” and to subtract the value of spares not required from the Contract Sum.

7.19.4 Spares shall be packed separately, clearly marked, and suitably protected to ensure that there is no deterioration during indefinite storage.

7.19.5 Each case and package shall be permanently and clearly marked with the Enquiry number, reference numbers, relevant drawing number and the description of the contents.

7.19.6 A packing list stating the contents shall be packed in each case or crate and a duplicate sent direct to the Engineer when the spares are dispatched.

8. PACKING, HANDLING AND MARKING

8.1 General

8.1.1 If nothing is stated to the contrary by the Tenderer, it will be assumed that all cable reels and packing materials are non-returnable and that the prices quoted include for all such reels, packing and packing material.

8.1.2 The Contractor shall be responsible for the safe handling, off-loading and transport of all materials into the storage site.

8.1.3 The Contractor shall provide his own cable floats, trailers, trucks, etc., for transportation of materials between storage site and working site.

8.1.4 All cable drums and parking crates shall be clearly marked with following:

8.1.4.1 Name of manufacturer

8.1.4.2 Place of manufacture

8.1.4.3 Type of cable or equipment

8.1.4.4 Size and number of cores

8.1.4.5 Identification code

8.1.4.6 Length of cable on drum, if applicable

8.1.4.7 Weight of cable and drum, or weight of crate and contents

8.1.4.8 Drum number, if applicable

8.1.4.9 Factory length number, if applicable

8.1.4.10 Lot number

8.1.4.11 Destination

8.2 132 kV cable reels and shipment

8.2.1 The cable shall be delivered directly from the factory by an approved method and route of transportation.

8.2.2 There shall be no detectable traces of water in the cable when the reel is shipped. Each end of each length of cable shall be durably capped before shipment to prevent the ingress of moisture.

8.2.3 Each length of cable listed on the purchase order or detail list shall be shipped on a separate reel. The reels shall be new, of adequate construction, and suitable in every way for the safe handling and transport thereof.

8.2.4 The reels shall be lagged or covered with suitable material and strapped with steel banding to provide physical protection for the cables during transit and during ordinary storage and handling operations.

8.2.5 The cable shall be placed on the reels in such a manner that it will be protected from damage during shipment. Each end of the cable shall be firmly secured to the reel. Care shall be taken to prevent looseness of reeled cables.

8.2.6 The inner or drum end of the cable shall be allowed to project through the flange of the reel so the cable can be tested on the reel at the Site prior to installation. The inner end shall be protected to approval in order to avoid damage to the cable or end seal.

8.2.7 Provision for possible factory storage for approximately 12 months shall be provided for in the "Schedule of Prices". If delivery to Site on completion of manufacturing is not possible, the Engineer is at liberty to instruct the successful Tenderer to arrange storage of the cable at the prices per drum per month quoted.

8.3 Auxiliary material

8.3.1 Spares, as specified in Clause 7.19 shall be delivered to the Sub-transmission System Works Stores, 1 Schoeman Street, Tshwane.

8.3.2 Spare parts, auxiliary material, jointing material and terminating material shall be packed so as not to deteriorate in transit or during storage. Spares shall be packed separately and clearly marked.

8.3.3 One copy of the complete packing lists showing the number/s, size marks, weight and contents of each package shall be posted to the Engineer immediately the material is shipped or railed.

9. SETTING OUT AND NOTIFICATION

9.1 General

9.1.1 The laying, jointing and termination of the cables will be done along the routes as shown on the route plans forming part of this Specification and listed in the Annexures.

9.1.2 The necessary wayleaves and right of admission will be obtained by the Council.

9.1.3 The Contractor shall give adequate written notice of the commencement of work to occupiers of all properties affected by his operations giving contact details and shall, at his own expense, make good any damage caused to fences, gates, walls, paving, roads, gardens, or other property.

9.1.4 The Council may appoint and pay a Clerk of Works for the specified period of the Contract, as stated in Clause 50 of the "Conditions of Contract.

9.2 Tenderer to inform himself fully

9.2.1 The onus is on the Tenderer to inform himself fully as to the details of the work involved and the plant and equipment required for carrying out this Contract. Tenderers shall visit the sites to familiarize themselves with all the conditions on site before tenders are submitted. Tenderers shall allow for all conditions on site. No claims for extra will be allowed whatsoever if Tenderers failed to allow for all costs and any conditions peculiar to the site.

9.3 Existing services

9.3.1 The Contractor shall inform himself fully as to the existence or not of existing services and shall be responsible for any loss or damage in accordance with Clause 32(b) of the "General Conditions of Contract".

9.3.2 To locate the exact position of existing services, the Contractor shall make cross-cuts at about at 30m intervals along the cable route, for each length of cable to be laid at a time. The cross-cuts shall be excavated by hand at the unit prices quoted in the "Schedule of Prices", and shall be 2m long straddling the trench center-line, 1m deep and 0,5m wide.

9.3.3 The positions of all services shall be carefully noted by the Contractor and this information shall be entered onto the final as-laid route plan.

9.3.4 See also Section 4 – Part 1.1 above.

10. WORK AND INSTALLATION

10.1 General

10.1.1 The work under this Contract consists generally of the following:

10.1.1.1 Manufacture, testing, supply, delivery and off-loading on Site of the cable and accessories called for in this specification at the prices stated in the "Schedule of Prices".

10.1.1.2 Excavating, preparing (including the handling and riddling of bedding soil), back-filling and reinstatement of a rectangular trench of adequate width to permit the laying of cables at the specified depths below general ground-level, and of the required number of joint bays of adequate size to permit the jointing of the cables as specified.

10.1.1.3 Laying, bedding, slabbing, piping, termination, installation and testing of the cable and accessories called for in this Specification.

10.1.1.4 Consolidation of back-fill, reinstatement of trench and joint bays and restoration of surfaces as specified.

10.1.1.5 Incidental work under Clauses 10.1.1.1, 10.1.1.2, 10.1.1.3 and 10.1.1.4 above that may be required for the proper completion of the Contract, and for the protection of existing services.

10.1.1.6 The Work and Installation shall be carried out in compliance with the Environmental Management Plan (EMP) in Annexure 2.

10.1.1.7 Payments for cable and auxiliary material will be adjusted for the measured and true quantities after completion of the work. Likewise progress payments will be made on application by the Contractor (see Clause 75) on measured quantities of excavation and back-fill, etc., completed and finally adjusted for the total quantity measured.

10.2 Working drawings

10.2.1 The work shall be carried out in accordance with the Specification and the drawings listed in the Annexures.

10.2.2 Drawings showing the approximate position of existing cables along the routes will be issued to the Contractor before he commences work. No guarantee is however given that the positions shown on these drawings are absolutely correct, nor is any guarantee given that all cables are shown on these drawings.

10.2.3 Excavations in the vicinity of existing 33kV or 132kV cables shall be carried out under the supervision of the Engineer or his representative.

10.2.4 The Contractor shall be responsible for obtaining drawings from other Municipal Departments and Authorities showing the positions of underground services.

10.2.5 All documents and drawings provided for the Contractor’s use during the execution of the Contract shall be returned to the Engineer on completion of the Contract.

10.2.6 See also Section 4 – Part 1.1 above.

10.3 Working hours

10.3.1 Site work carried out for the execution of this Contract shall be confined, as far as possible, to the normal working hours on normal working days (i.e. 07:00 to 17:00 on Mondays to Fridays) excluding Public Holidays.

10.3.2 Work to be done outside normal working hours shall be approved by the Engineer who shall be notified, with the reasons stated in writing, at least 3 days in advance of any work to be done outside normal working hours.

10.3.3 See also Section 4 – Part 1.2 above.

10.4 Office and storage site

10.4.1 A site to erect an office and storage facilities for the execution of the Contract will be made available to the Contractor, in a position as close to the cable routes as is practically possible.

10.4.2 The Contractor shall be responsible for all temporary buildings, fences, gates, latrines and equipment required on this site, and for all arrangements to obtain water, electricity, telephone, sewerage, or any service to the site.

10.4.3 The Contractor shall be solely responsible for all security arrangements for the safe storage of materials on site and the arrangements for safe storage positions along the route. The Council will not be liable for any loss or damage of any materials or equipment whatsoever.

10.4.4 All arrangements made by the Contractor under Clauses 10.4.1, 10.4.2 and 10.4.3 shall be to the approval of the Engineer.

10.4.5 Prices for the supply and delivery of materials shall allow for all railage, transport, handling, loading and off-loading on site.

10.4.6 The receiving on site of all materials and the handling thereafter shall be the responsibility of the Contractor.

10.4.7 No trees or shrubs on the site shall be removed or damaged.

10.4.8 On completion of the Contract the Contractor shall clear the site of all temporary offices, sheds, temporary structures waste material and rubbish.

10.4.9 All activities carried out on the Contractor’s Site facilities shall be strictly in accordance with the EMP.

10.4.10 The sum provided for in the “Schedule of Prices” for Plant, shall include for the supply, delivery, erection, maintenance and removal on completion of all plant of every description together with all tools required for the complete carrying out of all work under this Contract.

10.4.10 The Contractor’s claim for the sum for Plant and equipment will only be considered on completion of the Contract provided no Plant, equipment or labour has been withdrawn (without the Engineer’s consent) from the Contract, whereby completion of any part of the Contract has been delayed.

10.4.11 See also Section 4 – Parts 1.1, 1.2 and 1.9 above.

10.5 Security measures

10.5.1 Work inside electrical yards are subject to the Council's security measures and the Contractor shall contract the Council's Metro Police prior to the commencement of any work under the Contract to make the required security arrangements. The cost of security measures shall be included in the rates for site work.

10.5.2 If so required by the Council, all employees of the Contractor and his sub-contractors employed with regard to the execution of the Contract shall be security cleared on such conditions as laid down by the Council.

10.5.3 Should any employee of the Contractor or his sub-contractor, for whatever security reasons, be declared unfit, the Contractor or the sub-contractor shall have the right to appoint any person in lieu of the employee who had been disqualified for security reasons, subject to the Council's security clearance.

10.5.4 The Contractor undertakes to treat all information regarding the Contract and the execution thereof as strictly confidential.

10.5.5 The Contractor undertakes that he himself, his sub-contractors and all employees if required will sign the Council's Declaration of Secrecy.

10.5.6 The Contractor undertakes in the execution of the Contract, to report to the Metro Police, without delay and confidentially, any information regarding:

10.5.6.1 Any suspected espionage in respect of the lay-out of the site where the work is being executed, or in respect of sites where protective measures are applied.

10.5.6.2 Actions which may be interpreted as sabotage or planning in this regard.

10.5.6.3 Any suspected subversive activities among his employees.

10.5.6.4 The loss of any classified documents which came into his possession as a result of the Contract.

10.5.6.5 The contravention of any security measure by an employee.

10.5.6.6 Housebreaking, theft, arson, vandalism, loss of identity documents, security keys or lock combinations.

10.5.6.7 Corruption, blackmail, intimidation, striking or inciting striking or unauthorized access to an office or premises.

10.5.6.8 Any employee who is involved with the Contract and who is suspected of bringing drugs, intoxicating liquor, a weapon, ammunition or explosives on the site of the Council.

10.5.7 The Council shall have the right to inspect, at all reasonable times, and through its Metro Police, the Contractor's and sub-contractor's premises and offices where work in connection with the Contract is executed or where documents in that connection are kept, in order to prescribe suitable security measures, and to determine whether the prescribed security measures are being implemented

10.5.8 See also Section 4 – Part 1.2 above.

10.6 Excavations

10.6.1 The term "Excavation" shall mean all excavations necessary for the execution of the Contract, and shall include joint holes and excavations for any other purpose. The prices quoted in the "Schedule of prices " for excavation shall include for excavations in rock, earth, gravel, clay or any other material encountered and shall include all safeguards necessary to comply with Regulations and to protect the excavations from damage from any cause whatsoever. It shall be distinctly understood that the Council will not be responsible for any variation in the strata and type of material in between trial holes and under no circumstances will the Contractor be paid an extra price due to such variation.

10.6.2 The unit rate for excavation includes the cost of compliance with the EMP, suitable back-filling, the maintenance of the joint hole and the removal of foreign objects, water, rocks, stones, rubble, roots, etc. and of any surplus material and the reinstatement of the trench including the restoration of the sub-base (or Hydrofill), tarmac, concrete or tiled covering. Soil excavated on the route and used elsewhere on the route for back filling will be regarded as local soil and the distribution and handling of such soil shall be included in the unit rate for excavation.

10.6.3 A limited number of trial holes will be provided by the Electricity Department upon request and at points indicated by Tenderers, to serve as guidance to Tenderers who will be responsible for their own interpretation of the available evidence. Should Tenderers wish to undertake further investigation prior to tendering this might be done at their own expense and on their own responsibility, by arrangement with the Engineer.

10.6.4 The precise positions, gradients, descriptions, and levels of the various works, where not shown upon the drawings or described in the Specification, will be determined by the Engineer as the work proceeds and after the cross-cuts called for in Clause 9.3.2 has been excavated.

10.6.5 Steel pegs, to be used as references by the Contractor for setting out the line, may be placed at bends in the route, prior to the commencement of the Contract and will be pointed out to the Contractor, if applicable. These pegs shall not be removed until the progress of the works necessitates such removal.

10.6.6 The Contractor shall set out the works and keep them correct in every particular, according to the Contract Documents and according to drawings and directions that may be given from time to time, and he shall be responsible for the correctness thereof throughout the whole term of the Contract. He shall rectify any error that may arise in the execution of the Works at his own cost.

10.6.7 The Engineer prior to any excavations being made must check the Contractor's setting out and the Contractor shall then rectify any errors.

10.6.8 At least one day's notice of such setting out shall be given by the Contractor to the Engineer. The Contractor shall supply any material and labour required for the survey work.

10.6.9 The trench shall be excavated to 1,2m below general ground level or as directed by the Engineer. The trench shall be of adequate width to permit the laying of one or more cable circuits at the specified spacing and shall permit slabbing as specified in Clause 10.9 hereof. Moderate widening of the base of the trench to permit slabs to be aligned correctly over the cables will be permitted.

10.6.10 Tenderers shall state the proposed minimum basic trench width in Item 1.10 of the "Schedule of Particulars and Guarantees", Form A, attached.

10.6.11 The bottom of the trench shall be level, firm and of smooth contour. Trenches shall be kept as straight as possible, true to the approved formation.

10.6.12 Tenderers are to conduct a close and careful inspection of the whole Site of the Works so as to inform them fully of the nature of the ground to be excavated, the necessity for timbering (shoring) or side sloping in places, and generally to make them fully acquainted with all matters that will affect their pricing of the work.

10.6.13 No special payment will be made for side sloping or timbering trenches and the Contractor shall be entirely responsible for any falls, slides and caving-in, for the safety of workmen and work, and for timbering and shoring or battening the sides of trenches to make them safe for the workmen and to keep the sides standing throughout the whole period of excavation and maintenance of the open trench or to comply with any statutory requirements. (Eg. Occupational Health and Safety Act No 85 of 1993)

10.6.14 The sides of all cutting through rock shall be examined by the Contractor and cleared of all loose or insecure fragments, blocks, or stones that may at any time be likely to cause injury or damage.

10.6.15 Except where approved by the Engineer in writing to the contrary, the maximum length of trench which may be open at any time shall not exceed two successive cable lengths. Sufficient fencing, barricading, notices, traffic signs, etc., shall be provided to comply with the safety measures specified in respect of all open excavation. Drawings of the barricading to be used shall be submitted with the Tender. Self-supporting barricading constructed out of light steel pipe, painted yellow, will be preferred.

10.6.16 If during the course of excavation obstructions are encountered which necessitate alterations to the cable route, the trench, or utilisation of a special type of trench, these alterations shall be approved in writing by the Engineer beforehand.

10.6.17 A maximum tolerance of ±50mm in the level of the trench bottom will be allowed. All excess depths shall be filled with approved soil and properly consolidated. Where excavation additional to the 50mm tolerance is ordered or sanctioned by the Engineer, this excavation, filling and consolidation will be paid for as agreed in writing at the unit prices quoted in the "Schedule of Prices".

10.6.18 The decision as to whether mechanical excavators may be used on this Contract rests with the Engineer and the Contractor shall not use excavating machines without the written approval of the Engineer. In built up areas where numerous underground services exist the Contractor may be required to excavate by hand. Should the Engineer approve of the use of machines on sections of the route, such sections shall strictly be adhered to and the Engineer shall have the power at any time to revoke any permission granted for the use of excavating machines should he deem it necessary and the Contractor shall continue excavation by hand without extra costs to the Council.

10.6.19 Depending on the cable design and basic drum lengths, the final positions of joint bays shall be adjusted on site after each length has been laid to take advantage of any surplus cable gained. The Contractor in consultation with the Engineer shall decide upon such positions. (See also Clauses 7.1.11 to 7.1.13)

10.6.20 Except where otherwise specified or approved, the joint bays shall be excavated to the required depth, shall be rectangular and shall be of adequate size to enable jointers to carry out their work efficiently and expeditiously, and to permit the staggered jointing of two 132kV cable circuits in the same joint bay where applicable. The depths of excavation for joint bays shall be given in Item 3.7 of the "Schedule of particulars and Guarantees", Form A, attached.

10.6.21 The Contractor shall be entirely responsible for timbering and shoring or battering the sides to make the joint bays safe for workmen and to keep the sides standing until jointing has been completed.

10.6.22 All excavated material shall be removed from the trenches and stacked on that side of the trench ordered by the Engineer. No excavated material shall be nearer than 300mm from the side of the trench, and the material required for refilling around the cable as may be selected by the Engineer, shall be carefully deposited at the top of the bank of excavated material nearest the trench so as to be readily accessible. The excavated material shall be stacked as compactly as possible, consistent with the safety of the workmen and the Works so as not to cover an unnecessarily large area and in such a manner that the cables can be easily handled in the trench.

10.6.23 All excavated material shall be stacked in such a manner as not to unnecessarily inconvenience or disturb pedestrians and traffic. Where considered necessary by the Engineer to facilitate vehicular traffic or for other reasons, such portion of the excavated soil as he considers necessary, is to be removed by the Contractor immediately it is excavated and shall be deposited upon a site to be agreed upon and afterwards brought back and deposited where required. The cost of handling of excavated material shall be in addition to the unit rate for excavation as quoted in the 'Schedule of Prices".

10.6.24 In excavating in streets and roadways, if required, the Contractor shall treat all road material, such as tarmac, medalling and gravel as surplus material specified in Clause 10.6.26.

10.6.25 All excavated material shall be so deposited as to cause no injury to people, structures, private property, any services, or the Works, and the Contractor will be held entirely responsible for making good at his own expense any damage so caused.

10.6.26 All surplus excavated material not required for back-fill, including rocks, boulders, etc., shall be removed from the Site unless otherwise required by the Engineer. Any surplus material so removed shall be deposited, spread and leveled at dumping places approved by the Engineer, within a shortest road distance of 30km from the cable route. Such transport and dumping of surplus excavated material shall be paid for at the unit rate for transport, handling and dumping site fees quoted in the "Schedule of Prices".

10.6.27 Transport for dumping in excess of 30km road distance shall be paid for at the unit rate for transport quoted in the "Schedule of Prices".

10.6.28 The Contractor shall maintain the trench in a proper condition, free from storm-water, seepage, mud, loose earth, rocks and stones, or any foreign material until the cables are laid, bedded, slabbed and back-filled. Such maintenance of the trench is included in the unit rate for excavation. No excavation shall be left open for more than twenty-eight days without the Engineer's written consent.

10.6.29 The Contractor shall be liable for damage to excavations and surrounding property due to water or other foreign material entering the trench.

10.6.30 The Contractor shall be responsible for maintaining access to the trench where ordered by the Engineer and shall also be responsible for preventing excavated materials being washed into the trench by storm flow.

10.6.31 Clauses 10.6.28 to 10.6.30 are also applicable to cross cuts and joint bays.

10.6.32 Public and existing services shall be dealt with in accordance with Clauses 57 to 61 of the "General Conditions of Contract".

10.6.33 The Contractor will be responsible and liable for all damages to public and private property, existing services and to passers-by due to the execution of this Contract.

10.6.34 Unless otherwise agreed provision shall be made during excavation and until interim restoration has been completed for reasonable access of persons and vehicles to private and public property or places adjacent to the route, to the approval of the Engineer.

10.6.35 Any alterations to existing services shall be done by the Authority concerned.

10.6.36 Where the trench passed in the immediate vicinity of any stay, telephone, electric or robot poles, the Contractor shall, unless otherwise specified or approved, tunnel the trench past such a pole in order to safeguard the existing overhead services. The bridge of earth above the tunneled section shall be known as a bolster for the purpose of this Contract. Depending on the nature of the earth, the dimensions of a bolster shall be such that it will support or withstand any force or moment exercised on such a pole. Consideration shall also be given to the horizontal forces at the base of poles, where these are in the direction towards the cable trench. In the case of low-voltage overhead mains, poles are buried to an average depth of 1350mm.

10.6.37 Where ordered by the Engineer, the Contractor shall recover any redundant cable encountered in the trenches required for this Contract, and shall deliver such redundant cable to the Sub-transmission System Works Stores, 1 Schoeman Street, Tshwane.

10.6.38 Cable to be recovered will be identified and cut initially at both ends by the Electricity Department. The Contractor may do further cutting if the cable is to be recovered as scrap. If instructed by the Engineer to recover redundant cable for re-use, the recovered cable shall be handled with the usual care, consistent with good practice, and drummed on drums which may be obtained, free of charge, for this purpose only, from the abovementioned stores.

10.6.39 The unit rate quoted for the recovery of redundant cable in the "Schedule of Prices" shall include all cutting, drumming, handling and transportation costs of the cable.

10.6.40 Should the Engineer deem it advisable not to recover an existing cable in the trench, the Contractor shall excavate a recess in the trench wall so that the cable can be repositioned to permit laying of the 132kV and pilot cables or other approved measures shall be taken to safeguard the existing cable.

10.6.41 When the excavations for the trench/es and joint bay/s have been accurately executed, notice shall be given by the Contractor to the Engineer to enable an inspection and measuring up of the trench to be carried out without undue delay.

10.6.42 After inspection of the completed trench or portions of trench by the Engineer, payment will be made in accordance with Clause 75 of the "Conditions of Contract" <u>on a basis of linear metres of completed trench</u>. This payment for trenching shall include excavation, bedding, back filling, restoration of road crossings, tarmac, concrete driveways, concrete and tiled paving, etc., maintenance and reinstatement of the trench and all matters associated therewith, at the rates quoted in the "Price Schedule".

10.6.43 Where excavation below the bottom of the trench or widening of the trench was ordered by the Engineer in writing, such excavation will be measured in the solid and paid for separately at the prices per cubic meter to be quoted under the item "Additional Excavation" in the "Schedule of Prices".

10.7 Pipes and ducts

10.7.1 At certain road and street crossings, if required by the Engineer, 132kV cables shall be laid in at least 160mm diameter (OD) PVC pipes with sockets and control cables and earth bond in at least 110mm (OD) PVC pipes with sockets, in well rammed soil. The 132kV cable pipes shall be in identical arrangement to the 132kV cables. Spare pipes shall be provided at road crossings as directed by the Engineer. The top of the tier pipes shall be 900mm below general ground-level.

10.7.2 At storm-water canal crossings (or where ordered by the Engineer), cables shall be laid in 160mm diameter (OD) PVC pipes with sockets encased in concrete, at the discretion of the Engineer. The pipes shall be jointed to form the required length and spare pipes shall be provided where required. The diameter of the pipes for the earth bond shall be 110mm (OD).

10.7.3 Where cable pipes are required to be laid these shall be supplied, laid and jointed in an approved manner. After the pipes have been laid they shall be cleaned and a mandrel of diameter slightly less than the pipe shall be drawn through. A draw wire of galvanized steel shall be left in each pipe and the ends shall then be suitably plugged.

10.7.4 Where required, 132kV cable ducts shall be filled with bentonite.

10.7.5 The unit price for laying pipes shall include the supply, loading, transport, off-loading, handling and laying of the pipes in well rammed soil. The Engineer may order pipes to be embedded in a slightly moistured 12: 1 soil and cement mixture and a unit price for the placing of this shall be quoted in the “Schedule of Prices”.

10.7.6 Subject to the conditions of Clause 75 of the “Conditions of Contract”, payment for pipes and the laying of pipes across roads and storm water canals, will be made on a basis of linear meters of pipe laid, after the trench in which they have been laid, has been properly back-filled and reinstated. The price for filling with “bentonite” shall also be quoted per linear meter of pipe.

10.7.7 Extra concrete placed as ordered by the Engineer shall be measured in cubic meters and paid for at the rate quoted in the “Schedule of Prices”.

10.8 Cable installation and bedding

10.8.1 The Contractor shall satisfy the Council that he has wide experience in the laying of 132kV cable (of the type offered). If, in the opinion of the Engineer, the Contractor does not lay the cables in an efficient and satisfactory manner, the Engineer shall have the power to order the Contractor to employ additional plant, tools, labour or anything he may see fit in order that the work may thereafter be executed in a proper and efficient manner, at no extra cost to the Council.

10.8.2 The method of laying of cable shall be approved. Battens shall not be removed from cable drums before the actual day of laying and shall be replaced if the cable is not laid on that day.

10.8.3 Tenderers shall describe the method of cable laying they propose using. If a winch pulling technique is proposed, each length of cable shall be equipped with a suitable pulling eye designed to pull simultaneously on the sheath and all cores, and the cost of this item shall be included in the overall cost quoted for the cable. All spare lengths of main-run cable shall also be equipped with a pulling eye. Winch pulling shall not be used on fiber optic pilot cable.

10.8.4 Tenderers shall state the maximum tension permissible for pulling in Item 2.34 in the "Schedule of Particulars and Guarantees', Form A, attached

10.8.5 If a winch pulling technique is used, the winch shall be equipped with a suitable accurate dynamometer to register the tension exercised on the cable when pulling. The maximum tension on each length of cable shall be recorded in the laying report and a copy of each laying report shall be forwarded to the Engineer immediately after completion of each laying operation.

10.8.6 In order that the trench may be back-filled as soon as possible, the Contractor shall commence laying the cable in drum lengths with the minimum of delay. The Contractor shall not; however, back-fill the trench until each length of cable as laid has been inspected and approved by the Engineer.

10.8.7 In cable tunnels cables shall be laid in such a way that each feeder occupies the minimum space on a rack-arm 610mm long on two different racking levels. Provision shall be made for the necessary support to prevent overloading of the rack-arms in the "Schedule of Prices", if required.

10.8.8 When cable are being drawn through pipes, care shall be taken not to bend excessively or to damage the cable in any way. Short sections of removable rubber piping or other approved methods shall be used at pipe mouths to avoid damage.

10.8.9 Where the 132kV cables are to be laid directly in the ground, 80mm of selected, fine sifted imported earth shall first be placed on the bottom of the trench to form a bed for the cables. After the cables have been laid in the trench and have been inspected and approved by the Engineer, they shall be covered with selected fine sifted imported earth well punned over and around the cables to a level of 80mm the top of the cables. The Contractor shall arrange for the testing of at least one sample of imported soil from each source and a copy of each test report shall be submitted to the Engineer prior to any soil being imported. The Engineer shall have the power to order such further thermal resistivity tests on imported soil as he sees fit without additional cost to the Council. The thermal resistivity of imported bedding soil shall be less than 1,2 ^{o}K m/W.

10.8.10 On completion of the cable laying operations the removal of rollers (if used) from the trench shall be carried out as soon as the full length of cables has been drawn into the trench and this operation shall be carefully supervised. If applicable, the cables in each circuit shall be tied together in trefoil formation.

Pipe ends shall be sealed in an approved manner after the cable has been drawn through.

10.8.11 After each length of 132kV cable has been laid and fully embedded, but prior to back filling, a 10kV DC for 1 minute pressure test shall be done on the outer covering of individual cables in the presence of the Engineer

10.8.12 After the cables have been laid in the trench and prior to slabbing sharp tools such as spades or objects which may damage the cable shall not be used in the trench or placed in such a position that they may fall into the trench.

10.8.13 Where, in the opinion of the Engineer, the local excavated soil is not suitable for back-filling of the trench, the Contractor shall supply suitable back-filling to be obtained from a source to be approved by the Engineer.

10.8.14 The unit price for imported soil in the "Schedule of Prices" shall include the screening (for bedding soil), loading, transport, off-loading and distribution of the imported soil, as well as the cost of testing.

10.8.15 Where chemically active soil is encountered, the Contractor shall notify the Engineer immediately and be responsible for taking special precautions to protect the cables against chemical action and shall submit particulars of such special precautions to the Engineer for approval

10.8.16 Payment for cable will be based on the measured quantities of completed cable laid, with an allowance of 2 meter per 132kV joint and 1 meter per 132kV cable termination. Consideration will however be given to the Council taking over useful surplus lengths at unit prices, at the discretion of the Engineer.

10.8.17 Subject to Clause 75 of the "Conditions of Contract", payment for the laying and installation of the cables will be made on the basis of linear meters of cable laid.

10.8.19 The rate quoted for the laying of cables shall include for the transportation, handling, pulling, laying and installation of the cable.

10.9 Slabbing of cables

10.9.1 The use of cable slabs shall be in accordance with Clause 7.17.

10.9.2 The unit rate for laying slabs in the "Schedule of Prices" shall include the loading, transportation, off-loading and handling of the slabs.

10.9.3 Payment for placing of concrete slabs will be made at the rate quoted per slab in the "Schedule of Prices" subject to the "Conditions of Contract".

10.10 Cables in close proximity to and crossing of other services

10.10.1 The following minimum clearance between the 132kV cable and other services shall be maintained:

		Vertical	Horizontal
10.10.1.1	Telkom cables………………………………….	0,3 m	0,3 m

10.10.1.2	Oil pipe line and RW water pipe lines………..	1,0 m	1,0 m
10.10.1.3	Other water pipes…………………………….	0,3 m	0,3 m
10.10.1.4	Sewerage pipes………………………………	0,3 m	0,8 m
10.10.1.5	Storm water pipes……………………………	0,3 m	0,6 m
10.10.1.6	Other electrical cables………………………	0,3 m	0,075 m
10.10.1.7	All types of manholes and catch pits…………	_	0,1 m

10.10.2 At points where other services are crossed, the cables shall cross underneath any service encountered which are not deeper than 1500mm and over any service encountered which is in excess of 1500mm deep. All service crossings decisions shall be referred to the Engineer for approval.

10.10.3 When in the course of a Contract obstructions are encountered which necessitate the diversion or alteration of the above services or any other alteration, Contractor shall immediately notify the Engineer who will instruct the Contractor in writing to proceed with such work as may be necessary in the regard, subject to the provisions of the Conditions of Contract in so far as these are applicable.

10.10.4 The special conditions stipulated by Telkom for the crossing of telephone cables, shall be strictly complied with.

10.10.5 For oil pipeline and Rand Water pipe lines the Contractor shall obtain the written permission to cross these services from the Engineer and hold it available on site at all times.

10.10.6 The Contractor shall make an appointment with the oil pipeline and/or Rand Water authorities to supervise the crossing of these services strictly in accordance with the written permission granted. The cost of supervision shall be included in pipeline crossing unit prices in the “Schedule of Prices”.

10.10.7 In both cases (Clause 10.10.5) cable pipes shall be installed up to 1,5m on either side of the pipe lines, and these cable pipes covered over their entire length with concrete slabs.

10.10.8 The Contractor shall obtain the letter of consent setting out the conditions and requirements to cross Municipal, Provincial and/or National Roads from the relevant authorities and keep it available for scrutiny on site at all times. The work shall be carried out in strict accordance with the letter, and care shall be taken not to disrupt the traffic flow unnecessarily. Expenses incurred to obtain approval and submit traffic control plans, control of traffic, etc., shall be included in the road crossing unit prices in the “Schedule of Prices”.

10.10.9 Railway crossings shall be done in 150mm internal diameter PVC pipes in a concrete surround spanning the railway reserve from border to border with a minimum spacing of at least 1500mm between the top of the pipes and the bottom of the sleepers.

10.10.10 The Contractor shall be responsible to comply with all the requirements made by the Spoornet and shall obtain these requirements in writing. The Contractor shall bear all costs for supervision by Spoornet, and shall provide for this in the unit prices quoted in the "Schedule of Prices".

10.10.11 The crossing of rivers, canals and irrigation ditches shall be done with 150mm diameter PVC pipes encased by at least 100mm grade A concrete. (Refer to Clause 7.12.6.1). The length of pipe shall extend the riverbank by at least 1m on either side, and 50% spare pipes shall be provided. The top of the concrete shall be 300mm below the riverbed. The Contractor shall construct the cofferdams and retaining walls required to lay the pipes. The Contractor shall be responsible for adherence to the EMP. (See also Section 1.9 above)

10.10.12 If the crossing of a river alongside a bridge is approved by the Engineer, the cables shall be suspended in steel trays from the bridge side-walk. The cables shall be taken through the bridge retaining or abutment walls through holes lined with PVC pipes of minimum diameter required. The holes in the abutment wall shall be filled in around the pipes with grade B concrete and shall be finished flush and neat. For the first 5 meters from each retaining wall, the cables shall be fully enclosed by suitable steel covers to protect them willful damage. For the balance of the crossing, suitable heat shields shall be provided to protect the serving from radiation from the sun. Care shall be taken that no magnetic circuit is closed around individual cables. The Contractor shall submit full particulars of his proposal regarding the crossing to the Engineer for approval before the crossing is attempted.

10.10.13 At tunnel entrances the Contractor shall excavate up to the sealing wall and reseal the wall after the cables have been installed.

10.10.14 Subject to the conditions of Clause 75 of the "Conditions of Contract", payment for pipes and the laying of pipes across roads and storm water canals, will be made on a basis of linear meters of pipe laid, after the trench in which they have been laid, has been properly back-filled and reinstated. The price for filling with "bentonite" shall also be quoted per linear meter of pipe.

10.10.15 Payment for placing of concrete slabs will be made at the rate quoted per slab in the "Schedule of Prices" subject to the "Conditions of Contract".

10.10.16 Extra concrete placed when ordered by the Engineer shall be measured in cubic meters and paid for at the rate quoted in the "Schedule of Prices".

10.10.14 See also Clause 10.7 above.

10.11 Construction of joint bays

10.11.1 Joint bays shall be constructed so as to enable jointers to carry out their work efficiently and expeditiously.

10.11.2 Joint bays shall be provided with an approved base of grade B concrete (see Clause 7.12.6.2), not less than 75mm thick.

10.11.3 The sides of each joint bay shall be timbered or boarded where necessary to avoid subsidence of soil, damage to cables, or interference with the jointing operations.

10.11.4 The unit rate quoted in the "Schedule of Prices" for construction of the joint bays, shall include the supply and delivery of all materials required, the casting of the concrete, boarding of the walls and all other work required for the construction of the joint bays.

10.11.5 Burried 132kV joints shall be protected by concrete, or brick coffins, covered with concrete slabs. Tenderers shall include in their Tender layout and constructional details of joint bays and outer joint boxes. Tenderers shall state the filling medium used in these coffins or outer joint boxes, and generally describe the precautions taken against corrosion and damage from other external causes.

10.12 Construction of testing facilities and manholes (Refer Clause 7.15)

10.12.1 The Contractor shall provide, built, cast and construct suitable manholes where required for the accommodation of underground high voltage testing facilities on fully insulated serving systems.

10.13 Clamping and cleating of cables on racks in cable tunnels

10.13.1 The clamps, cleats and cable racks required in tunnels shall be supplied by the Contractor in accordance with Clause 7.14 and installed to the approval of the Engineer.

10.14 Jointing

10.14.1 Tenderers shall satisfy the suppliers of the cable and the Council that they are competent to joint the cable offered. Jointing shall be carried out strictly in accordance with the "Jointing Instructions", and shall be paid for at the unit rates quoted in the "Schedule of Prices". The Contractor shall furnish 1 copy of the Manufacturer's jointing instructions to the Engineer before jointing is commenced.

10.14.2 During jointing operations, the joint bays shall be adequately covered with tents of clean waterproof sheeting suitably supported, and where necessary a trench shall be excavated and coffer-dams be constructed around the joint bays to prevent the ingress of water.

10.14.3 The joint bays shall be adequately illuminated throughout the jointing operations and shall as far as possible be maintained free from dust, dirt and water. If required by the jointing technique such joint bays shall be adequately sealed off and air-conditioned.

10.14.4 All surplus materials remaining from jointing shall be removed and dumped by the Contractor at a site approved by the Engineer.

10.14.5 Each joint shall be numbered and referred to by such number on all records, test sheets, cable cards and sketches called for in Clause 11.1.3.

10.14.6 Tenderers shall include in their prices for jointing for all normal and incidental jointing material required in this respect, in accordance with the Specification. (Clause 7).

10.14.7 The Contractor shall provide and fill all boxes with approved filling medium to the correct level, and shall be responsible for maintaining the medium at the correct level and pressure during the maintenance period.

10.14.8 Subject to the "Conditions of Contract", payment for jointing will be made at rates quoted for each joint and termination in the "Schedule of Prices".

10.14.9 The rates for each type of joint shall include the transportation and handling of all material required, the provision of all waterproof sheeting, tarpaulins, tools, etc., the application of all special techniques required and the filling of all cable, joint and termination boxes.

10.15 Cable terminations

10.15.1 The Contractor shall provide all terminating materials in accordance with the Specification (Clause 7) and shall carry out the work at the prices quoted in the "Schedule of Prices".

10.15.2 Except where special techniques apply, the ends of all cable including the ends of the cable on the drum, shall be sealed immediately after cutting to prevent the ingress of moisture.

10.15.3 Cables shall be made off and terminated in strict accordance with the manufacturer's instructions for terminating. The successful Tenderer shall furnish 1 copy of the manufacturer's terminating instructions to the Engineer before terminating is commenced.

10.15.4 The Contractor shall provide and fill all boxes with approved filling medium to the correct level, and shall be responsible for maintaining the medium at the correct level and pressure during the maintenance period.

10.15.5 All cores and tails shall be identified, labeled marked and/or coloured in an approved manner.

10.15.6 The Contractor shall be responsible for the correct phasing of all terminations.

10.15.7 The positions of sealing ends will be indicated on site by the Engineer.

10.15.8 Subject to the "Conditions of Contract", payment for termination will be made at rates quoted for each joint and termination in the "Schedule of Prices".

10.15.9 The rates for each type of termination shall include the transportation and handling of all material required, the provision of all waterproof sheeting, tarpaulins, tools, etc., the application of all special techniques required and the filling of all cable, joint and termination boxes.

10.16 Earthing and bonding

10.16.1 The material shall be supplied in accordance with Clause 7.9 and installed by the Contractor at the unit prices quoted in the "Schedule of Prices".

10.16.2 At terminations all cable sheaths and armouring shall be bonded to the cable terminating box and earthed, using sweated connections wherever possible.

10.16.3 Where provision has to be made for high-voltage serving tests, removable links in accessible positions (see Clause 7.15.1) shall be provided, and these portions of the earthing system to which high voltage will be applied under test conditions, shall be adequately insulated for a 10kV DC test voltage.

10.16.4 The Contractor shall submit a schematic earthing and bonding diagram to the Engineer for approval.

10.17 Reinstatement of trenches and joint bays

10.17.1 As soon as possible after each length of cable or cables have been laid, covered and slabbed, tested and proved satisfactory, the joint bays and trench shall be back-filled in layers of not more than 300mm thick.

10.17.2 The earth in each layer shall be well rammed, and consolidated and sufficient allowance made for settlement before permanent reinstatement is carried out. The Engineer reserves the right to insist that mechanical tampers be used at no extra cost if in his opinion consolidation is not satisfactory.

10.17.3 No boulders or stones larger than 30mm in diameter shall be used in back-filling. Waste materials shall be disposed of as described in Clause 10.6.26. Where the local soil is not suitable for back-filling, and there is no surplus back-fill further along the route, the Contractor shall supply imported back-fill obtained from a site to be approved by the Engineer at the unit rates quoted in the "Schedule of Prices". (see Clause 10.8.13)

10.17.4 Completed sections of the cable routes shall be maintained by the Contractor at his expense in a thoroughly safe condition for the duration of the Contract, i.e. until the expiry of the maintenance period.

10.17.5 The costs of reinstatement of trenches and joint bays in unmade ground shall be included in the rates for excavation.

10.17.6 On completion, the Contractor shall clear the site of all stumps, debris, surplus material, waste material and rubbish at the rates quoted in the "Schedule of Prices". (see Clause 10.6.26). The Contractor shall level of all ground on Site and shall reasonably restore the Site to the conditions existing immediately prior to the commencement of such works, except where otherwise provided for, and shall leave the Site in a clean and tidy order, to the satisfaction of the Engineer.

10.17.7 The cost of clearing the Site shall be included in the various unit prices for work.

10.18 Reinstatement of road and covered pavement surfaces

10.18.1 Where the trench has crossed roads, tarmac and covered pavements, back-filling shall be done in layers of 150mm maximum, each layer well rammed and consolidated. Care shall be taken not to disturb pipes, and to avoid air pockets where pipes have been laid. The Contractor shall establish the compaction standards required by the particular roads authority, and arrange for the inspection and testing of the back-fill and compaction of the crossing.

10.18.2 The refilled trench shall be temporarily reinstated and maintained in a thoroughly safe condition and suitable for permanent reinstatement using approved sub-base material (or Hydro fill) as required by the particular roads authority.

10.18.3 The Contractor shall arrange with the particular roads authority for the repair of such roads, tarmac, pavements, etc., as may be required.

10.18.4 No claim for excavation of a section will be considered before the surface coverings of that section have been reinstated permanently.

10.18.5 Subject to the conditions of Clause 75 of the “Conditions of Contract”, payment for pipes and the laying of pipes across roads and storm water canals, will be made on a basis of linear meters of pipe laid, after the trench in which they have been laid, has been properly back-filled and reinstated. The price for filling with “bentonite” shall also be quoted per linear meter of pipe.

10.18.6 Payment for placing of concrete slabs will be made at the rate quoted per slab in the “Schedule of Prices” subject to the “Conditions of Contract”.

10.18.7 Extra concrete placed when ordered by the Engineer shall be measured in cubic meters and paid for at the rate quoted in the “Schedule of Prices”.

10.18.8 Where the cable route runs under the tarmac road surface as indicated on the route plan, payment for the cutting of the tarmac with a circular cutter shall be at the rates per linear meter quoted in the “Schedule of Prices” in accordance with the “Conditions of Contract”.

10.18.9 Where the cable route runs under the tarmac road surface (not at street crossings) as indicated on the route plan, payment for the reinstatement of the road surface as described in this Specification, shall be at the rates per square meter quoted in the “Schedule of Prices” in accordance with the “Conditions of Contract”.

11. RECORDING AND TESTING

11.1 Recording

11.1.1 A Site book with duplicate pages shall be kept by the Contractor, and must at all times be accessible to the Engineer. All the Site instructions and agreements reached between the Contractor and the Engineer shall be entered in this book, and signed by both. No claims for payment for incidental work and/or material supplied will be considered if the full details are not entered in the Site book. A copy of each entry in the Site book will be handed to the Engineer on signature.

11.1.2 Each inner joint box, outer joint box or coffin, and each length of cable shall be numbered distinctly and after Site testing, these numbers shall appear on the test sheet covering the respective joint box and/or length of cable.

11.1.3 Approved dimensioned plans, sketches and cable cards for record purposes shall be prepared by the Contractor, who shall include in these sketches any information available to him regarding particulars of the depth of the trench, the position of the cable, the position of all joints and the position of all obstructions or other services revealed during the course of the excavations. The Contractor shall include in his price for the provision of approved cable cards, plans or sketches of “plant as installed”. All plans or sketches shall be supplied on a CD-ROM in DWG DGN format in the case of CAD drawings, or ESRI shape file format in the case of GIS data, and shall be to approval.

11.2 Factory testing

11.2.1 All cable and associated equipment supplied to this specification shall be tested in accordance with the requirements of the relevant Standard Specification, specifically IEC 502.

11.2.2 Factory tests shall be regarded as an integral part of the manufacturing of the various items and shall be allowed for in the unit prices quoted for supplying.

11.2.3 Not less than seven days notice shall be given to the Engineer, or his representative appointed at the commencement of the Contract, of all Factory tests, in order that he may be present if he so desires.

11.2.4 A copy of the Contractor’s records of all factory tests shall be furnished to the Engineer, immediately after such tests and before any material is shipped. No material shall be installed before the Engineer has officially approved these tests.

11.2.5 The following <u>sample</u> (type) tests shall be carried out by the Contractor at the Factory (unless an alternative place of testing is specified or approved) on a sample of the 132kV cable taken from each drum length:

11.2.5.1 The insulation physical properties <u>before</u> ageing shall be determined and shall meet the minimum requirements quoted in Item 2.5 of the “Schedule of Particulars and Guarantees”, Form A, attached.

11.2.5.2 The insulation physical properties after ageing shall be determined in accordance with the relevant SANS Standards and shall meet the minimum requirements as quoted in Item 2.6 of the "Schedule of Particulars and Guarantees", Form A, attached.

11.2.5.3 A conductor shield void and contaminant determination shall be done on at least one meter sample for each 3000m of stock length, or from the outer end of each reel if a number of reels of identical cable are being run. Voids, contaminants and translucent shall not exceed the following dimensions:

Voids	20 microns
Contaminants	100 microns
Translucents	100 microns

11.2.5.4 The semi-conducting shielding shall be tested to determine that the elongation test for thermosetting material at 135°C ± 1°C for 168 hours is less than 100%, and that the brittleness temperature is not warmer than –10°C.

11.2.5.5 A solvent extraction test shall be done on the semi-conducting shielding on each reel and the tested shielding shall be inspected thereafter for continuity and integrity.

11.2.5.6 The PVC serving shall be tested in accordance with SANS 1507-3 Edition 1 of 2002 for the compliance with physical requirements as quoted in Item 2.11 of the "Schedule of Particulars and Guarantees", Form A, attached.

11.2.5.7 A bending test shall be done on at least one sample of each type and size of cable to be supplied.

11.2.6 The following routine tests shall be carried out by the Contractor at the Factory (unless an alternative place of testing is specified or approved) on the 132kV cable:

11.2.6.1 Conductor resistance test, where the conductor resistance of each completed cable length is measured at ambient temperature and corrected to 20°C. The figure so obtained and recorded shall not exceed the figure stated in Item 2.1.6 of the "Schedule of Particulars and Guarantees", Form A, attached.

11.2.6.2 High-voltage test in accordance with IEC 60840 Edition 3 of 2004 Clause 9.2, where each completed cable length is tested for 30 minutes at a voltage of rms value 2,5 x U_0 at 50 Hz applied between the conductor and earth (i.e. outer core screens and sheath earthed).

11.2.6.3 Partial discharge test in accordance with IEC 60840 Edition 3 of 2004, where each reel of completed cable shall be tested at the rated AC rms voltage of 1,5 x U_0 without the discharge magnitude exceeding 5 pico-coulombs at 50Hz frequency.

11.2.6.4 Dielectric power factor/voltage test, where each length of completed cable is tested for power factor at normal frequency, a temperature of 15°C and at the following percentages of normal voltage:

50, 100, 150 and 200.

The power factor of the charging kVA shall not exceed the values in accordance with IEC 502, i.e. a maximum value of 0,004 at 100% with a maximum increment of 0,002 between 50% and 200%.

11.2.6.5 Outer serving high-voltage test in accordance with IEC 60840 Edition 3 of 2004 Clause 15.1 (IEC 60229 Clause 9), where each completed length of cable shall be tested by means of a 10kV DC voltage applied between the metal sheath and the external cable surface (i.e. earth) for one minute. The leakage current shall be measured and recorded.

11.2.6.6 Capacitance test (if it can not be determined from an approved method from test 11.2.6.4 above), where the capacitance between the core and screen for each length of cable shall be measured and recorded. If the capacitance can not be determined by test 11.2.6.4, the Tenderer shall state the method.

11.2.6.7 The cross-linked polyethylene insulation shall be tested for dimensional stability. To ensure acceptable shrink back, each reel of cable shall be tested by exposing the cable core for one meter and heating a maximum of 500mm of the exposed core for one hour to a minimum of 160°C. The heated part shall then be allowed to cool naturally for at least 9 hours. Forced cooling is unacceptable. The maximum allowable shrink back is 8mm. If the end exhibits more than 8 mm shrink back the entire reel shall be rejected. The details of the testing, i.e. time duration, temperatures, measurements, etc., shall be recorded on the cable test sheets.

11.2.7 Routine tests shall be done on each and every length of power cable supplied.

11.2.8 Tenderers shall submit with their Tenders comprehensive and detailed type test certificates to substantiate compliance with the above standards and the requirements of this Specification.

11.2.9 All 132kV XLPE type cable and associated equipment offered shall be supported by an approved test record by an independent testing institute, certifying a minimum life expectancy of 50 years proved by accelerated ageing tests. Type test certificates shall also be submitted for all joints and terminations offered, confirming compliance with this Specification and compatibility with the cable system offered.

11.3 Site and commissioning tests

11.3.1 All cable and associated equipment supplied to this Specification shall be tested in accordance with the requirements of the relevant Standard Specifications.

11.3.2 Site and commissioning tests shall be regarded as an integral part of the work and installation of the various items, and shall be allowed for in the unit prices quoted for work and installation.

11.3.3 Not less than seven days notice shall be given to the Engineer, or his representative/s appointed at the commencement of the Contract, of all Site and commissioning tests, in order that he may be present if he so desires.

11.3.4 One copy of the Contractor's records of all Site and commissioning tests shall be furnished to the Engineer, immediately after such tests and before any further work is done on the Contract.

11.3.5 The Engineer shall have the power to order such additional tests as in his opinion, may be necessary to determine that the Plant complies with the requirements of the Specification.

11.3.6 The following routine site tests shall be carried out by the Contractor on the 132kV cable:

11.3.6.1 132kV cable outer serving high-voltage test in accordance with IEC 60840 Edition 3 of 2004 Clause 15.1 (IEC 60229 Clause 9), where each laid length of cable shall be tested by means of a 10kV DC voltage applied between the metal sheath and the external cable surface (i.e. earth) for one minute. The leakage current shall be measured and recorded. Serving faults shall be located and repaired by the Contractor at his own cost, and the serving high-voltage test repeated.

11.3.6.2 132kV cable outer serving high-voltage test as detailed in Clause 11.3.6.1 above, on the cable lengths already jointed after completion (and bedding) of each successive joint.

11.3.6.3 After installation and on completion of the Plant, a conductor resistance test, where the conductor resistance of each completed 132kV power cable circuit including joints, terminations and accessories is measured at ambient temperature and corrected to 20°C. The figure so obtained and recorded shall not exceed the figure stated in Item 2.2.3 of the "Schedule of Particulars and Guarantees", Form A, attached.

11.3.6.4 After installation and completion of the Plant, a high-voltage test in accordance with IEC 60840 Edition 3 of 2004 Clause 15.2, where each completed 132kV power cable circuit, including joints, terminations and accessories is tested for 60 minutes at a voltage of 132kV applied between the conductor and earth (i.e. outer core screens and sheath earthed).

11.3.6.5 After installation and on completion of the Plant, an outer serving high-voltage test in accordance with IEC 60840 Edition 3 of 2004 Clause 15.1 (IEC 60229 Clause 9), where each completed length of 132kV power cable including joints, terminations and accessories shall be tested by means of a 10kV DC voltage applied between the metal sheath and the external cable surface (i.e. earth) for one minute. The leakage current shall be measured and recorded. Serving faults shall be located, repaired and retested by the Contractor at his own cost.

11.3.6.6 After installation and on completion of the Plant, a capacitance test where the capacitance between each core and screen for each length of 132kV power cable including joints, terminations and accessories shall be measured and recorded. The value shall not exceed the value given in Item 2.21 of the “Schedule of Particulars and Guarantees”, Form A, attached. In addition, a positive and zero impedance measurement of the completed installation shall be carried out and stated on the final test certificates submitted.

11.4 Other tests

11.4.1 The Tenderer shall state and detail additional tests that he considers necessary on the cable and the cable installation.

12 DRAWINGS AND DESCRIPTIVE LITERATURE

12.1 Information supplied at the tendering stage

12.1.1 Tenderers shall include in their Tenders full descriptive material relating to the equipment offered, including cross sectional drawings and constructional detail on the 132kV cable.

12.1.2 Tenderers shall also supply the drawings and information called for elsewhere in this Specification.

12.1.3 Tenderers shall submit one complete set of prints of the relevant types of joints, joint boxes, terminations and terminating materials for the cables offered, as well as a complete list of materials required for each type of joint or termination.

12.1.4 Tenderers shall submit detail of surface mounted and/or underground facilities for testing the insulation of the serving of the cables, including manholes and manhole covers.

12.1.5 Tenderers shall submit the complete bonding and earthing design called for in Clause 7.9 of the Specification.

12.1.6 All Tenderers shall return one copy of the route drawing/s with their Tender on which proposed positions of joints and auxiliary equipment are indicated.

12.1.7 Tenderers shall submit a schedule listing the proposed section lengths of the cable offered, together with the corresponding drum weights and sizes.

12.1.7 Tenderers shall submit the type test (sample) certificates called for in Clause 11.2.8 of the Specification.

12.2 Final manuals

12.2.1 The Contractor shall supply one copy of all test results, test sheets or test certificates elsewhere called for in the Specification, immediately after such tests are completed.

12.2.2 The Contractor shall supply two copies of the following information at least one month prior to commencing laying and jointing operations:

12.2.2.1 Any special instructions relating to the laying of the cable offered.
12.2.2.2 Complete jointing instructions relevant to the cable offered.
12.2.2.3 Complete terminating instructions relevant to the cable offered.
12.2.2.4 Any special commissioning instructions.
12.2.2.5 Detailed maintenance instructions.

12.3 Final drawings

12.3.1 The Contractor shall supply a true to scale transparency drawing drawn in Microstations (or Autocad) at least one month prior to commencing laying and jointing operations of each of the following:

12.3.1.1 Detail of each joint used on the Contract.
12.3.1.2 Detail of surface cubicles.
12.3.1.3 Detail of clamps and cleats.
12.3.1.4 Detail of each sealing end and termination used on the Contract, including the pilot cubicle, fibre optic terminating cubicle and supporting structures.
12.3.1.5 A schematic earthing and bonding diagram.
12.3.2 On completion of the Contract the following true to scale drawings drawn in Microstations (or Autocad) on CD-ROM shall be supplied by the Contractor:
12.3.2.1 Detail of each joint used on the Contract.
12.3.2.2 Detail of surface cubicles.
12.3.2.3 Detail of clamps and cleats.
12.3.2.4 Detail of each sealing end and termination used on the Contract, including the pilot cubicle, fibre optic terminating cubicle and supporting structures.
12.3.2.5 A schematic earthing and bonding diagram.
12.3.2.6 Constructional detail of cable supports, racks, etc., detail for river and other crossings, special terminations, etc.
12.3.2.7 An “as laid” final route plan detailing the exact positions of joints, terminations, cables and equipment installed, as described in Clause 11.1.3 of this Specification. The route plan shall be GEO referenced on a WGS 94 datum within the LO29 band (could be in ESRI shape file format).
12.3.2.8 It is a requirement of this Contract that all final operating and maintenance manuals, drawings, route records, test results and detail as called for in this Specification be provided to the Engineer prior to commissioning of the cable circuits. Any outstanding drawings, manuals or certificates will result in commissioning being delayed and may result in the Contract payments being delayed.

B. TURBINE EXAMPLES

A turbine uses the energy of moving water to generate electricity by converting the kinetic energy of the water into rotational energy used to power the generator (Paish, 2002).

Turbines can be classified according to their type of action as either impulse or reaction turbines. Impulse turbines are surrounded by air while reaction turbines are submerged in water (Paish, 2002). **Table B-1** provides a summary of the classification of turbines.

Table B-1: Groups of water turbines (Natural Resources Canada, 2004)

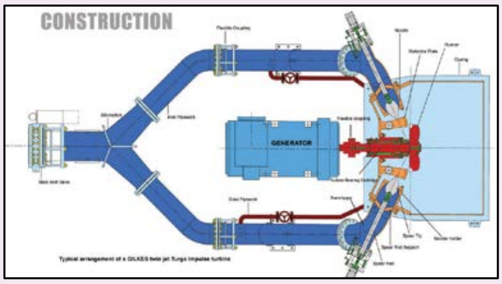
Turbine runner	**High head**	**Medium head**	**Low head**	**Ultra-low head**
	> 100 m	**20 m - 100 m**	**5 m - 20 m**	**< 5 m**
Impulse	Pelton Turgo	Cross-flow Turgo Multi-jet Pelton	Cross-flow Multi-jet Turgo	Water wheel
Reaction	-	Francis Pump-as-Turbine	Propeller Kaplan	Propeller Kaplan

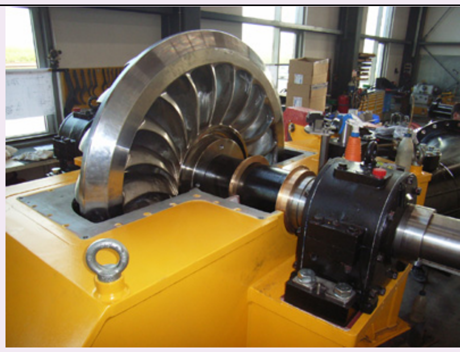
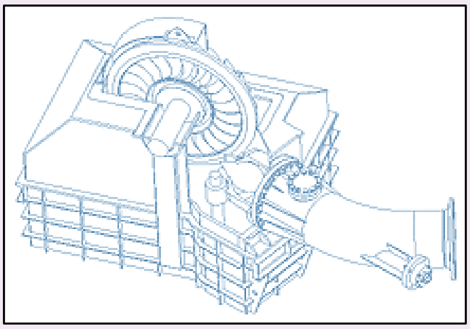
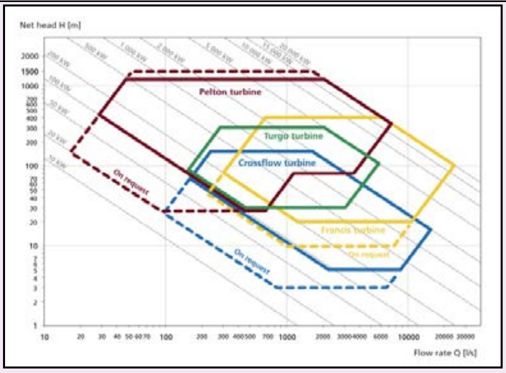
This appendix discusses several examples of turbines. Different types and manufacturers have been included, with contact details. It is important to note that all information was directly sourced from manufacturer – and supplier websites and therefore the source of each table is the included website reference. Table B-2 provides a summary of the content of this appendix, with turbines color-coded according to type, name and manufacturer.

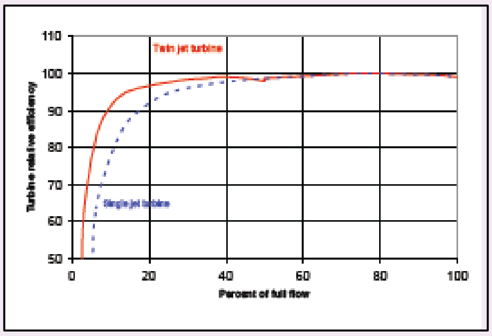
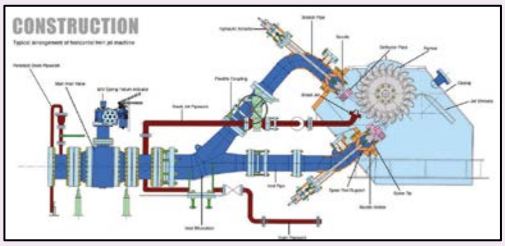
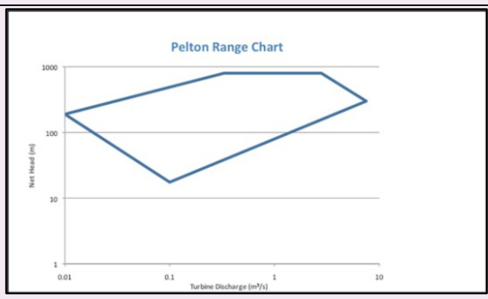
Table B-2: Layout of Appendix B

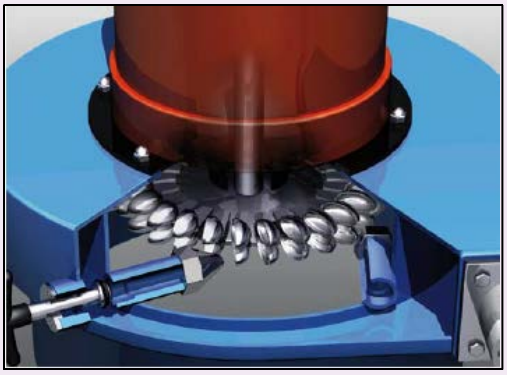
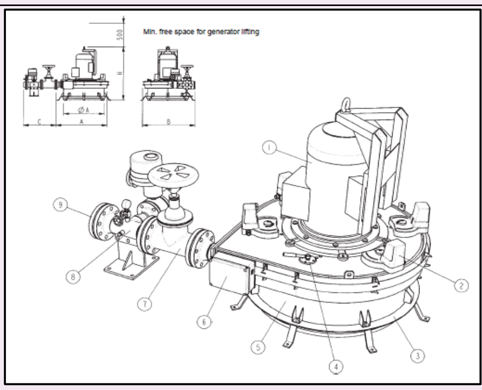
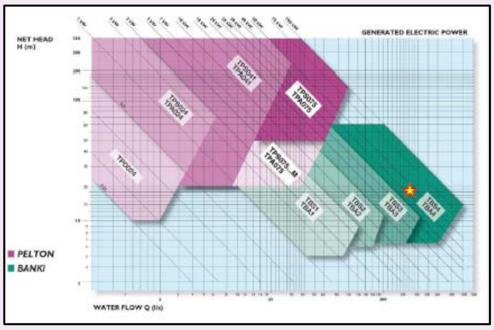
Type	Turbine	Supplier
Impulse	Turgo	Gilkes
		Wasserkraft Volk
	Pelton	Gilkes
		IREM
		Powerspout
		Mavel
		Voith
		Wasserkraft Volk
	Crossflow	IREM
		Ossberger
		Wasserkraft Volk
	Hydrodynamic Screw	Andritz
Reaction	Kaplan	Ossberger
		Mavel
		Voith
	Bulb	Voith
	Francis	Wasserkraft Volk
		Gilkes
		Mavel
		Voith
	Pump-turbine	Voith
	Syphon-turbine	Mavel
	Inline Turbines	Kawasaki Ring
		Lucidpipe Spherical

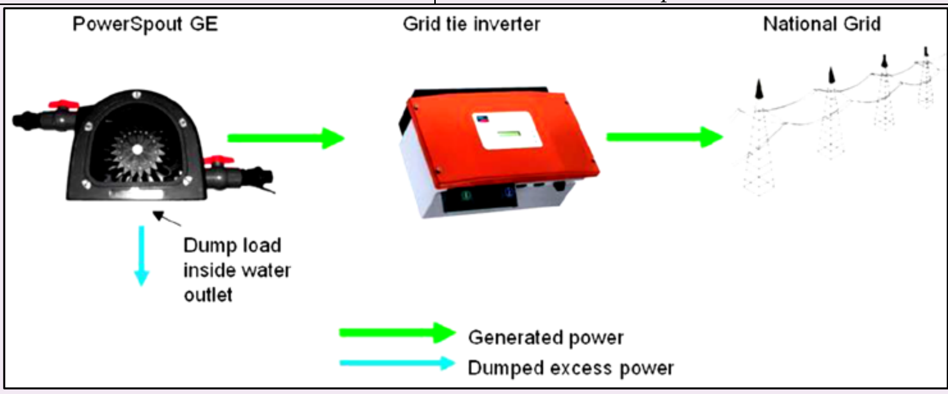
B.1 IMPULSE TYPE TURBINES

Turbine Name:	**TURGO TURBINE**
Company name:	**Gilbert Gilkes & Gordon Ltd**
Company Address:	Canal Head North Kendal Cumbria UK
Company Tel:	+44 (0) 1539 720028
Company E-mail:	enquiries@gilkes.com
Website:	www.gilkes.com
Turbine Description:	The Gilkes Turgo is a simple machine with high specific speed, where water is directed at an angle onto the runner. It can handle dirty water.
Pressure Head Range	Up to 300 m
Flow Range	0.04 m^3/s to 6 m^3/s
Power Range	Up to 10 000 kW
Illustrations, Photos and Applicable Graphs:	 *Turgo runner*  *Turgo turbine installation*  *Typical layout*  *Turbine range*

Turbine Name:	**TURGO TURBINE**	
Company name:	**Wasserkraft Volk AG**	
Company Address:	Am Stollen 13 D-79261 Gutach GERMANY	
Company Tel:	+49 7685-9106-0	
Company E-mail:	mail@wkv-ag.com	
Website:	www.wkv-ag.com	
Turbine Description:	Wasserkraft Volk Turgo turbines have low equipment cost due to high specific speed, maintenance-free shaft-seal design, with bearings rated for more than 100 000 operating hours.	
Pressure Head Range	30 m to 300 m	
Flow Range	Not given	
Power Range	Up to 5 000 kW	
Illustrations and Applicable Graphs:	 *Turgo turbine room*	 *Turgo turbine wheel*
	 *Typical turbine drawing*	 *Wasserkraft Volk turbine ranges*

Turbine Name:	**PELTON TURBINE**	
Company name:	**Gilbert Gilkes & Gordon Ltd**	
Company Address:	Canal Head North Kendal Cumbria UK	
Company Tel:	+44 (0) 1539 720028	
Company E-mail:	enquiries@gilkes.com	
Website:	www.gilkes.com	
Turbine Description:	Gilkes Pelton turbines can be supplied as horizontal (single or twin jet) units or vertical (three, four or six jet) units and high efficiencies over a wide range.	
Pressure Head Range	Up to 1 000 m	
Flow Range	0.01 m^3/s to 10 m^3/s	
Power Range	Up to 20 000 kW	
Illustrations, Photos and Applicable Graphs:	 *Pelton runner*	 *Pelton turbine efficiency*
	 *Typical layout*	 *Turbine range*

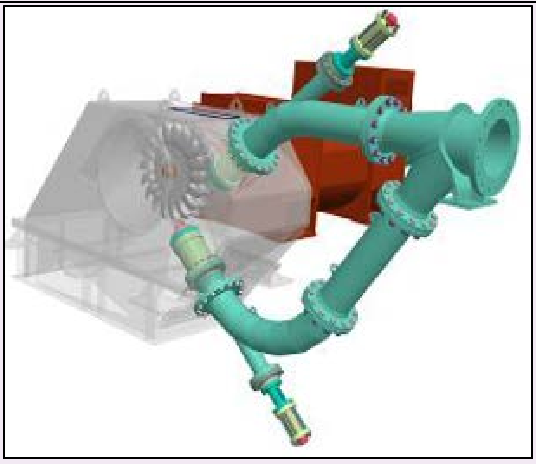
Turbine Name:	**PELTON TURBINE**
Company name:	**IREM SpA a Socio Unico**
Company Address:	Via Abegg 75 Borgone Susa ITALY
Company Tel:	+39 011 9648211
Company E-mail:	irem@irem.it
Website:	www.irem.it
Turbine Description:	IREM Pelton turbines have six nozzles and are splined directly onto a synchronous or asynchronous generator shaft, depending on the electricity use.
Pressure Head Range	20 m to 350 m
Flow Range	0.0005 m^3/s to 0.1 m^3/s
Power Range	Up to 100 kW
Illustrations, Photos and Applicable Graphs:	 *Pelton runner*  *Pelton turbine*  *Turbine components*  *IREM turbine range*

Turbine Name:	**POWERSPOUT PELTON TURBINE**
Company name:	**POWERSPOUT (Papersmith and Son (PTY) Ltd.** (South African Distribution))
Company Address:	PO BOX 72548 Parkview GT 2122 SOUTH AFRICA
Company Tel:	+27 011 2406900
Company E-mail:	jo@papersmith.co.za
Website:	www.powerspout.com
Turbine Description:	Powerspout Pelton turbines are made from more than 60% recycled material. This pico turbine can be installed in series to generate up to 16kW.
Pressure Head Range	3 m to 100 m
Flow Range	0.008 m^3/s to 0.01 m^3/s
Power Range	Up to 1.6 kW per turbine
Illustrations, Photos and Applicable Graphs:	 *Pelton runner*  *Powerspout turbine room*  *Turbine set-up*

Turbine Name:	**PELTON TURBINE**
Company name:	**Mavel Hydro Turbines** (**Scion Technologies** (South African Distribution))
Company Address:	Northbank 3rd Floor Northbank Lane Century City, Cape Town SOUTH AFRICA
Company Tel:	+27 21 552 9993
Company E-mail:	karenr@sciontechnologies.co.za
Website:	www.mavel.cz
Turbine Description:	Mavel Pelton runners are customized and can be configured either vertically or horizontally.
Pressure Head Range	80 m to 1000 m
Flow Range	0.1 m^3/s to 10 m^3/s
Power Range	70 kW to 30 MW

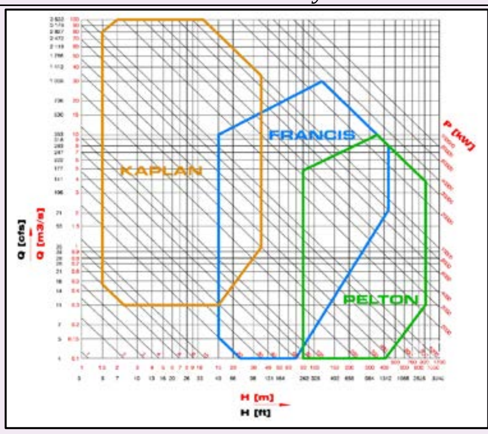
Illustrations and Applicable Graphs:

Pelton turbine runner



Pelton turbine layout

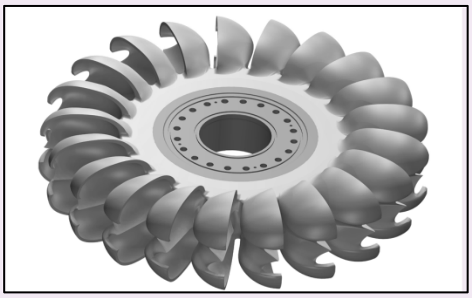
Installed vertical Pelton turbines



Turbine range

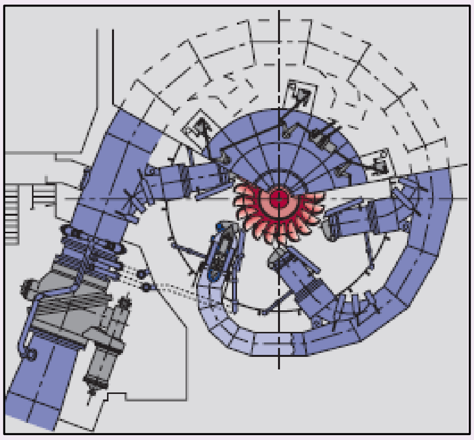
Turbine Name:	**PELTON TURBINE**
Company name:	**Voith Hydro Holding GmbH & Co. KG**
Company Address:	Alexanderstrasse 11 89522 Heidenheim GERMANY
Company Tel:	+49 7321 37 0
Company E-mail:	info.voithhydro@voith.com
Website:	www.voithhydro.com
Turbine Description:	A full range, from large custom-built machines, to standard small hydro turbines, is available from Voith.
Pressure Head Range	95 m to 1 500 m
Flow Range	Not given
Power Range	10k W to 400 MW

Illustrations and Applicable Graphs:

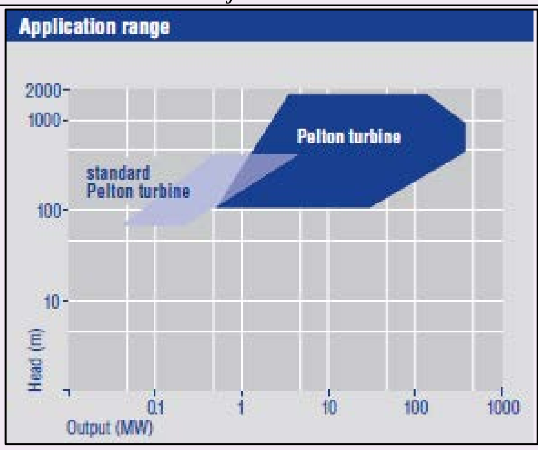


Pelton turbine runner

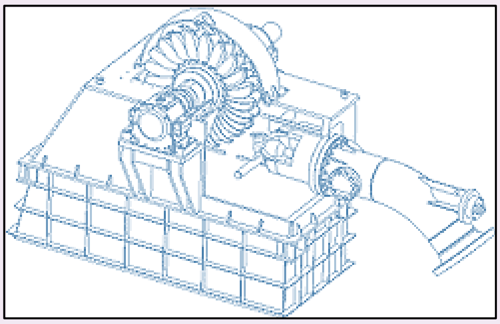
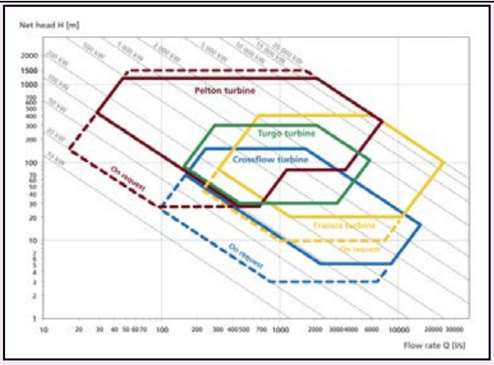
5-jet turbine

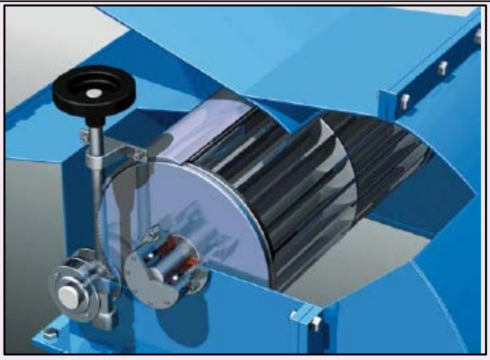
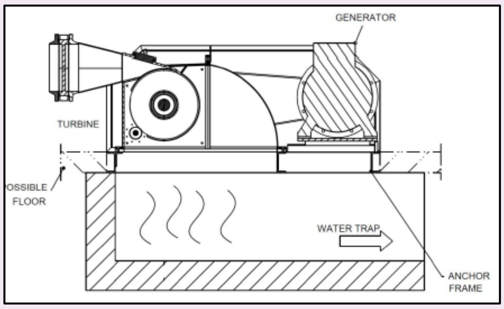
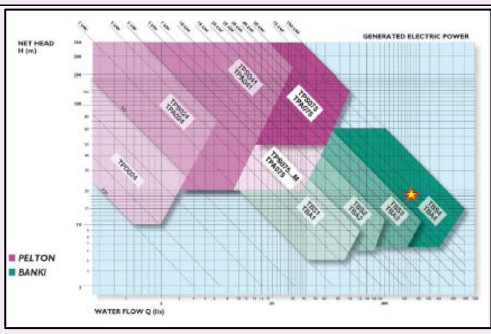


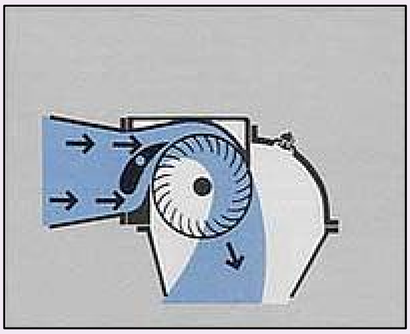
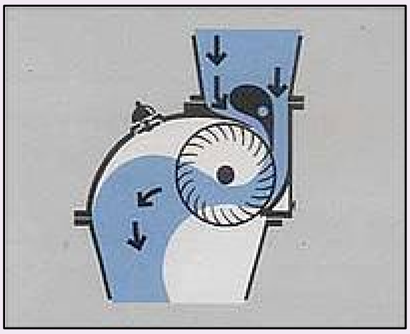
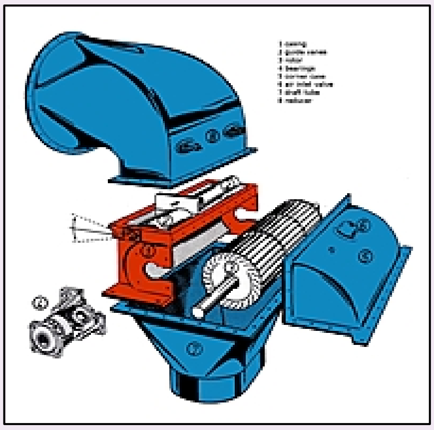
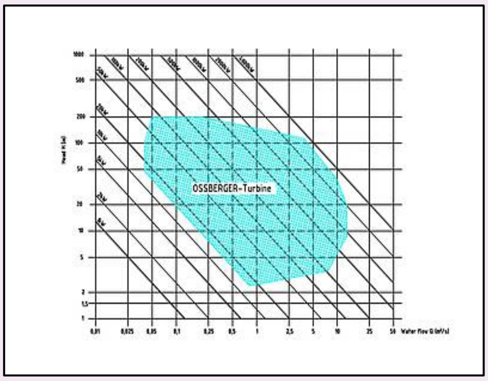
Drawing of 6-jet turbine

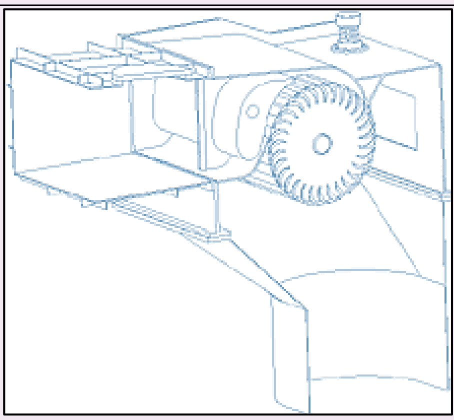
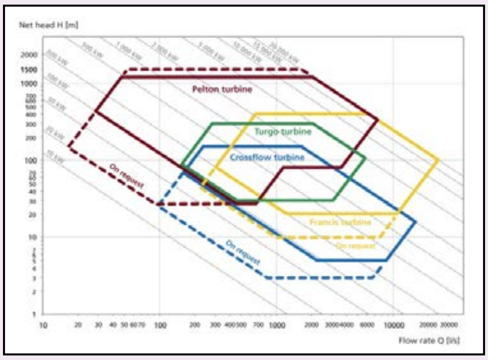


Turbine range

Turbine Name:	**PELTON TURBINE**	
Company name:	**Wasserkraft Volk AG**	
Company Address:	Am Stollen 13 D-79261 Gutach GERMANY	
Company Tel:	+49 7685-9106-0	
Company E-mail:	mail@wkv-ag.com	
Website:	www.wkv-ag.com	
Turbine Description:	Wasserkraft Volk Pelton turbines can have up to six jets. These machines have high efficiency with fluctuating flow and can handle debris.	
Pressure Head Range	30 m to 1 00 0m	
Flow Range	0.04 m^3/s to 13 m^3/s	
Power Range	Up to 20 000 kW	
Illustrations and Applicable Graphs:	 *5 WKV twin-jet Pelton turbines, total power about 40 MW*	 *Pelton wheel*
	 *Typical turbine drawing*	 *Wasserkraft Volk turbine ranges*

Turbine Name:	**BANKI (CROSS-FLOW) TURBINE**
Company name:	**IREM SpA a Socio Unico**
Company Address:	Via Abegg 75 Borgone Susa ITALY
Company Tel:	+39 011 9648211
Company E-mail:	irem@irem.it
Website:	www.irem.it
Turbine Description:	The IREM Banki turbine is connected to a belt driven synchronous or asynchronous generator shaft, depending on the electricity use.
Pressure Head Range	5 m to 60 m
Flow Range	0.01 m^3/s to 1 m^3/s
Power Range	Up to 100 kW
Illustrations, Photos and Applicable Graphs:	 *Banki runner*  *Banki turbine*  *Turbine set-up*  *IREM turbine range*

Turbine Name:	**OSSBERGER-TURBINE**
Company name:	**OSSBERGER GmbH + Co**
Company Address:	Otto-Rieder-Str. 7 91781 Weissenburg / Bavaria GERMANY
Company Tel:	+49 (0)9141/977-0
Company E-mail:	info@ossberger.de
Website:	www.ossberger.de/cms/pt/hydro/contact/
Turbine Description:	Ossberger turbines are designed so that water passes through the runner twice.
Pressure Head Range	2.5 m to 200 m
Flow Range	0.04 m^3/s to 13 m^3/s
Power Range	15 kW to 3 000 kW
Illustrations, Photos and Applicable Graphs:	 *Inflow horizontal*  *Inflow vertical*  *Two-cell Ossberger turbine*  *Turbine range*

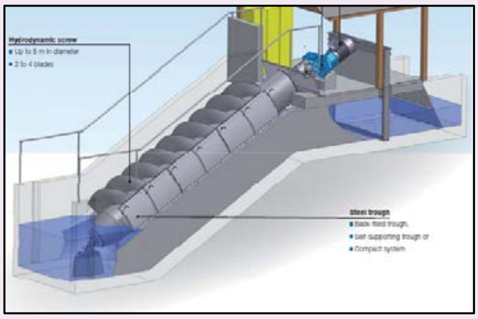
<table>
<tr><th></th><th colspan="2"></th></tr>
<tr><td>Turbine Name:</td><td colspan="2">CROSS-FLOW TURBINE</td></tr>
<tr><td>Company name:</td><td colspan="2">Wasserkraft Volk AG</td></tr>
<tr><td>Company Address:</td><td colspan="2">Am Stollen 13
D-79261 Gutach
GERMANY</td></tr>
<tr><td>Company Tel:</td><td colspan="2">+49 7685-9106-0</td></tr>
<tr><td>Company E-mail:</td><td colspan="2">mail@wkv-ag.com</td></tr>
<tr><td>Website:</td><td colspan="2">www.wkv-ag.com</td></tr>
<tr><td>Turbine Description:</td><td colspan="2">These turbines have high efficiencies down to 17% of design flow. They offer an economic solution, have easily accessible inspection ports and hatches and with bearings rated for more than 100 000 operating hours.</td></tr>
<tr><td>Pressure Head Range</td><td colspan="2">1.5 m to 150 m</td></tr>
<tr><td>Flow Range</td><td colspan="2">Not given</td></tr>
<tr><td>Power Range</td><td colspan="2">Up to 2 000 kW</td></tr>
<tr><td rowspan="2">Illustrations and Applicable Graphs:</td><td>
Crossflow turbine room</td><td>
Crossflow turbine wheel</td></tr>
<tr><td>
Typical turbine drawing</td><td>

Wasserkraft Volk turbine ranges</td></tr>
</table>

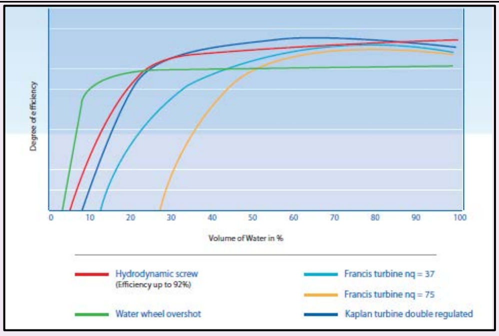
Turbine Name:	**HYDRODYNAMIC SCREW**
Company name:	**ANDRITZ Atro**
Company Address:	Penzinger Strasse 76 Vienna AUSTRIA
Company Tel:	+43 (1)891 00 0
Company E-mail:	hydro@andritz.com
Website:	www.andritz.com
Turbine Description:	This turbine is based on the Archimedean screw and is applicable to very low head open water installations. No control system is necessary. Simple installation and maintenance procedures apply.
Pressure Head Range	Up to 10 m
Flow Range	Up to 10 m^3/s
Power Range	Up to 500 kW
Illustrations, Photos and Applicable Graphs:	

Hydrodynamic Screw

Hydrodynamic screw installation

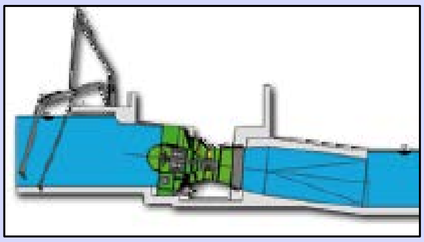
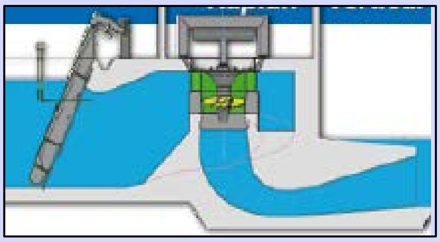
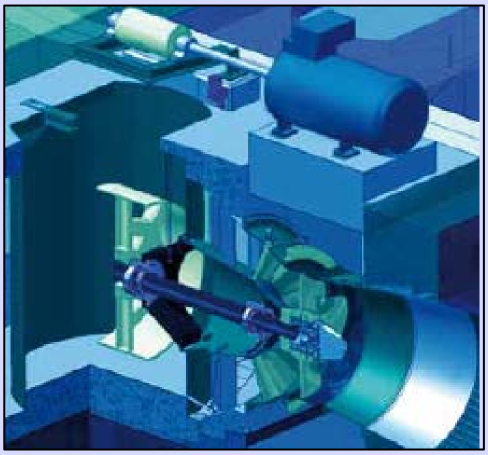
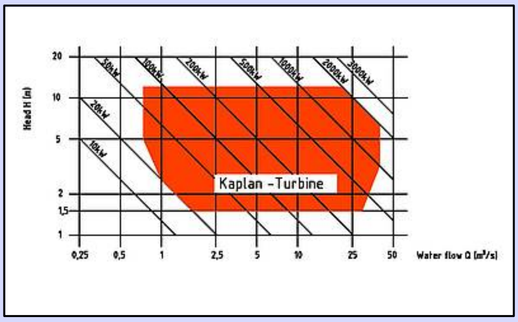


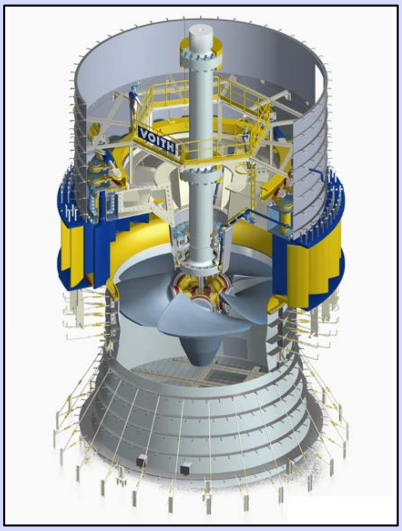
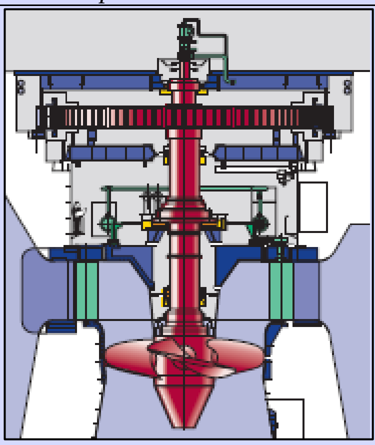
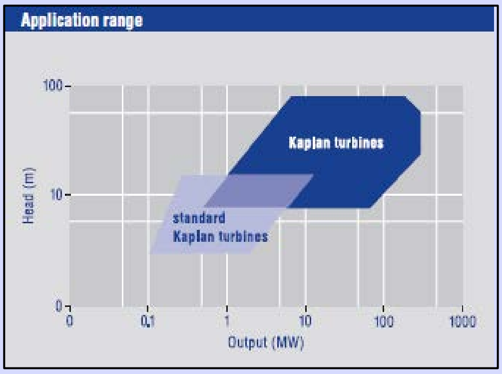
Typical layout



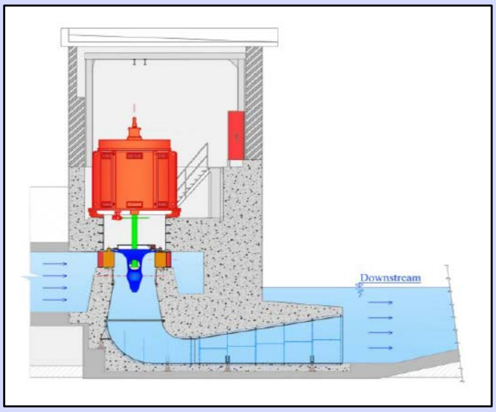
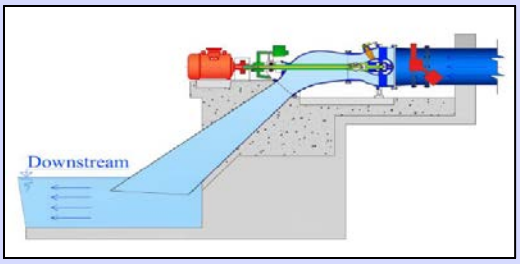
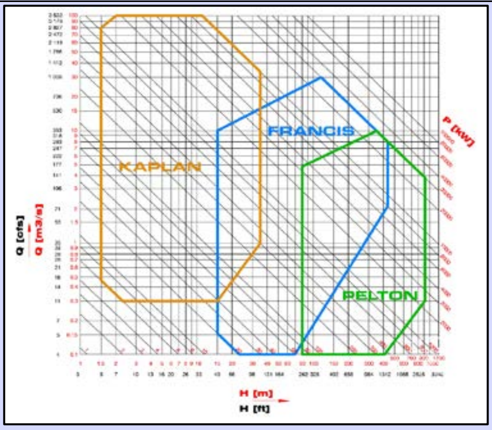
Turbine efficiency

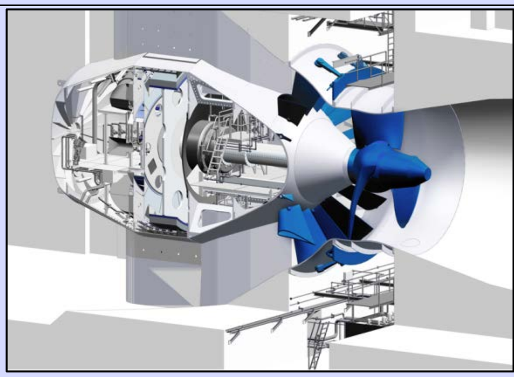
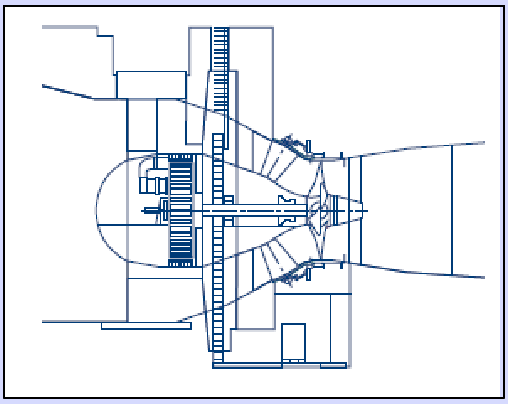
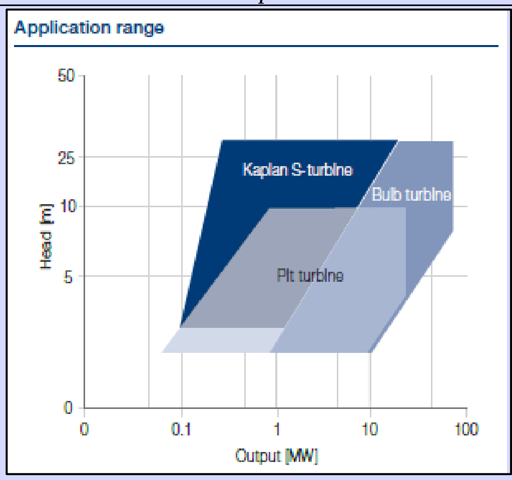
B.2 REACTION TYPE TURBINES

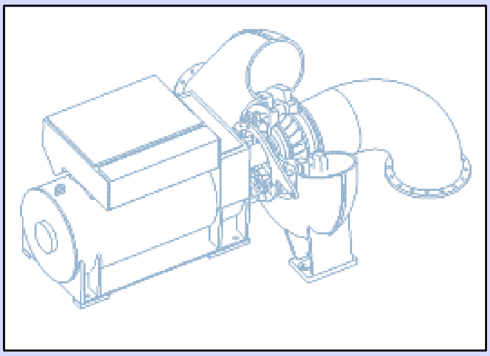
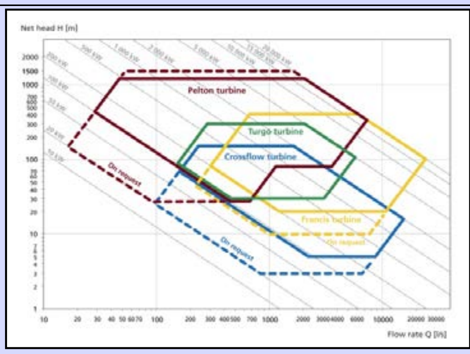
Turbine Name:	**KAPLAN TURBINE**
Company name:	**OSSBERGER GmbH + Co**
Company Address:	Otto-Rieder-Str. 7 91781 Weissenburg / Bavaria GERMANY
Company Tel:	+49 (0)9141/977-0
Company E-mail:	info@ossberger.de
Website:	www.ossberger.de/cms/pt/hydro/contact/
Turbine Description:	The Ossberger Kaplan turbine has a compact, low-maintenance construction and is easily installed.
Pressure Head Range	1.5 m to 20 m
Flow Range	1.5 m^3/s to 60 m^3/s
Power Range	20 kW to 3 500 kW
Illustrations, Photos and Applicable Graphs:	 *Inflow horizontal*  *Inflow vertical*  *Computer generated view of Kaplan*  *Turbine range*

<table>
<tr><th></th><th colspan="2"></th></tr>
<tr><td>Turbine Name:</td><td colspan="2">KAPLAN TURBINE</td></tr>
<tr><td>Company name:</td><td colspan="2">Voith Hydro Holding GmbH & Co. KG</td></tr>
<tr><td>Company Address:</td><td colspan="2">Alexanderstrasse 11
89522 Heidenheim
GERMANY</td></tr>
<tr><td>Company Tel:</td><td colspan="2">+49 7321 37 0</td></tr>
<tr><td>Company E-mail:</td><td colspan="2">info.voithhydro@voith.com</td></tr>
<tr><td>Website:</td><td colspan="2">www.voithhydro.com</td></tr>
<tr><td>Turbine Description:</td><td colspan="2">Voith Kaplan turbines are designed to function with low head and high flow rates.</td></tr>
<tr><td>Pressure Head Range</td><td colspan="2">3 m to 95 m</td></tr>
<tr><td>Flow Range</td><td colspan="2">Not given</td></tr>
<tr><td>Power Range</td><td colspan="2">100 kW to 400 MW</td></tr>
<tr><td rowspan="2">Illustrations and Applicable Graphs:</td><td>
Kaplan turbine runner</td><td>
Turbine layout</td></tr>
<tr><td>
Cross section of a Kaplan runner</td><td>

Turbine range</td></tr>
</table>

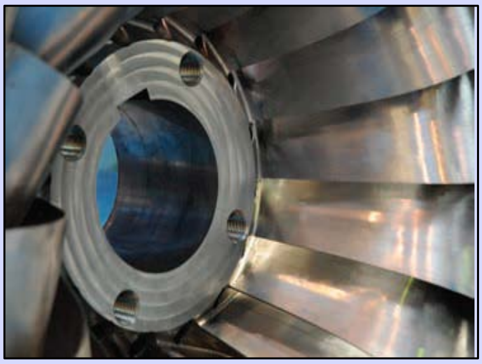
Turbine Name:	**KAPLAN TURBINE**
Company name:	**Mavel Hydro Turbines** (**Scion Technologies** (South African Distribution))
Company Address:	Northbank 3rd Floor Northbank Lane Century City, Cape Town SOUTH AFRICA
Company Tel:	+27 21 552 9993
Company E-mail:	karenr@sciontechnologies.co.za
Website:	www.mavel.cz
Turbine Description:	Mavel Kaplan turbines are designed to function with low head and high flow rates.
Pressure Head Range	1.5 m to 35 m
Flow Range	0.3 m^3/s to 150 m^3/s
Power Range	30 kW to 20 MW
Illustrations and Applicable Graphs:	 *Kaplan turbine runner*  Downstream *Vertical turbine layout*  Downstream *S-type turbine layout*  KAPLAN FRANCIS PELTON Q [cfs] Q [m3/s] H [m] H [ft] P [kW] *Turbine range*

Turbine Name:	**BULB TURBINE**
Company name:	**Voith Hydro Holding GmbH & Co. KG**
Company Address:	Alexanderstrasse 11 89522 Heidenheim GERMANY
Company Tel:	+49 7321 37 0
Company E-mail:	info.voithhydro@voith.com
Website:	www.voithhydro.com
Turbine Description:	Voith bulb turbines are used primarily for low heads and high flows. These units can achieve higher full-load efficiencies and flow capacities than vertical Kaplan turbines.
Pressure Head Range	2 m to 30 m
Flow Range	Not given
Power Range	1 MW to 80 MW
Illustrations and Applicable Graphs:	 *Bulb turbine*  *Bulb turbine computer illustration*  *Cross section of a bulb turbine*  *Turbine range*

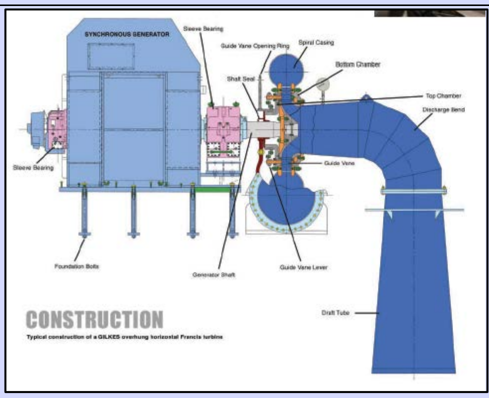
Turbine Name:	**FRANCIS TURBINE**
Company name:	**Wasserkraft Volk AG**
Company Address:	Am Stollen 13 D-79261 Gutach GERMANY
Company Tel:	+49 7685-9106-0
Company E-mail:	mail@wkv-ag.com
Website:	www.wkv-ag.com
Turbine Description:	This turbine has a high peak capacity, compact design and low maintenance, with bearings rated for more than 100 000 operating hours.
Pressure Head Range	Up to 300 m
Flow Range	Not given
Power Range	Up to 20 000 kW
Illustrations and Applicable Graphs:	 *Francis turbine room*  *Francis turbines manufacturing*  *Typical turbine drawing*  *Wasserkraft Volk turbine ranges*

Turbine Name:	**FRANCIS TURBINE**
Company name:	**Gilbert Gilkes & Gordon Ltd**
Company Address:	Canal Head North Kendal Cumbria UK
Company Tel:	+44 (0) 1539 720028
Company E-mail:	enquiries@gilkes.com
Website:	www.gilkes.com
Turbine Description:	This turbine can be supplied as a horizontal or vertical unit and directs water through a series of moveable guide vanes to the turbine runner, from where it is discharged through a draft tube to the tailrace.
Pressure Head Range	Up to 400 m
Flow Range	0.05 m^3/s to 40 m^3/s
Power Range	Up to 20 000 kW

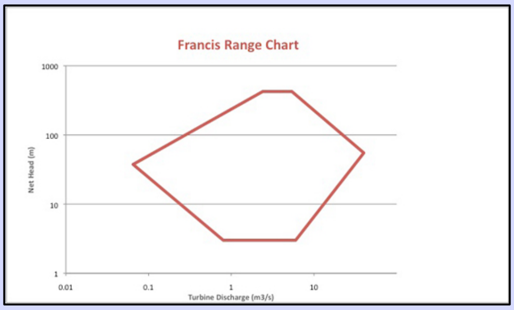
Illustrations, Photos and Applicable Graphs:


Francis runner

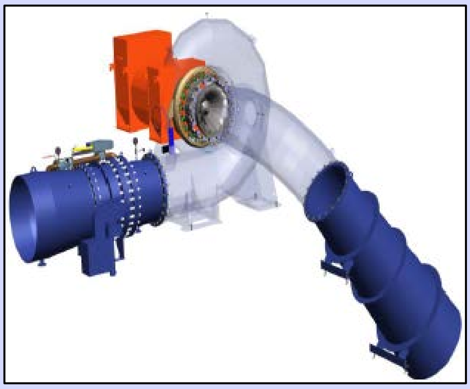
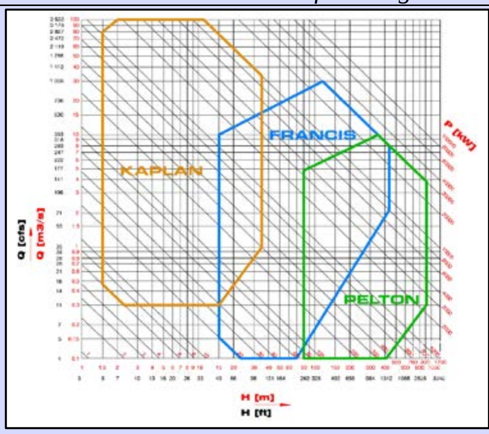
Francis turbine



Typical layout



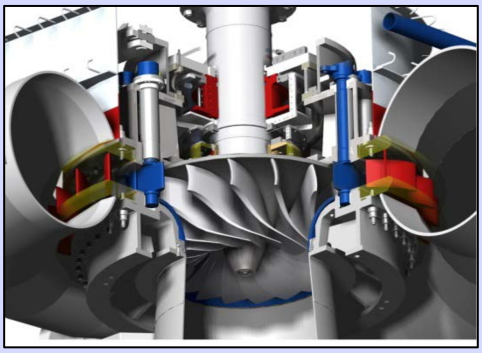
Turbine range

Turbine Name:	**FRANCIS TURBINE**
Company name:	**Mavel Hydro Turbines** (**Scion Technologies** (South African Distribution))
Company Address:	Northbank 3rd Floor Northbank Lane Century City, Cape Town SOUTH AFRICA
Company Tel:	+27 21 552 9993
Company E-mail:	karenr@sciontechnologies.co.za
Website:	www.mavel.cz
Turbine Description:	Mavel Francis turbines are milled from a single block of forged steel and can be applied to medium heads and medium flow ranges.
Pressure Head Range	15 m to 440 m
Flow Range	0.1 m^3/s to 30 m^3/s
Power Range	20 kW to 30 MW
Illustrations, Photos and Applicable Graphs:	 *Francis runner*  *Francis turbine manufacturing*  *Typical layout*  *Turbine range*

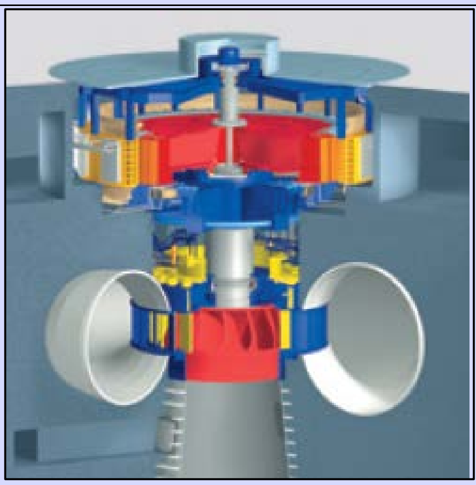
Turbine Name:	**FRANCIS TURBINE**
Company name:	**Voith Hydro Holding GmbH & Co. KG**
Company Address:	Alexanderstrasse 11 89522 Heidenheim GERMANY
Company Tel:	+49 7321 37 0
Company E-mail:	info.voithhydro@voith.com
Website:	www.voithhydro.com
Turbine Description:	The Voith Francis turbines are used primarily for medium heads and large flows. These units run at high specific speeds and are therefore compact. Standardized designs can be ordered for small installations.
Pressure Head Range	3 m to 95 m
Flow Range	Not given
Power Range	5 kW to 1 000 MW

Illustrations and Applicable Graphs:

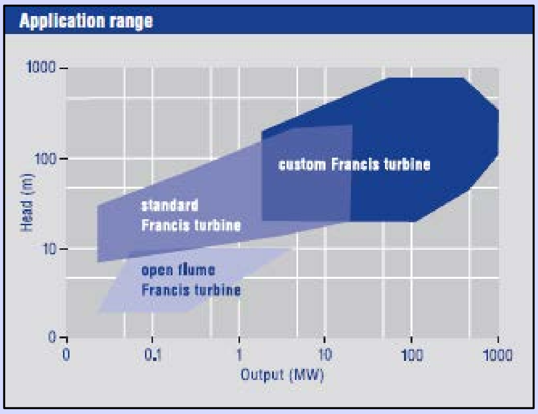
Francis turbine runner



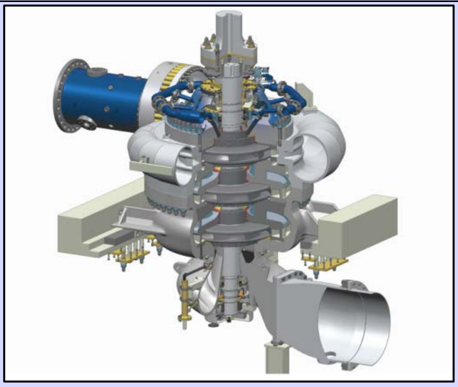
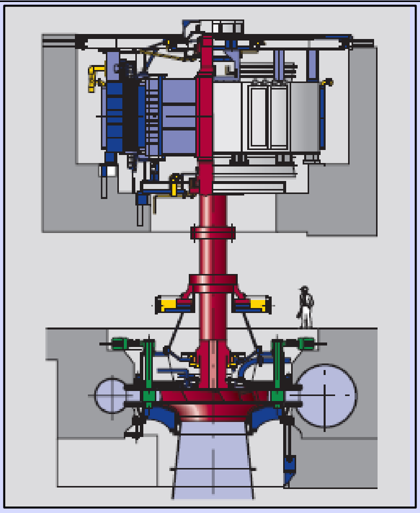
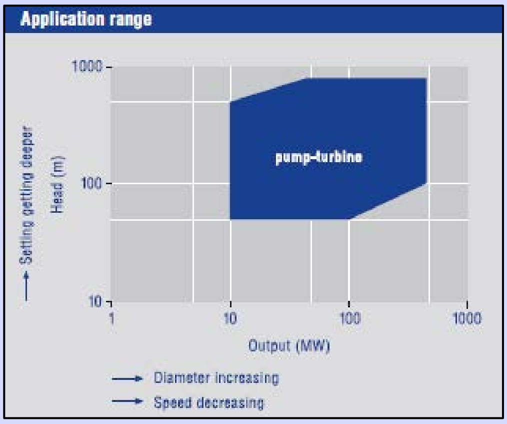
Turbine layout

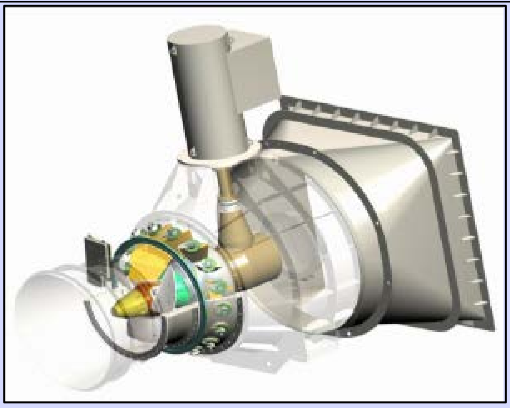
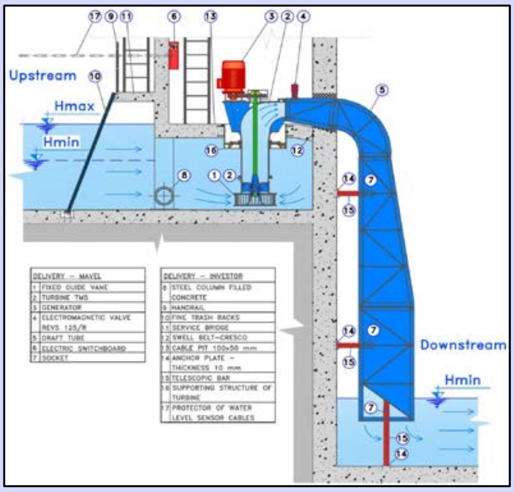
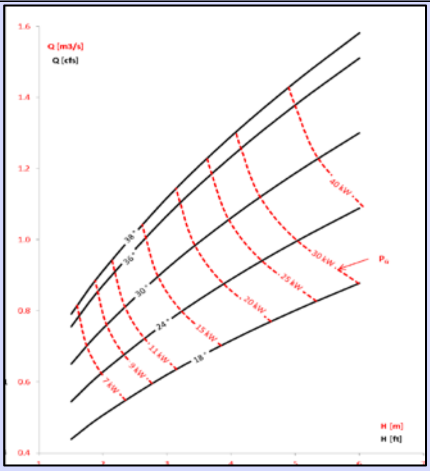


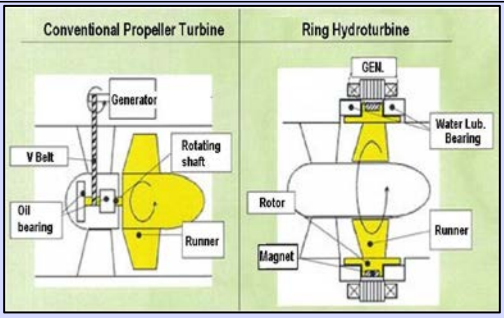
Cross section of a Francis turbine

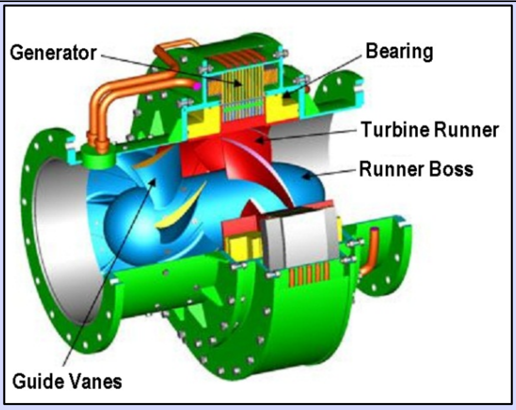


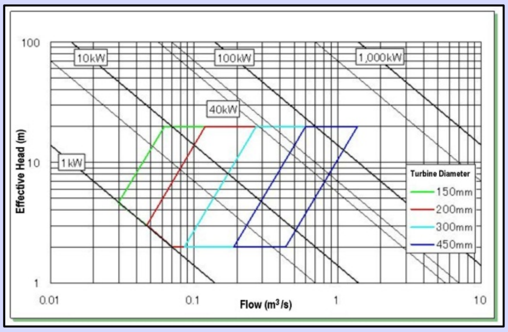
Turbine range

Turbine Name:	**PUMP-TURBINE**
Company name:	**Voith Hydro Holding GmbH & Co. KG**
Company Address:	Alexanderstrasse 11 89522 Heidenheim GERMANY
Company Tel:	+49 7321 37 0
Company E-mail:	info.voithhydro@voith.com
Website:	www.voithhydro.com
Turbine Description:	These machines can function both as turbines and, in reverse direction, as pumps. They are generally used in pumped storage schemes.
Pressure Head Range	50 m to 900 m
Flow Range	Not given
Power Range	10 MW to 500 MW
Illustrations and Applicable Graphs:	 *Turbine runner for Palmiet, South Africa*  *Turbine layout*  *Cross of a variable speed pump-turbine runner*  *Turbine range*

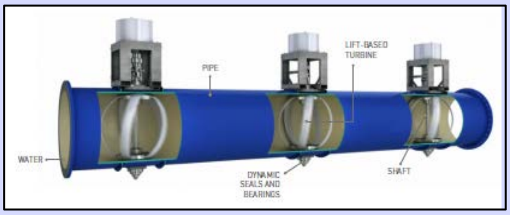
Turbine Name:	**SYPHON-TYPE TURBINE**
Company name:	**Mavel Hydro Turbines** (**Scion Technologies** (South African Distribution))
Company Address:	Northbank 3rd Floor Northbank Lane Century City, Cape Town SOUTH AFRICA
Company Tel:	+27 21 552 9993
Company E-mail:	karenr@sciontechnologies.co.za
Website:	www.mavel.cz
Turbine Description:	Mavel Micro turbines are designed to function with low head and work on the principle of syphoning water over a weir. Turbines can be placed in series.
Pressure Head Range	1.5 m to 6 m
Flow Range	0.15 m^3/s to 4.5 m^3/s (per turbine)
Power Range	1 kW to 180 kW
Illustrations and Applicable Graphs:	 *Three micro turbines in parallel*  *Turbine layout*  *Construction drawing of a syphon turbine*  *Turbine range (MT5)*

<table>
<tr><th></th><th colspan="2"></th></tr>
<tr><td>Turbine Name:</td><td colspan="2">RING HYDROTURBINE</td></tr>
<tr><td>Company name:</td><td colspan="2">Kawasaki Plant Systems Ltd.</td></tr>
<tr><td>Company Address:</td><td colspan="2">1-14-5, Kaigan, Minato-ku
Toyo
JAPAN</td></tr>
<tr><td>Company Tel:</td><td colspan="2">+81-3-3435-2111</td></tr>
<tr><td>Company E-mail:</td><td colspan="2">Not given</td></tr>
<tr><td>Website:</td><td colspan="2">www.khi.co.jp</td></tr>
<tr><td>Turbine Description:</td><td colspan="2">This high efficiency inline system is easily installed in small spaces and requires little maintenance.</td></tr>
<tr><td>Pressure Head Range</td><td colspan="2">3 m to 30 m</td></tr>
<tr><td>Flow Range</td><td colspan="2">0.14 m^3/s to 2.8 m^3/s</td></tr>
<tr><td>Power Range</td><td colspan="2">20 to 500 kW</td></tr>
<tr><td rowspan="2">Illustrations and Applicable Graphs:</td><td>
Ring hydroturbine</td><td>

Ring and propeller comparison</td></tr>
<tr><td>

Turbine layout</td><td>

Turbine ranges</td></tr>
</table>

Turbine Name:	**LUCIDPIPE POWER SYSTEM**
Company name:	**LucidEnergy**
Company Address:	108 NW 9th Avenue Suite 201C Portland USA
Company Tel:	+1 574-238-5415
Company E-mail:	Josh.kanagy@lucidenergy.com
Website:	www.lucidenergy.com
Turbine Description:	These spherical turbines are installed inline in large diameter pipes. A number of turbines can be installed in series and can operate across a wide range of head and flow conditions.
Pressure Head Range	0.5 m to 10 m head drop through turbine; pressure head in the pipe can be higher
Flow Range	1 m^3/s to 5.6 m^3/s
Power Range	14 kW to 100 kW
Illustrations and Applicable Graphs:	 *Computer-generated drawing of turbine*  *Three Lucidpipe turbines in series*  *Turbine in pipe*  *Installed turbine*

C. CHD TOOL DEFAULT VALUES AND FUNCTIONS

C.1 INTRODUCTION

This appendix discusses the derivations and assumptions relevant to all default values and functions in the CHD Tool. It is important that users understand the origin of default values and functions, so that they may be altered if different circumstances are prevalent for a certain project.

C.2 DEFAULT VALUES

Table C-1 shows all the default values used in the CHD Tool that are not related to project economics, with motivation for each of the default values.

Table C-1: Default values not related to economic analyses

Component	Abbreviation	Applicable phase	Default value	Unit	Motivation
Fluid density	(ρ)	1, 2, 3	1 000	kg/m^3	Industry-accepted value (Chadwick et al., 2004)
Gravitational acceleration	(g)	1, 2, 3	9.81	m/s^2	Industry-accepted value (Chadwick et al., 2004)
Efficiency	(η)	1, 2, 3	70	%	BHA (2005) considers this a typical system efficiency for micro-hydropower systems.
Annual operational percentage		1	60	%	Conservative value
Percentage of peak pressure head used		1	60	%	Based on comparative values between Phase 1 and Phase 2 potential power for the three case studies.
Annual maintenance days		2, 3	7	days	Conservative assumption

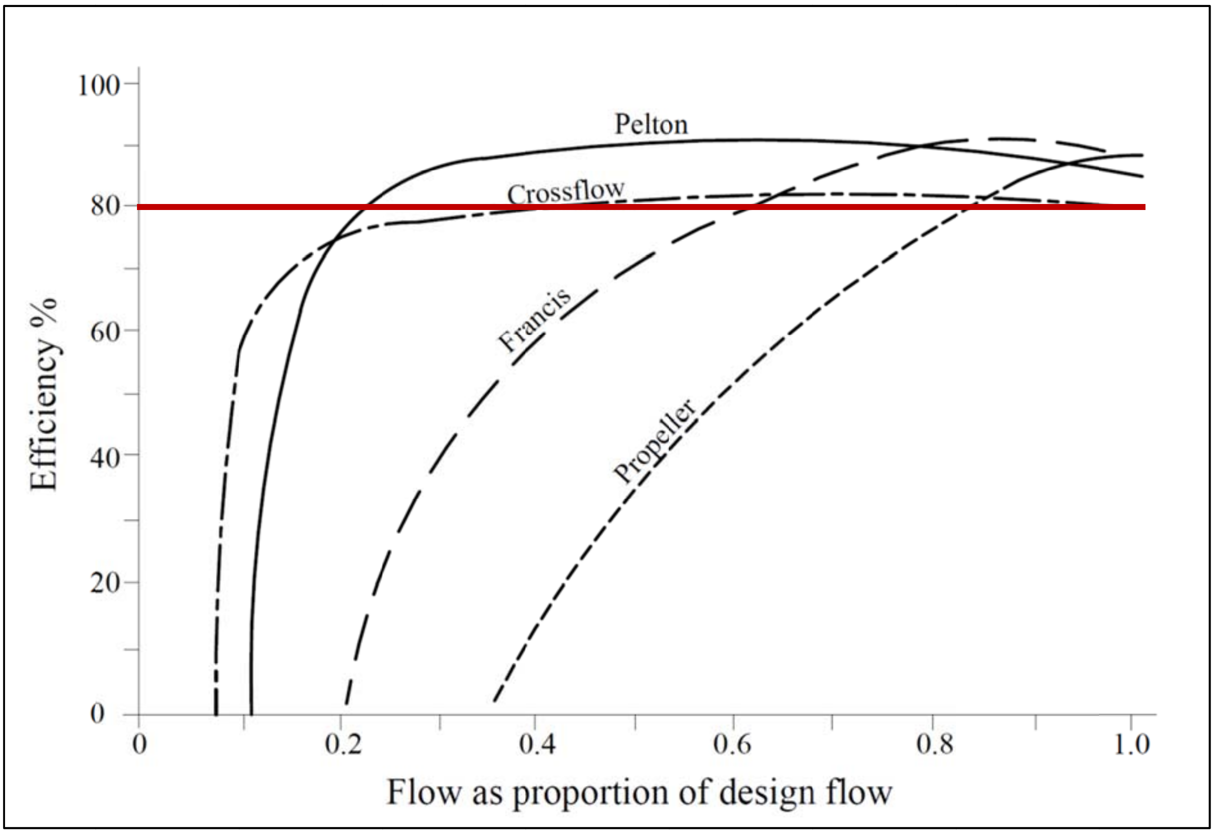


Figure C-1: Typical turbine part-flow efficiencies (Paish, 2002)

C.3 FUNCTIONS USED FOR ECONOMIC ANALYSES

The following sections will discuss the default values and functions applicable to the economic analyses for each of the three phases.

C.3.1 COST FUNCTIONS AND DEFAULT COST VALUES

Various sources were studied in an attempt to include realistic cost functions in the CHD Tool. These cost functions were compared using a turbine with a capacity of 1 MW and an available pressure head of 85 m, which can be seen as a typical head for a high pressure conduit hydropower installation. As indicated in **Table C-2** there are major discrepancies between the values obtained using cost functions from different sources. The turbine cost functions used in the CHD Tool were chosen from functions used in articles in peer reviewed journals and adapted using applicable inflation and exchange rates to suit South African circumstances. The applicable information is shown in **Tables C-3** to **C-8**.

Tables C-9 to **C-11** were populated using information gathered by Barta (2012), considering South African hydropower installations.

Table C-2: Typical turbine cost comparison

Typical turbine cost comparison (R/MW)				
Turbine	**Source**			
	Aggidis et al. (2010)	**Ogayar and Vidal (2009)**	**Singal et al. (2010)**	**USBR (2011b)**
Pelton	R 1 787 000	R 5 359 900		R 2 767 000
Kaplan (low head)	R 6 327 800	R 4 677 400		R 5 925 600
Kaplan (high head)	R 2 589 500			R 5 776 700
Francis (low head)	R 3 111 500			
Francis (medium head)	R 6 154 900	R 4 002 100		R 3 084 000
Francis (high head)	R 2 791 600			R 3 458 800
Other turbines			R 1 573 500	R 3 084 000

Table C-3: Overall project cost function for capacities above 20 kW

Component	Overall cost
Original cost function (£)	$C_{\mathrm{Pr}}=45\ 500\times\left(\frac{P}{H^{0.3}}\right)^{0.6}$
Source	Aggidis et al. (2010)
Cost function base year	2008
Base currency	Pound Sterling (£)
Average inflation rate	3.20%
Exchange rate (12 January 2013)	R 14.08/£
Modified cost function (R)	$C_{\mathrm{Pr}}=600\ 000\times\left(\frac{P}{H^{0.3}}\right)^{0.6}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function in a peer reviewed journal, bearing in mind that conventional hydropower has a larger civil construction component than conduit hydropower (40% vs. 20%) (Ogayar and Vidal, 2009 and Barta, 2012)

Table C-4: Initial overall project cost function for pico installations (capacity < 20 kW)

Component	Overall cost
Original cost function (£)	$C_{Pr}=25\,000\times(\frac{P}{H^{0.35}})^{0.65}$
Source	Aggidis et al. (2010)
Cost function base year	2008
Base currency	Pound Sterling (£)
Average inflation rate	3.20%
Exchange rate (12 January 2013)	R 14.08/£
Modified cost function (R)	$C_{Pr}=333\,500\times(\frac{P}{H^{0.35}})^{0.65}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function (for applications with pressure head between two and 30m) in a peer reviewed journal, bearing in mind that conventional hydropower has a larger civil construction component than conduit hydropower (40% vs. 20%) (Ogayar and Vidal, 2009 and Barta, 2012)

However, the function derived in **Table C-4** gave an overly conservative cost of R 891 000 for the Pierre van Ryneveld case study, whereas actual capital expenditure was only R 546 000 (excluding design and construction related cost, that would amount to approximately R 140 000). Therefore the function was adjusted as shown in **Table C-5**, to offer a slightly less conservative capital expenditure value of R 704 600 for the Pierre van Ryneveld case study.

Table C-5: Final overall project cost function for pico installations (capacity < 20 kW)

Component	Overall cost
Original cost function (£)	$C_{Pr}=333\ 500\times(\frac{P}{H^{0.35}})^{0.65}$
Source	Derived in **Table C-4**
Pierre van Ryneveld case study value	R 891 000
Modified cost function (R)	$C_{Pr}=265\ 000\times(\frac{P}{H^{0.3}})^{0.6}$
Pierre van Ryneveld case study value	R 718 200
Motivation	Adapted for inflation and exchange rate from a conservative cost function (for applications with pressure head between two and 30m) in a peer reviewed journal, bearing in mind that conventional hydropower has a larger civil construction component than conduit hydropower (40% vs. 20%) (Ogayar and Vidal, 2009 and Barta, 2012) and then adjusted to suit the actual project cost at the Pierre van Ryneveld plant.

Using the adapted function (C_{Pr}) for a typical 1 MW installation, will lead to a total project cost of R 17 000 000. Subtracting a typical turbine cost of R 3 700 000 (derived using the average of used cost functions, for a typical 1 MW installation), will give a total project cost (excluding turbine) of R 13 300 000. This value was used as the default value for "Capital cost per MW installed (excl. turbine cost)" used in the Phase 2 analysis.

Table C-6: Pelton turbine cost function

Component	Pelton turbine
Original cost function (€/kW)	C_{PEL}=17 693×$P^{-0.3644725}$×$H^{-0.281735}$
Source	Ogayar and Vidal (2009)
Cost function base year	2007
Base currency	Euro (€)
Average inflation rate	2.01%
Exchange rate (12 January 2013)	R 11.65/€
Modified cost function (R)	C_{PEL}=232 300×$P^{0.6355275}$×$H^{-0.281735}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function in a peer reviewed journal

Table C-7: Small Kaplan turbine cost function

Component	Kaplan turbine (small)
Original cost function (€/kW)	C_{K1}=3 500×$(P)^{0.68}$
Applicability	Flow rates 0.5 m^3/s to 5 m^3/s
Source	Aggidis et al. (2010)
Cost function base year	2008
Base currency	Pound Sterling (£)
Average inflation rate	3.20%
Exchange rate (12 January 2013)	R 14.08/£
Modified cost function (R)	C_{K1}=57 700×$(P)^{0.68}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function in a peer reviewed journal

Table C-8: Large Kaplan turbine cost function

Component	Kaplan turbine (large)
Original cost function (£)	C_{K2}=14 000×$(P)^{0.35}$
Applicability	Flow rates 5 m^3/s to 30 m^3/s
Source	Aggidis et al. (2010)
Cost function base year	2008
Base currency	Pound Sterling (£)
Average inflation rate	3.20%
Exchange rate (12 January 2013)	R 14.08/£
Modified cost function (R)	C_{K2}=230 700×$(P)^{0.35}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function in a peer reviewed journal

Table C-9: Francis turbine cost function

Component	Francis turbine
Original cost function (€/kW)	C_F=25 698×$P^{-0.560135}$×$H^{-0.127243}$
Source	Ogayar and Vidal (2009)
Cost function base year	2007
Base currency	Euro (€)
Average inflation rate	2.01%
Exchange rate (12 January 2013)	R 11.65/€
Modified cost function (R)	C_F=337 400×$P^{0.560135}$×$H^{-0.127243}$
Motivation	Adapted for inflation and exchange rate from a conservative cost function in a peer reviewed journal

Table C-10: Other turbines cost function

Component	Other turbines
Original cost function (€/kW)	C_{OT}=25 698×$P^{-0.560135}$×$H^{-0.127243}$
Source	Ogayar and Vidal (2009)
Cost function base year	2007
Base currency	Euro (€)
Average inflation rate	2.01%
Exchange rate (12 January 2013)	R 11.65/€
Modified cost function (R)	C_{OT}=337 350×$P^{0.560135}$×$H^{-0.127243}$
Motivation	The USBR (2011b) proposes a similar cost function for Francis turbines and other turbines (excluding Kaplan and Pelton). Therefore, the chosen function for Francis turbines was applied for other turbines. It was a conservative cost function in a peer reviewed journal.

Table C-11: Initial planning cost functions

Initial planning cost (IPC) (Total IPC in 2010 was R 1 200 000 per MW (Barta, 2012)			
Component	**Percentage of IPC for component**	**Source**	**Motivation**
Legal and regulatory	3%	Barta (2012)	Although the source is unpublished, the information has been derived from a continuing study on South African hydropower installations and percentages correlate well with those in Chutachindakate (2012), and USBR (2011b)
Environmental and social assessment	27%		
Investigation and preliminary design	70%		

Table C-12: Capital expenditure cost functions

Capital expenditure cost (CEC)				
Component	**Percentage of CEC**		**Source**	**Motivation**
	(Incl. turbine)	**(Excl. turbine)**		
Preliminary and general	20.0%	24.5%	Barta (2012)	Although the source is unpublished, the information has been derived from a continuing study on South African hydropower installations and percentages correlate well with those in Chutachindakate (2012), Aggidis (2009) and USBR (2011b)
Access to site	0.5%	0.5%		
Pipework and valves	5.0%	6.5%		
Power station housing	15.0%	20.0%		
Electrical and mechanical	30.0%	12.0%		
Transformer/ transmission	10.0%	12.5%		
Construction management	4.5%	5.5%		
Contingency	14.0%	17.0%		
Disposal	1.0%	1.5%		

Table C-13: Annual operation and maintenance cost functions

Annual operation and maintenance cost (OMC)			
Component	**Percentage of CEC for component**	**Source**	**Motivation**
Civil	0.25%	Barta (2012)	Although the source is unpublished, the information has been derived from a continuing study on South African hydropower installations and percentages correlate well with those in Chutachindakate (2012), and USBR (2011b)
Electrical and mechanical	2.00%		
Transmission	0.80%		
Operation	0.40%		
Insurance	0.30%		
Overall	1.0%		

C.3.2 ELECTRICITY TARIFFS

Table C-14 shows the calculations that were performed to obtain an average rate (in c/kWh) for Megaflex tariffs in 2012-2013. Megaflex tariffs were used; as this is the tariff structure paid by metropolitan municipalities, like the City of Tshwane, to Eskom. This rate does not include reactive energy charges, distribution network charges or service and administration charges, but the entire tariff structure can be seen in **Table C-15**, with the peak and off-peak periods depicted in **Figure C-2** (Eskom, 2012c).

Table C-14: Average value of generated electricity for Megaflex tariffs

Megaflex tariffs 2012-2013	Time of day	Winter (c/kWh)			Total (c/kWh)	Summer (c/kWh)			Total (c/kWh)
		Weekdays	Saturday	Sunday		Weekdays	Saturday	Sunday	
	00:00	34.31	34.31	34.31		29.51	29.51	29.51	
	01:00	34.31	34.31	34.31		29.51	29.51	29.51	
	02:00	34.31	34.31	34.31		29.51	29.51	29.51	
	03:00	34.31	34.31	34.31		29.51	29.51	29.51	
	04:00	34.31	34.31	34.31		29.51	29.51	29.51	
	05:00	34.31	34.31	34.31		29.51	29.51	29.51	
	06:00	64.26	34.31	34.31		42.25	29.51	29.51	
	07:00	247.37	64.26	34.31		69.02	42.25	29.51	
	08:00	247.37	64.26	34.31		69.02	42.25	29.51	
	09:00	247.37	64.26	34.31		69.02	42.25	29.51	
	10:00	64.26	64.26	34.31		42.25	42.25	29.51	
	11:00	64.26	64.26	34.31		42.25	42.25	29.51	
	12:00	64.26	34.31	34.31		42.25	29.51	29.51	
	13:00	64.26	34.31	34.31		42.25	29.51	29.51	
	14:00	64.26	34.31	34.31		42.25	29.51	29.51	
	15:00	64.26	34.31	34.31		42.25	29.51	29.51	
	16:00	64.26	34.31	34.31		42.25	29.51	29.51	
	17:00	64.26	34.31	34.31		42.25	29.51	29.51	
	18:00	247.37	64.26	34.31		69.02	42.25	29.51	
	19:00	247.37	64.26	34.31		69.02	42.25	29.51	
	20:00	64.26	34.31	34.31		42.25	29.51	29.51	
	21:00	64.26	34.31	34.31		42.25	29.51	29.51	
	22:00	34.31	34.31	34.31		29.51	29.51	29.51	
	23:00	34.31	34.31	34.31		29.51	29.51	29.51	
Daily total		2218.19	1033.09	823.44		1045.93	797.42	708.24	
Weekly cost per time period		11090.95	1033.09	823.44		5229.65	797.42	708.24	
Total weekly cost per season					12947.5				6735.31
Weeks per season					13				39.43
Total annual cost per season					168317				265559.80
Total annual cost									433877.04
Average annual cost									49.53
Rural subsidy									5.20
Average environmental levy									3.56
Other cost									
Total average direct cost									**58.29**

Table C-15: Megaflex local authority rates 2012-2013 (Eskom, 2012c)

		Active energy charge [c/kWh]												Transmission network charges [R/kVA/m]	
Transmission zone	Voltage	High demand season [Jun - Aug]						Low demand season [Sep - May]							
		Peak	VAT incl	Standard	VAT incl	Off Peak	VAT incl	Peak	VAT incl	Standard	VAT incl	Off Peak	VAT incl		VAT incl
≤ 300km	< 500V	216.99	247.37	56.37	64.26	30.10	34.31	60.54	69.02	37.06	42.25	25.89	29.51	R 5.40	R 6.16
	≥ 500V & < 66kV	210.06	239.47	54.61	62.26	29.16	33.24	58.65	66.86	35.95	40.98	25.13	28.65	R 4.94	R 5.63
	≥ 66kV & ≤ 132kV	202.47	230.82	52.68	60.06	28.18	32.13	56.58	64.50	34.70	39.56	24.28	27.68	R 4.81	R 5.48
	> 132kV	195.39	222.74	50.91	58.04	27.28	31.10	54.65	62.30	33.55	38.25	23.53	26.82	R 6.09	R 6.94
> 300km and ≤ 600km	< 500V	219.14	249.82	56.90	64.87	30.37	34.62	61.13	69.69	37.39	42.62	26.15	29.81	R 5.46	R 6.22
	≥ 500V & < 66kV	212.11	241.81	55.12	62.84	29.43	33.55	59.22	67.51	36.26	41.34	25.36	28.91	R 4.98	R 5.68
	≥ 66kV & ≤ 132kV	204.44	233.06	53.18	60.63	28.47	32.46	57.13	65.13	35.01	39.91	24.51	27.94	R 4.84	R 5.52
	> 132kV	197.32	224.94	51.42	58.62	27.52	31.37	55.19	62.92	33.86	38.60	23.69	27.01	R 6.15	R 7.01
> 600km and ≤ 900km	< 500V	221.28	252.26	57.44	65.48	30.61	34.90	61.70	70.34	37.75	43.04	26.37	30.03	R 5.52	R 6.29
	≥ 500V & < 66kV	214.23	244.22	55.64	63.43	29.71	33.87	59.77	68.14	36.59	41.71	25.58	29.16	R 5.04	R 5.75
	≥ 66kV & ≤ 132kV	206.47	235.38	53.69	61.21	28.71	32.73	57.65	65.72	35.32	40.26	24.73	28.19	R 4.89	R 5.57
	> 132kV	199.30	227.20	51.86	59.12	27.79	31.68	55.74	63.54	34.17	38.95	23.92	27.27	R 6.23	R 7.10
> 900km	< 500V	223.48	254.77	58.00	66.12	30.92	35.25	62.29	71.01	38.08	43.41	26.63	30.36	R 5.54	R 6.32
	≥ 500V & < 66kV	216.33	246.62	56.18	64.05	29.98	34.18	60.35	68.80	36.92	42.09	25.84	29.46	R 5.09	R 5.80
	≥ 66kV & ≤ 132kV	208.53	237.72	54.19	61.78	28.97	33.03	58.21	66.36	35.68	40.68	24.95	28.44	R 4.91	R 5.60
	> 132kV	201.26	229.44	52.37	59.70	28.01	31.93	56.22	64.09	34.49	39.32	24.15	27.53	R 6.27	R 7.15

Electrification and rural subsidy [c/kWh]		Environmental levy charge [c/kWh]				Reactive energy charge [c/kvarh]			
All seasons		Apr 2012 to Jun 2012		Jul 2012 to Mar 2013		High season		Low season	
	VAT incl		VAT incl		VAT incl		VAT incl		VAT incl
4.56	5.20	2.00	2.28	3.50	3.99	8.72	9.94	0.00	0.00

Distribution network charges				
Voltage	Network access charge [R/kVA/m]	VAT incl	Network demand charge [R/kVA/m]	VAT incl
< 500V	R 10.80	R 12.31	R 20.49	R 23.36
≥ 500V & < 66kV	R 9.90	R 11.29	R 18.78	R 21.41
≥ 66kV & ≤ 132kV	R 9.59	R 10.93	R 18.20	R 20.75
> 132kV	R 0.00	R 0.00	R 16.41	R 18.71

Monthly utilised capacity	Service charge [R/Account/day]	VAT incl	Administration charge [R/POD/day]	VAT incl
> 1 MVA	R 123.36	R 140.63	R 55.59	R 63.37
Key customers	R 2 417.62	R 2 756.09	R 77.20	R 88.01

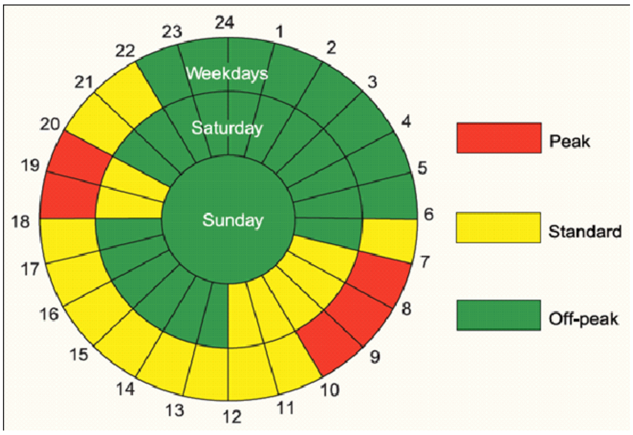


Figure C-2: Eskom's defined time periods for Megaflex (Eskom 2012c)

C.3.3 INFLATION RATES

Figure C-3 shows the general inflation rate in South Africa between 1997 and 2012, with estimated inflation rates for 2013 and 2014 (National Treasury, 2012). The average inflation rate in the country for the last ten years (2003 to 2013) is approximately 5.9%.

For many years, the average inflation in electricity tariffs in the country was below general inflation. However, this situation changed in 2003, as indicated in **Figure C-3** (Eskom, 2007). Since April 2008, electricity tariff increases have been significantly above inflation every year. NERSA has recently approved an average annual electricity hike of 8% for the next five years until April 2017. This will cause an average electricity tariff increase of more than 220% between 1997 and 2017 (Eskom, 2012b; Eskom 2012e; Eskom 2013b), as shown in

Figure C-4.

The main reason for the significant hike in electricity prices is because electricity generation has been subsidized for many years. It has therefore been supplied at below cost to consumers. However, this practice is not sustainable and electricity prices need to become cost-reflective to support a sustainable industry in future. (Eskom, 2012b) Therefore, as the approved annual increase of 8% was significantly below the 16% applied for, it is expected that higher-than-inflation electricity tariff increases will continue for a number of years until electricity prices are more cost-reflective.

As it is difficult to accurately estimate inflation even for 5 or 10 years, the average general inflation in the country was used as a default value for general, operation, and maintenance inflation. However, electricity inflation was estimated higher, especially after 2017, as Eskom will probably continue to strive to become cost-reflective. The higher rates were estimated for the next 15 years, until 2027, from where general inflation was assumed for electricity tariffs.

Maintenance factors were populated assuming that little maintenance will be necessary in the first few years of operation, but increasing as the equipment ages.

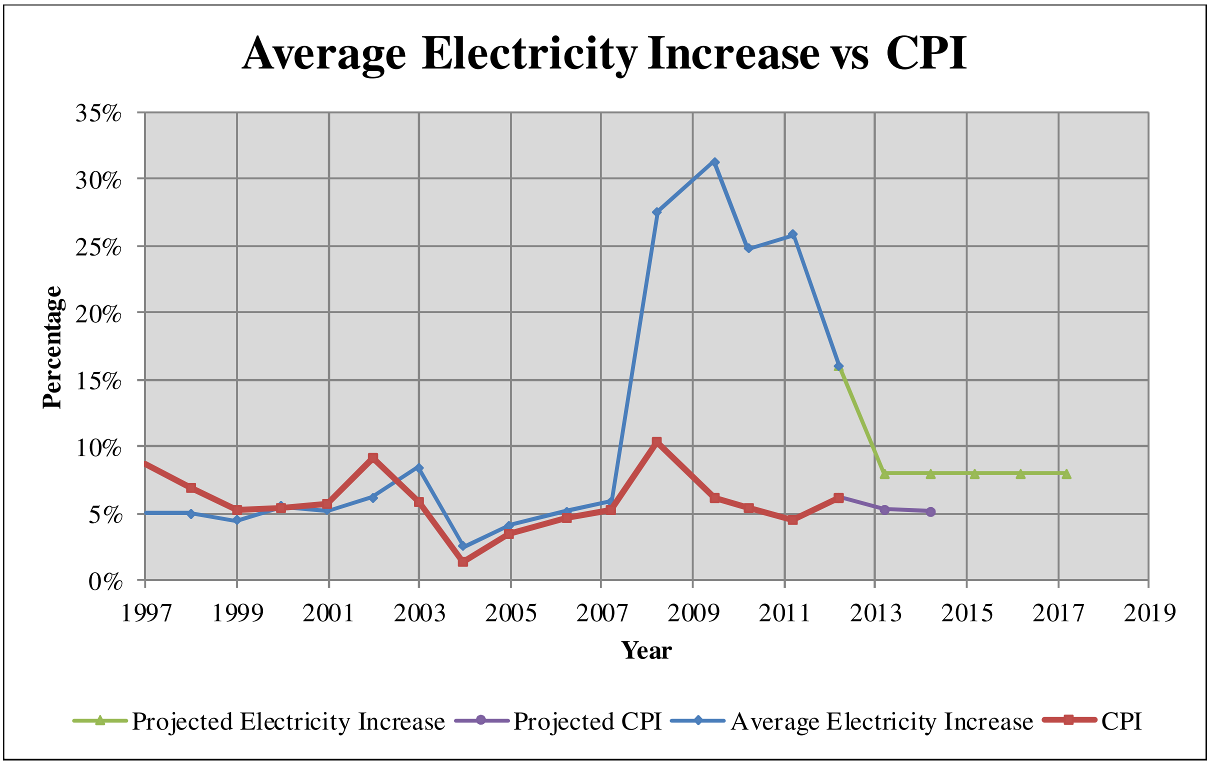


Figure C-3: Average energy increases vs. CPI (Eskom, 2007; 2012b; Eskom 2012e; National Treasury, 2012; Eskom 2013b)

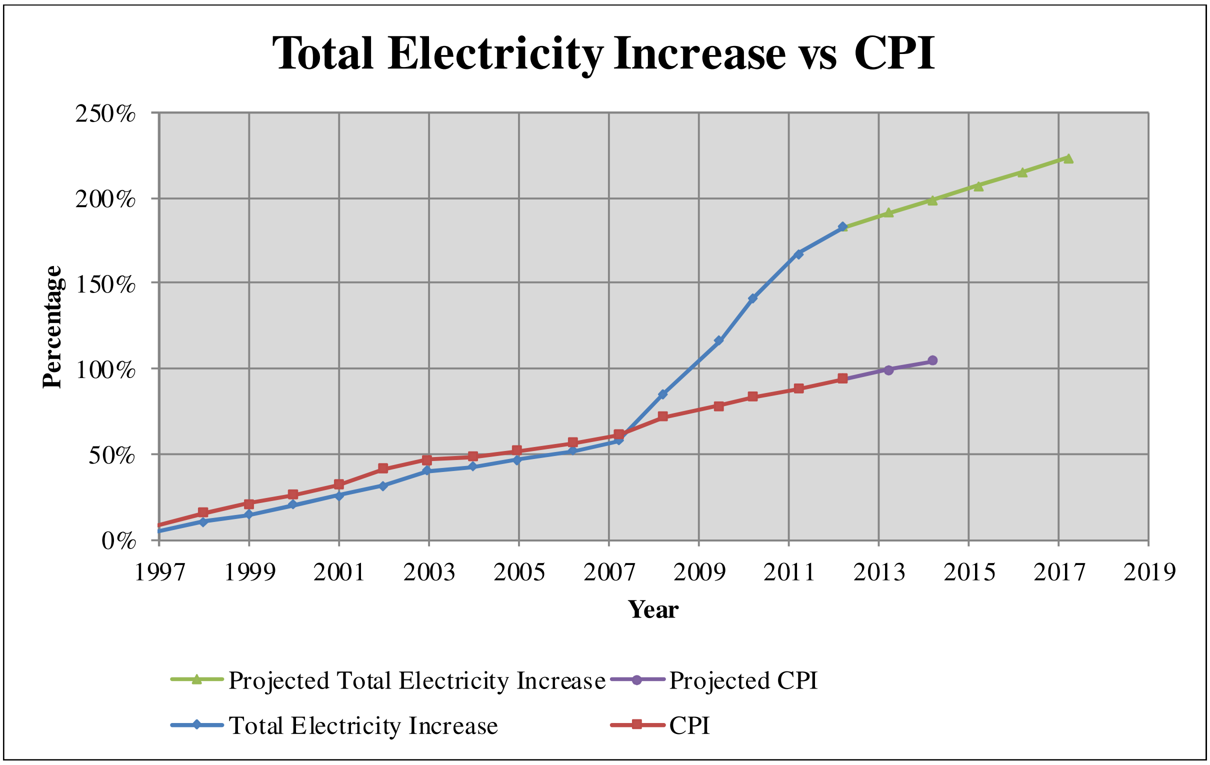


Figure C-4: Total energy increases vs. CPI (Eskom, 2007; 2012b; Eskom 2012e; National Treasury, 2012; Eskom 2013b)

Table C-16: Default inflation rates in CHD Tool

Inflation and maintenance factors over design life					
Year	Annual inflation				Maintenance factor
	Electricity	Operation	Maintenance	General	
2013	8.0%	5.3%	5.3%	5.3%	0.8
2014	8.0%	5.1%	5.1%	5.1%	0.8
2015	8.0%	6.0%	6.0%	6.0%	0.8
2016	8.0%	6.0%	6.0%	6.0%	0.8
2017	8.0%	6.0%	6.0%	6.0%	0.8
2018	10.0%	6.0%	6.0%	6.0%	1
2019	10.0%	6.0%	6.0%	6.0%	1
2020	10.0%	6.0%	6.0%	6.0%	1
2021	10.0%	6.0%	6.0%	6.0%	1
2022	10.0%	6.0%	6.0%	6.0%	1
2023	10.0%	6.0%	6.0%	6.0%	1
2024	10.0%	6.0%	6.0%	6.0%	1
2025	10.0%	6.0%	6.0%	6.0%	1
2026	10.0%	6.0%	6.0%	6.0%	1
2027	10.0%	6.0%	6.0%	6.0%	1
2028	6.0%	6.0%	6.0%	6.0%	1.2
2029	6.0%	6.0%	6.0%	6.0%	1.2
2030	6.0%	6.0%	6.0%	6.0%	1.2
2031	6.0%	6.0%	6.0%	6.0%	1.2
2032	6.0%	6.0%	6.0%	6.0%	1.2
2033	6.0%	6.0%	6.0%	6.0%	1.25
2034	6.0%	6.0%	6.0%	6.0%	1.25
2035	6.0%	6.0%	6.0%	6.0%	1.25
2036	6.0%	6.0%	6.0%	6.0%	1.25
2037	6.0%	6.0%	6.0%	6.0%	1.25
2038	6.0%	6.0%	6.0%	6.0%	1.25

D. NERSA ELECTRICITY GENERATION APPLICATION FORM

D.1 INTRODUCTION

Various application forms and specifications are applicable if a hydropower plant is planned. This appendix provides an example of a completed *Application for an Electricity Distribution Licence of the Electricity Regulation Act, 2006 (Act No. 4 of 2006)* for the National Energy Regulator of South Africa (NERSA) for the case study at Garsfontein Reservoir.

APPLICATION FOR AN ELECTRICITY GENERATION LICENCE IN TERMS OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006).

Please return completed form to:

HOD: Electricity Licensing and Compliance
National Energy Regulator of South Africa
Kulawula House, 526 Vermeulen Street
Arcadia, 0083
Pretoria

Or:

HOD: Electricity Licensing and Compliance
National Energy Regulator of South Africa
P.O. Box 40343
Arcadia
0007

Tel (012) 401 - 4600
Fax (012) 401 - 4700

SECTION A PARTICULARS OF APPLICANT

A1 Full name of applicant (business name) and business registration number

City of Tshwane Metropolitan Municipality: Water and Sanitation Division________

____

____

A2 Address of applicant, or in the case of a body corporate, the registered head office

Physical address

Capitol Towers North____

225 Madiba Street____

Pretoria____

Postal address

Capitol Towers North____

225 Madiba Street____

Pretoria____

A3 Telephone number of applicant

(_012_)__358 3505____________________________

A4 Fax number of applicant

(_012_)__358 7785____________________________

A5 Email address of applicant

adriaank@tshwane.gov.za______________________

A6 Contact person

First name Adriaan____

Surname Kurtz____

Telephone No (012) 358 3505____

Mobile No ____

Fax No. (012) 358 7785____

Email address adriaank@tshwane.gov.za__________________________________

A7 Legal form of applicant

Local government body: Service Delivery________________________________

____

____

Note to Section A

1) State whether the applicant is a local government body, a juristic person established in terms of an act of parliament, a department of state, a company or other legal body.

2) If the applicant is a local government body, attach a copy of the proclamation establishing such body. Where the applicant is a company, the full names of the current directors and the company registration number are required.

SECTION B COMMENCEMENT DATE OF LICENCE

B1 Desired date from which the licence (if granted) is to take effect

November 2013____

____

____

Note to Section B

3) The normal processing time for a licence application is 120 days once all relevant information has been provided and there are no objections received.

4) If the applicant intends operating more than one generation station under the proposed licence, please complete separate application forms for each generation station.

SECTION C PARTICULARS OF PROPOSED GENERATION STATION

C1 Name of generation station

Garsfontein Conduit Hydropower Plant ________________________________

C2 Geographical location of generation station (please attach maps)

Wekker Street, Pretoria (see attached map) ________________________________

C3 Address of generation station

Garsfontein Reservoir ________________________________

Wekker Street ________________________________

Moreleta Park, Pretoria ________________________________

C4 Contact person at generation station

First name and Surname Gerhard Stoop __________________

Telephone No (012) 358 8089 __________________

Mobile No ________________________________

Fax No (012) 358 7785 __________________

Email address gerhards@tshwane.gov.za ____________

C5 Type of generation station (thermal, nuclear, hydro, pumped storage, gas turbine, diesel generator or other)

Conduit Hydropower ________________________________

C6 Expected commissioning date for a proposed generation station or at which the station was commissioned (if an existing station).

November 2013 ________________________________

C7 The installed capacity (existing and/or planned) of each unit within the generation station (MW)

Existing Capacity

None ________________________________

Planned Capacity

730kW ________________________________

C8 Maximum generation capacity (MW) expected to be available from the generation station and energy to be produced (MWh) over the next 5years of operation. These estimates should be based on modelling of how the power station will fit into the demand profile of its customers, taking into account the least cost energy purchase consideration and demand management options of customers.

YEAR	Max MW	Total MWh	Own use MWh	Export (Sales) MWh
2014	0.73	4666	0.17	4665.8
2015	0.73	4666	0.17	4665.8
2016	0.73	4666	0.17	4665.8
2017	0.73	4666	0.17	4665.8
2018	0.73	4666	0.17	4665.8
2019	0.73	4666	0.17	4665.8

C9 Estimate of the energy conversion efficiency of the generation station.

84%_

C10 Expected future life of the generation station.

15 Years

SECTION D PARTICULARS OF LONG TERM ARRANGEMENTS WITH PRIMARY ENERGY SUPPLIERS

D1 Name of primary energy supplier/s (mining house, colliery or other fuel supplier)

Water is supplied by Rand Water

D2 Particulars of the contractual arrangements with primary energy supplier

The City of Tshwane Metropolitan Municipality has an existing contractual agreement for supply with Eskom. This arrangement will not be affected by the proposed project.

Water is supplied by Rand Water and the Municipality has a long term supply agreement with Rand water for water supply to the area where the power plant is proposed.

Notes to Section D

5) Please provide brief particulars of any long term agreements entered into with fuel suppliers and copies of such contracts (Signed Fuel Supply Agreements).

Not Applicable

SECTION E MAINTENANCE PROGRAMMES AND DECOMMISSIONING COSTS

E1 Details of any proposed major maintenance programmes, including the expected cost and duration thereof, covering the next six years. Project proposals to state the expected availability, planned outage rate and forced outage rate of the plant over the first five years of operation.

7 Days per year are scheduled for maintenance.

As the equipment is new, minimal maintenance is expected in the first 5 years.

E2 Details of any major decommissioning costs expected during the life span of the power station and provided for in the project feasibility study.

Not Applicable

E3 Details of major generation station expansion and modifications planned for in the feasibility study (Dates, Costs in Rands (state year) and description)

Not Applicable

SECTION F CUSTOMER PROFILE

F1 Particulars of the person or persons to whom the applicant is providing or intends to provide electricity from the generation station

City of Tshwane Metropalitan Municipality: Electrical Division

F2 Network connection details (connection points, voltages, wheeling arrangement, single line diagram)

11 kV line to connect to the municipal grid 500 m from the generation point.

F3 Provide summary details of Power Purchase Agreements with customer including purchasing price etc. (Please attach Power Purchase Agreements).

The Municipality has an existing NERSA distribution licence. This project will fall under the umbrella of the existing agreement.

Notes to Section F

6) For example, supply to ESKOM or supply to local government distribution system. Please include the details of power purchase agreements entered into and the price structure of the contract.

SECTION G FINANCIAL INFORMATION

G1 Submit projections of and current statements of the accounts in respect of the undertaking carried on by the applicant, showing the financial state of affairs of the most recent period, together with copies of the latest audited annual accounts where such have been prepared.

Attached

G2 Submit annual forecasts for the next five years of costs, sales and revenues generated by the project, stating the assumptions underlying the figures.

An average revenue of 58 c/kWh was determined using the rate at which the Municipality purchases electricity from Eskom. This rate will increase by 8% per year for the next 5 years, in accordance with the NERSA agreement.

G3 Estimates of net annual cash flows for subsequent periods (5 years; 10 years; 15 years) sufficient to demonstrate the financial security and feasibility of operating the generation station.

Attached

G4 Project financing: Who will finance the project, how is funding split between debt and equity, and what is the terms and conditions of the funding agreements.

Internal budget funding will be used.

Notes to Section G

7) The financial projections should be based on a production plan for the generation station and the revenue generated by participating in the electricity market and by bilateral contracts (Power Purchase Agreements) with customers. Reference to the latest version of National Integrated Resource Plan (IRP) is required to demonstrate that the proposed power purchase agreement is the least cost solution available to the electricity purchaser.

SECTION H HUMAN RESOURCES INFORMATION

H1 Submit details of the number of staff and employees and their categories in the service of the applicant at the generation station and in any support services separate from the generation station. Also provide information regarding relevant qualifications and experience in critical areas e.g. Professional registration (Engineering Council of South Africa – ECSA), Government Certificate of Competency.

Not applicable: Municipality has standing agreement with NERSA_______________

SECTION I PERMISSION FROM OTHER GOVERNMENT DEPARTMENTS OR REGULATORY AUTHORITIES

I1 What progress has been made to obtain the required permits and approvals for the generation project? Please provide copies of permits issued by the relevant environmental and safety agencies in respect of the operation of the generation station.

Permits are not needed as the project falls within the boundaries set by the National Environmental Management Act. a notice board, meeting the requirements set in Government Notice 543 of 18 June 2010, will be displayed on the boundary fence.

SECTION J BROAD-BASED BLACK ECONOMIC EMPOWERMENT

J1 Please provide information in terms of the following categories:

COMPONENTS	POINTS	0.5	0.75	1
Direct Empowerment	Black Ownership	10% to <20%	20% to 50%	>50%
	Black Management	20% to <35%	35% to 50%	>50%
	Black Female Management	1% to <5%	5% to 10%	>10%
Human Resource Development	Black Skilled Personnel as % of payroll	20% to <35%	35% to 50%	>50%
	Skills Development Programs as % of payroll	1% to <5%	5% to 10%	>10%
	Employment Equite i.e. Women Representation	20% to <35%	35% to 50%	>50%
Indirect Empowerment	Procurement from Black/BEE Suppliers	20% to <35%	35% to 50%	>50%
	Enterprise Development i.e. Monetary Investment or quantifiable non-monetary support in SMME with BEE contributions as % of Net Asset Value/EBITDA/Total Procurement	10% to <20%	20% to 25%	>25%
	Industry specific initiative to facilitate the inclusion of black people in the sector as % of net profit	1% to <5%	5% to 10%	>10%
NERSA's Discretionary Points	Based on skills transfer and fulfilment or acceleration of other national objectives e.g. employment of disabled personnel robust implementation of mechanisms to verify the BEE status of suppliers reported under preferential procurement and utilization of DTI approved accreditation agencies and so on.	1% to <5%	5% to 10%	>10%

SECTION K ADDITIONAL INFORMATION

Provide any other relevant information related to this application

SECTION L DECLARATION

On behalf of the applicant, I hereby declare that:

(a) the applicant shall at all times comply in every respect with the conditions attached to any licence that may be granted to the applicant;

(b) the applicant shall at all times comply with lawful directions of the National Energy Regulator of South Africa;

(c) the information provided by me on behalf of the applicant is accurate and complete in all respects; and

(d) I am authorised to make this declaration on behalf of the applicant.

Signed:

Full name(s) of Signator(y/ies):

Adriaan Kurtz	

Position held (if the applicant is a company, co-operative, partnership, unincorporated association or any other body corporate):

Consultant to Tshwane Water and Sanitation Division	

Date:

01/01/2013

NERSA ELECTRICITY GENERATION APPLICATION FORM: ECONOMIC INFORMATION

Table 1: Economic analysis

PHASE 3 ECONOMIC ANALYSIS			
Power information for current scenario			
Power rating		727	kW
Design flow	(Q)	0.780	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		4 666	MWh/a
Turbine type		Turgo	
Total power information for future scenario			
Power rating		727	kW
Design flow	(Q)	1.561	m^3/s
Design flow corresponding head	(H)	114	m
Potential annual power		9 307	MWh/a
Turbine type		Turgo	
Design life		15	years
Cost			
Initial planning cost (IPC)			
Legal and regulatory		R 0	
Environmental and social assessment		R 0	
Investigation and preliminary design		R 1 200 000	
Subtotal		**R 1 200 000**	
Capital expenditure (CEC)			
Construction year		2014	
Turbine		R 7 404 665	
Preliminary and general		R 1 300 000	
Access to site		R 0	
Pipework and valves		R 1 100 000	
Power station housing and tailrace		R 1 600 000	
Electromechanical and controls		R 1 100 000	
Transformer/transmission		R 700 000	
Construction supervision		R 1 000 000	
Contingencies		R 1 300 000	
Other (Data logging)		R 20 000	
Disposal (Present value (PV))		R 0	
Subtotal		**R 15 524 665**	
Additional capital expenditure due to expansion (PV)		R 0	
Year of expansion		2029	
Annual operation and maintenance cost (OMC)	% of CEC for component		
Civil items	0.25%	R 6 750	
Electrical and mechanical items	2.00%	R 170 093.29	
Transmission	0.80%	R 5 600	
Operation	0.40%	R 62 099	
Insurance	0.30%	R 46 574	
Subtotal (PV)		**R 291 116**	
Income			
Annual income for current scenario	R/kWh		
Average value of generated electricity	0.58	R 2 706 251	
Revenue		R 0	
Subtotal (PV)		**R 2 706 251**	
Annual income for future scenario	R/kWh		
Average value of generated electricity	0.58	R 5 398 243	
Revenue		R 0	
Subtotal (PV)		**R 5 398 243**	
Results			
Net present value of costs	-R 20 617 844		
Net present value of income	R 49 185 573		
Total NPV	**R 28 567 728**		
Internal rate of return	**22.14%**		

Inflation and maintenance factors over design life

Year	Annual Inflation: Electricity	Operation	Maintenance	General	Maintenance factors
0	8.0%	5.3%	5.3%	5.3%	0.8
1	8.0%	5.1%	5.1%	5.1%	0.8
2	8.0%	6.0%	6.0%	6.0%	0.8
3	8.0%	6.0%	6.0%	6.0%	0.8
4	8.0%	6.0%	6.0%	6.0%	0.8
5	10.0%	6.0%	6.0%	6.0%	1
6	10.0%	6.0%	6.0%	6.0%	1
7	10.0%	6.0%	6.0%	6.0%	1
8	10.0%	6.0%	6.0%	6.0%	1
9	10.0%	6.0%	6.0%	6.0%	1
10	10.0%	6.0%	6.0%	6.0%	1
11	10.0%	6.0%	6.0%	6.0%	1
12	10.0%	6.0%	6.0%	6.0%	1
13	10.0%	6.0%	6.0%	6.0%	1
14	10.0%	6.0%	6.0%	6.0%	1
15	6.0%	6.0%	6.0%	6.0%	1.2
16	6.0%	6.0%	6.0%	6.0%	1.2
17	6.0%	6.0%	6.0%	6.0%	1.2
18	6.0%	6.0%	6.0%	6.0%	1.2
19	6.0%	6.0%	6.0%	6.0%	1.2
20	6.0%	6.0%	6.0%	6.0%	1.25
21	6.0%	6.0%	6.0%	6.0%	1.25
22	6.0%	6.0%	6.0%	6.0%	1.25
23	6.0%	6.0%	6.0%	6.0%	1.25
24	6.0%	6.0%	6.0%	6.0%	1.25
25	6.0%	6.0%	6.0%	6.0%	1.25
26	6.0%	6.0%	6.0%	6.0%	1.25
27	6.0%	6.0%	6.0%	6.0%	1.25
28	6.0%	6.0%	6.0%	6.0%	1.25
29	6.0%	6.0%	6.0%	6.0%	1.25
30	6.0%	6.0%	6.0%	6.0%	1.5
31	6.0%	6.0%	6.0%	6.0%	1.5
32	6.0%	6.0%	6.0%	6.0%	1.5
33	6.0%	6.0%	6.0%	6.0%	1.5
34	6.0%	6.0%	6.0%	6.0%	1.5
35	6.0%	6.0%	6.0%	6.0%	1.5
36	6.0%	6.0%	6.0%	6.0%	1.5
37	6.0%	6.0%	6.0%	6.0%	1.5
38	6.0%	6.0%	6.0%	6.0%	1.5
39	6.0%	6.0%	6.0%	6.0%	1.5
40	6.0%	6.0%	6.0%	6.0%	1.5
41	6.0%	6.0%	6.0%	6.0%	1.5
42	6.0%	6.0%	6.0%	6.0%	1.5
43	6.0%	6.0%	6.0%	6.0%	1.5
44	6.0%	6.0%	6.0%	6.0%	1.5
45	6.0%	6.0%	6.0%	6.0%	1.5
46	6.0%	6.0%	6.0%	6.0%	1.5
47	6.0%	6.0%	6.0%	6.0%	1.5
48	6.0%	6.0%	6.0%	6.0%	1.5
49	6.0%	6.0%	6.0%	6.0%	1.5
50	6.0%	6.0%	6.0%	6.0%	1.5

Table 2: Cash flow sensitivity analysis

PHASE 3 SENSITIVITY ANALYSIS					
	Total NPV				
Year	Elec high	O&M high	Expected	O&M low	Elec low
0	-R 1 200 000.00	-R 1 200 000.00	-R 1 200 000.00	-R 1 200 000.00	-R 1 200 000.00
1	-R 16 724 664.56	-R 16 724 664.56	-R 16 724 664.56	-R 16 724 664.56	-R 16 724 664.56
2	-R 14 145 897.14	-R 14 153 103.57	-R 14 145 897.14	-R 14 141 092.85	-R 14 145 897.14
3	-R 11 513 669.44	-R 11 535 492.70	-R 11 513 669.44	-R 11 499 347.23	-R 11 513 669.44
4	-R 8 826 972.79	-R 8 871 032.98	-R 8 826 972.79	-R 8 798 507.93	-R 8 826 972.79
5	-R 5 973 786.10	-R 6 103 415.68	-R 6 029 282.77	-R 5 982 137.84	-R 6 140 276.13
6	-R 2 944 685.41	-R 3 228 674.15	-R 3 116 410.98	-R 3 046 134.13	-R 3 453 579.47
7	R 233 798.02	-R 285 830.09	-R 120 499.57	-R 18 782.19	-R 803 371.48
8	R 3 608 673.86	R 2 771 311.70	R 2 999 450.60	R 3 137 508.05	R 1 846 836.52
9	R 7 191 058.67	R 5 947 156.23	R 6 248 120.26	R 6 427 324.85	R 4 497 044.52
10	R 10 992 698.25	R 9 246 277.37	R 9 630 366.72	R 9 855 434.87	R 7 147 252.52
11	R 15 026 003.23	R 12 673 424.21	R 13 151 230.64	R 13 426 789.73	R 9 797 460.52
12	R 19 304 086.75	R 16 233 527.86	R 16 815 942.85	R 17 146 532.99	R 12 447 668.52
13	R 23 840 804.20	R 19 931 708.29	R 20 629 931.59	R 21 020 007.21	R 15 097 876.51
14	R 28 650 795.24	R 23 773 281.60	R 24 598 829.95	R 25 052 761.43	R 17 748 084.51
15	R 33 749 528.19	R 27 603 012.25	R 28 567 728.31	R 29 089 803.58	R 20 398 292.51

Table 3: IRR sensitivity analysis

IRR				
Elec high	O&M high	Expected	O&M low	Elec low
23.47%	21.81%	22.14%	22.32%	19.53%

E. CASE STUDY CALCULATIONS

E.1 INTRODUCTION

Various calculations were made, using the developed CHD Tool, to determine hydropower potential at the three chosen case study sites. This appendix provides a list of the Microsoft Excel documents that are available on the attached CD.

E.2 MICROSOFT EXCEL DOCUMENTS INCLUDED ON CD

The following documents are included on the attached CD:

E1. CHD_TOOL_CASE_STUDY_1_GARSFONTEIN

E2. CHD_TOOL_CASE_STUDY_2_PIERRE_VAN_RYNEVELD

E3. CHD_TOOL_CASE_STUDY_3_WATERKLOOF