

EFFECTIVENESS OF PLANNED MAINTENANCE IN POWER STATIONS

by

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ABSTRACT

Title of treatise: Effectiveness of planned maintenance in power stations

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Eskom has subdivided its power generation into competitive clusters. This has been done with a view to measuring individual plant reliability. The objective of this project is to study the impact of preventive maintenance on the performance of power stations and reliability of power supply. The project also intends to study the resultant benefits of preventive maintenance to consumers. This study is based on the evaluation of the effectiveness of preventive maintenance, which is a form of planned maintenance in Eskom's power-generating utilities, as opposed to reactive maintenance (unplanned maintenance). A critical analysis of the performance of various power stations over a three-year period will be done. Reasons for loss of power supply of different plants will also be identified, including raising concerns to key role players to embrace preventive maintenance as a tool to sustain power supply and minimise disruptions in order to enhance economic growth.

Keywords: Preventive (planned) maintenance, Predictive (condition-based) maintenance, Time-based maintenance, Turbine, Boiler

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CHAPTER 1: INTRODUCTION

1.1 Background to the problem

In South Africa, electricity consumption is growing faster than other energy sectors in comparable emerging market economies. To provide an economic incentive to investors, South Africa's electricity was one of the cheapest in the world (McKenzie, 2011). Due to the prevailing constraints as a result of the deficit in terms of power supply, it has become critical for an organisation such as Eskom to look at the maintenance and reliability of supply in order to support the economic growth of the country.

Maintenance cost and downtime losses of a power plant can be reduced by adopting a proper mix of maintenance strategies that ensure its reliable availability (Mohan, Gandhi and Agrawal, 2004). Greamer (2009) holds the view that increases in electricity demand are a result of faster than anticipated economic growth and its residual rapid urbanisation. In order to sustain continued economic growth, companies cannot afford to have disruption of their production activities.

Therefore, Eskom has to have a proper maintenance schedule of its existing power supply to provide investors with necessary confidence in the stability of energy supply. Cloete (2001) further argues that proper maintenance is the work directed at prevention against failure of a facility in order to ensure its continued operation within the anticipated endurance time of that facility.

The replacement, repair, or maintenance of plant equipment as it deteriorates over time has been studied in many contexts. It is commonly agreed nowadays that preventive maintenance can be successful in improving equipment reliability while minimising maintenance-related costs. According to Ismail, Zulkif, Makhtar, and Deros (2009), preventive maintenance consists of actions that improve the integrity of system elements before they fail. Preventive maintenance is defined by Zulkif et al as an action involving inspection, servicing, repairing or replacing of physical components of machineries, plant and equipment by following the planned schedule. This is very important in order to achieve more efficient and economical plant and equipment operation. In addition, Worsham (2005) states that preventive maintenance is a planned maintenance activity of plant and equipment that is designed to improve machine life and avoid any unplanned maintenance activity. This will stabilise production capability by maintaining production levels of the plant safely without any perceptible impact on customers. As part of Eskom's fulfilment of its mandate, it needs to pay particular attention to the management and maintenance of its production assets.

According to Anderson (2003), the term “preventive maintenance” refers to any activity that is performed:

- to predict the onset of component failure;
- to detect a failure before it has an impact on the asset function; and
- to repair or replace the asset before failure occurs.

Electricity is a vital resource for the macroeconomic survival of Southern Africa; yet, at the same time, it is a commodity greatly taken for granted by all stakeholders, industries, and the public sector. Without clear security of supply, no economic growth can take place, and unreliable supply at present, as such planned maintenance plays an important role in terms of ensuring security and reliability of supply.

Gross (2002) argues that, without sufficient maintenance planning and long-term plant health and redundancy of equipment becomes an important factor. Due to the obsolescence of spares, original spares are not readily available. As such the inventory of spare parts becomes a very strategic component which is catered for as part of preventive maintenance. New technology has to be looked at, and it has to be managed with the planned maintenance of power station. Various authors have done a lot of research in this field of preventive, predictive, and time-based maintenance in relation to cost benefits for different plants worldwide (Hunter, 2009; McKelway, 2009; Philippidis, 2002; Foong, Simpson, Maier and Stolp, 2007). The constraints with which Eskom is faced as far as the tight margin of electricity supply is

concerned are a direct result of inadequate planning and lack of investment for adding to the generating capacity. Due to this prevailing state of affairs, plants are forced to run for a longer period without planned maintenance being applied.

Maintenance management and the reduction of costs are of the utmost importance for any business to sustain profitability and competitiveness. What is however crucial is to understand that cost is not a stand-alone variable, but an inseparable part of the three variables, namely cost, risk and performance (Kelly and Harris, 1978).

The electricity blackouts that swept the country around January 2008 (Eskom, 2010) left a negative dent on the image and reputation of the organisation – hence, the drive by one of its employees to conduct a study on maintenance strategy to shed light on how we can improve on the gaps that will be identified. A cut in cost, according to (Kelly and Harris (1978) in critical areas of maintenance could bring about an increase in risk of unplanned failures and therefore a reduction in plant performance results. According to (Eskom, 2007) to maintain a plant to maximum performance, one needs to spend money and ensure that key strategic spares are available in line with the lifespan of the equipment. Maintenance departments are constantly under pressure to reduce costs, and it should be realised that not all variables in the maintenance environment are always quantifiable in monetary terms. White (1979) defines planned maintenance as work that is

required to prevent an equipment functional failure. This would include work related to time-based and predictive maintenance. Planned maintenance usually reoccurs and is typically well planned. "Well planned" means that the plant personnel have identified all required resources and are available when needed to carry out maintenance tasks (White, 1979).

The South African government identified electricity as a strategic sector under the planning, growth, and developmental objectives set out by the Government (Globaltech, 2010). Over the next few years the country is expected to experience continued growth in electricity demand driven by the growth in the industrial, mining and commercial consumer sectors. As a result of higher than anticipated growth and limited investment in new generation infrastructure over the last 15 years, Eskom's generation reserve has fallen below the 10% margin. This reserve margin is below conventional industry bench marks and Eskom plans to restore generation reserve margin to around 15% in the medium to long-term (Globaltech 2010).

As a result of the low reserve margin, Eskom has reacted to the situation by putting in place a proactive maintenance strategy that ensures that existing reserve margins are maintained for continued and reliable supply of electricity. In the event of any forced (unplanned) maintenance, the country will be exposed to the risk of sporadic blackouts. This will put pressure on other power stations that are on load to postpone their planned maintenance schedules in order to cater for the shortfall.

1.2 Statement of the problem

Is there a positive relationship between planned maintenance and high performance and reliability of power station plants in South Africa?

1.2.1 Sub-problem 1

What is the level of planned maintenance taking place at the power stations?

1.2.2 Sub-problem 2

Does planned maintenance affect the operational costs of power stations?

1.3 Hypotheses

1.3.1 The first hypothesis

There is a positive relationship between planned maintenance and high performance of power stations.

1.3.2 The second hypothesis

There is a high level of planned maintenance taking place in the power stations.

1.3.3 The third hypothesis

Planned maintenance has an effect on the operational costs of power stations.

1.4 Delimitations of the research problems

The research study is limited to electricity-generating plant within one South African utility, namely Eskom. Only coal-fired power stations are included in the study. Power stations are grouped into clusters by Eskom and they compete in terms of their performance and reliability. These power stations have been selected based on their age, that is, those built around the 1950s to 1960s and commissioned around 1970s, and those built around the 1970s to 1980s and commissioned around 1980s and 1990s. The research is also limited to the Generation Division, which is responsible for the maintenance of the power stations as well as the daily production of electricity.

Electricity is transported and sold by the Transmission and Distribution Divisions, but neither was considered for this research; hence, it is difficult to come up with the actual quantifiable cost benefit.

1.5 Goals and objectives

The study is based on an attempt to establish whether planned maintenance does lead to effectiveness of power station's operations, longevity of critical plant parts and subsequent lowering of maintenance costs of power stations and excludes the effect of planned maintenance on the lowering of electricity tariffs to the consumers. Lastly it seeks to recommend the best practices of maintenance in line with internationally accepted industrial benchmarks.

1.6 Assumptions

The effectiveness of planned maintenance will be viewed from the perspective of relevant stakeholders. An effort will be made to ensure that the best maintenance practices used in the electricity industry throughout the world are incorporated. This will improve the efficiency, reliability, and performance of the plant – hence, ensuring a good return on investment for investors.

1.7 Benefit of the study

This research, its findings, and its recommendations will add value for a number of stakeholders, namely, power station management, cluster maintenance teams, the maintenance departments of power stations, the Department of Minerals and Energy (DME), the business community, and members of the public. The study will indicate the causal relationship between effectiveness in operating power plants as a result of having planned maintenance and breakdown as a result of unplanned maintenance. The value of this research is to focus on the cause in order to eliminate the undesired effects of plant breakdown or decreased lifespan of the equipment. Through this research, Eskom's coal fired power stations will be able to identify and select the best planned maintenance practices in line with their business.

CHAPTER 2: LITERATURE REVIEW

2.1 Sustainability of generation of power supply (reliability and security of generating capacity)

2.1.1 Global norms (universal standards used in maintenance of power plants)

There is variety of maintenance benchmarking in relation to maintenance of any plant. These benchmarking indicators are also applicable to power generation plants. Robert (2002) identifies the benchmarked indicators as consisting of costs, parts, and customer service. In relation to the cost benchmark, the ownership structure of traditional electric utilities, with a few exceptions, favoured state ownership and were subjected to regulatory protection within a particular geographical location with few entrants to the market (United Nations, 2010). As a result some of these utilities were breeding monopoly and were not profit driven. The emphasis was on maximisation of reliability of the plant, with cost being the least considered.

With globalisation and a shift in political power blocks, most of the electrical utilities have been privatised, and those that are state-owned face growing fierce external competitive pressure (McKenzie, 2011).

2.1.1.1 Costs

For a generating plant to be maintained successfully and run efficiently, one has to factor in the cost to the budget. Due to financial constraints in all profit-driven entities, the most common benchmark, in this case, is how global companies are doing in relation to maintenance cost to the budget. This will show problematic areas in terms of keeping up with maintenance costs. Khatib (1997) argues that, for any economy, an unreliable energy supply results in both short- and long-term costs. These costs are translated or measured in terms of loss of production, and companies have to make adjustments in relation to unreliable fuel and electrical power supply in order to minimise the impact on their business. These interruptions in supply may cause loss of production, cost related to unfinished products, and overall damage to manufacturing plants.

Globally, power utilities make use of a system of demand-side management to balance potential losses by identifying time phases for the additional purchase of power supply from neighbouring countries to augment their deficit. In the case of the South African situation, Eskom sells 6.2% of the electricity it produces to the SADEC countries (Mail and Guardian, 2011). It is, therefore, critical for Eskom to minimise spiralling costs related to electrical disruption as a result of planned and unplanned maintenance for its generating plants by issuing advance notification regarding the duration of power outages.

A power station is an asset in which investors have invested capital. Therefore a good return on their investment is expected by Eskom. Globally, maintenance cost per unit for producing electricity should be less than the income to enable the business to be sustainable.

According to Carroll, Sterman, and Marcus (1994), maintenance expenses globally account for 15% to 40% of production costs, depending on the type of manufacturing process. This finding is supported by a survey carried out by the Sloan School of Management in 1991 show that the amount of money spend by most power plants world-wide on maintenance are roughly equal to its net income.

2.1.1.2 Parts

It is crucial for power plants worldwide to ensure that an inventory of critical spares is maintained to balance of critical and non-critical parts components (Eskom, 2007). This inventory helps with cost reduction as maintenance personnel are able to focus and ensure that preventative maintenance is not delayed. By keeping a strategic inventory of critical spares, a power utility can ensure that downtime is kept to a minimum. Unnecessary waiting and exorbitant costs can be negated by ensuring that a strategic stock of critical spares is maintained.

2.1.1.3 Labour costs

Most power plants are coming increasingly under pressure to improve its cost effectiveness in terms of labour (Eskom, 2007). Power plant managers believe that overtime on regular basis is a source of cost inflation. For any power plant to be effective and competitive internationally, the number of personnel employed to maintain the plant should be such that the company is profitable and should be able to maintain the plant operation to its maximum capacity. Power plants strive to reduce maintenance costs by employing least number of personnel, which lowers costs related to salaries and increases plant capacity by maximising their output as a result of resources allocated properly.

2.1.1.4 Customer service

Frequent interruptions and unreliable supply of electricity is a priority concern to electricity consumers. Planned maintenance will ensure that there are few electricity supply disruptions. This means that as part of planned maintenance, there will be timeous notification of scheduled maintenance and outages. Consumer awareness as part of planned maintenance is also essential in sensitising the public about the implications of their electricity usage. Where all this practices are implemented, plant electricity supply will be maximised.

2.1.2 The South African situation (Eskom)

According to the Engineering News (2010), a reliable, secure, and competitive electrical supply is a vital ingredient in the competitiveness of the South African industry and the South African Development Community's long-term economic and sustainable development. South Africa's ability to continue to attract high levels of foreign direct investment and a conducive business environment will depend on its generating capacity to deliver a secure and uninterrupted electricity supply at a competitive cost.

The assumed commercial life of Eskom power stations is approximately 40 years (Eskom, 2007). The majority of them are in their midlife and, as such, require extensive maintenance, including inspection and replacement of major components. The challenge is how Eskom fully implement reliability and continuous supply in terms of international best practices with regards to cost, parts, and labour costs are concerned

The country had also started to experience a significance shortage of electricity in 2008 for a period of approximately three months starting in February (rolling blackouts and unexpected shutdowns for repairs and maintenance) (Eskom, 2008). As a result of continuous growth in the demand for electricity and to ensure continuous supply, there was a need on the side of Eskom to have a coherent strategy on maintenance.

2.1.2.1 Costs

When compared to its global counterparts, Eskom's pricing of electricity is relatively low (Muller, 2008). This has been made possible by the abundance of coal and over supply of generating capacity up until 2008. The demand for coal globally has resulted in sharp increase in the cost of coal which in turn has resulted in increase in operating costs. Economic growth in South Africa has resulted in increased demand for electricity and the moratorium on new infrastructure had a combined effect that led to substantial decrease in the supply margin. This has put a burden on existing operating plants to maximise uptime. This process stresses the plants and equipment. Carroll et al (1994) argues that despite effort to maximise uptime, the average power plant uptime is approximately 83-95%. The remainder of the downtime is caused by critical equipment being serviced or awaiting service.

Given the prevailing scenario whereby Eskom is operating on tight reserve margin, if energy saving by consumers can be enhanced this will result in increased unit lifespan due to decreased electricity demand and less overrunning of the power plants. Eskom will not have to purchase more electricity but less from the independent power producers as well as from neighbouring countries.

2.1.2.2 Parts

Wireman (2005) holds the view that company can protect their plant by holding more stock of business critical components. When there is a breakdown of critical component, a spare component is available at hand, ready for the maintenance team to fix the problem. The organisation will be in a position to maintain stock inventory at optimal level and as such enhancing the plant reliability. In some midlife power plants in Eskom group there is a tendency of incurring increased stockholding costs as a result of keeping too much spare parts for a longer period (Eskom, 2008). Wireman (2005) argues that stock holding should not be seen as a capital outlay, but as an insurance against the risk of downtime or loss of production.

2.1.2.3 Labour costs

For an organisation such as Eskom to realise its true downtime cost, it has to take into account variables such as labour costs associated with downtime. According to Fitchett and Sondalini (2008), downtime cost includes all costs associated with downtime or production lost time. Without predictive and preventive maintenance, Eskom is likely to incur hidden costs associated with labour. Most of the South African companies are still relying on the traditional approach to preventative maintenance in relation to division of labour. In the traditional approach as opposed to the non-traditional one, there is no interfacing between different divisions critical to the overall

effectiveness of the company. He shows that there is a gap between the plant operators who perform the routine maintenance function, the maintenance technicians responsible for specialised maintenance and improving maintainability of a plant, and the engineering team responsible for improving the plant processes.

2.2 Interventions for reliability of plant

The following will be discussed under interventions for reliability of plants: asset management, reliability basis optimisation, routine work management and strategic spares.

2.2.1 Asset management

Eskom's objectives with regards to power stations is to increase their contribution to its corporate success through improved generating unit reliability, which is accomplished through optimisation of cost of production and high reliability which will be achieved through developing and implementing Industry best maintenance practices, (Eskom, 2008). With the entry of Independent Power Producers to the generating electricity market, it has become increasingly important for Eskom business units to be reliable and cost effective in terms of security of supply and maintenance in order to sustain the business. The manner in which such Eskom Holdings will be profitable is to achieve and maintain a low Unplanned Capacity Lost Factor

(UCLF), avoid unnecessary Planned Capacity Lost Factor (PCLF) and achieve high availability at an optimal cost per kWh. For an asset to be able to maintain its value, critical failures should be analysed, tracked and predicted. Once the prediction has been carried out, the maintenance will be executed so that equipment performance and condition effectively support safe and environmentally responsible and reliable plant operation. This will enhance the value of Eskom generation assets.

2.2.2 Reliability basis optimisation

According to the Generation Skills Delivery Unit's Maintenance Philosophy (Eskom Generation, 2007), maintenance management and the reduction of costs are of the utmost importance for any business to sustain profitability and competitiveness. What is critical to understand, however, is that cost is not a stand-alone variable, but an inseparable part of the trilogy, namely, cost, risk, and performance. A cut in cost in the wrong area will mean that there is a high risk to performance of plants. It is of the utmost importance to note that all three elements, that is, cost, risk, and performance, have a direct relationship to each other, so a change in any of the three will mean that the other two elements will have to be adjusted as well. There should be a minimum cost allocated for the purpose of maintenance in order to maintain minimum plant health. Since maintenance management is under pressure to reduce costs, it should be clearly noted that not all the variables in the maintenance environment are always quantifiable.

Maintenance is a combination of all technical, administrative, and managerial actions during the life cycle of an item, with the aim of retaining and restoring it to a state where it can perform the required function.

The Core Principles of Reliability Basis Optimisation (Eskom Generation Manual, 2007) refers to failure mode as the manner in which equipment or a component fails to perform a required function such as the following:

- Seizing of a ball bearing
- Boiler tube rupture
- Overheating of circuit-breaker contacts
- Valve stem leakage
- Drive belt breakage
- Wearing out of pump impellers

Equipment should be capable of performing its intended function. Failing to do so can be classified as failure mode, and this greatly affects electricity generation.

Reliability basis optimisation, according to the Core Principles of Reliability Basis Optimisation (Eskom Generation Manual, 2007), optimises the plant reliability basis, incorporating plant-specific knowledge, maintenance and failure history, and industry best practice, to finally achieve an effective maintenance strategy for each plant and equipment, while optimising the

knowledge and understanding of how the equipment fails, the development of defence mechanisms to counteract these failures, and the application of technology to predict potential failures. This is accomplished by performing the following maintenance strategies:

- Time-based preventive maintenance
- Condition-based maintenance (for example, oil analysis, vibration analysis, and thermography)

2.2.2.1 Time-based preventive maintenance

South Africa has a low level of spare electricity capacity over and above peak demand compared to other developing countries (Eskom Generation Manual, 2007). To ensure Eskom's generation adequacy in the short to medium term, it is critical that the performance of the existing power stations is enhanced and stabilised.

According to the Generation Skills Delivery Unit's Maintenance Philosophy (Eskom Generation, 2007), maintenance management and the reduction of costs are of the utmost importance for any business to sustain profitability and competitiveness. Again, it must be remembered that cost is not a stand-alone variable, but an inseparable part of the trilogy of cost, risk, and performance. A cut in cost in the wrong area will mean that there is a high risk to performance in plant, as there is a direct relationship among the three, which means one will mean that the other two elements will have to be

adjusted as well. This is proven by McCall (1965) in his argument on preventive maintenance policies, where he highlights that most literature on preventive maintenance is designed for randomly failing equipment whose state is assumed to be known with certainty. This implies that changes of state of any equipment or plant can be immediately detected, thereby prompting initiation of an appropriate maintenance action.

The author further argues that preventive maintenance models are, in most cases, affected by a single source of uncertainty, which is the inability to predict the exact time of state changes. It is this uncertainty that creates opportunities in replacing or repairing equipment, rather than waiting for equipment failure. There should be a minimum cost allocated for the purpose of maintenance in order to maintain minimum plant health. Since maintenance management is under pressure to reduce costs, it should be clearly noted that not all the variables in the maintenance environment are always quantifiable. In the presence of uncertainty, it is better to replace equipment in order to avoid the high cost of failure.

Time-based maintenance can be subdivided into age-based and calendar-based maintenance. Time-based maintenance is defined as significant activities that are carried out on regular basis according to predetermined schedule to maintain the condition of a plant. Age-based maintenance is defined as a maintenance plan in which the policy age of equipment is adjusted after any maintenance and inspection activity, thereby extending the

lifespan of equipment without increasing the risk. For aging plant, the time between scheduled preventive maintenance should be decreased to avoid increase in risk or failure. Calendar-based maintenance is a strategy where specified activities are undertaken at predetermined schedule at fixed intervals of time. Time-based maintenance is utilised because of its ability to yield positive results in relation to accurate information about the reliability pattern of the equipment in relation to its age. Both age- and calendar-based maintenance can be classified into scheduled overhaul and scheduled replacement.

2.2.2.1.1 Scheduled overhaul

Scheduled overhaul maintenance policy is designed as a tool to be used to ensure that plant and equipment are regularly inspected and that, as such, it is easy to detect probable failures (McCall, 1965). The critical parts related to mills, for example, mill gearboxes, can be subjected to scheduled overhaul or repair whenever failure is detected. Since there is a regular overhaul of critical parts, comparison is required between the cost of regular servicing and the cost of replacement before failure occurs.

2.2.2.1.2 Scheduled replacement

McCall (1965) states that scheduled replacement is mostly preferred, as it takes into account the specified age and the replacement interval of

equipment. This will necessitate that the maintenance department will not run equipment to obsolescence. The manufacturer usually specifies the lifespan of the equipment, but the reality is that some of the plant equipment is subjected to stressful conditions.

2.2.2.1.3 Age and deterioration

According to Moubray (1979:130), any physical asset that is required to fulfil a function that brings it into contact with the real world will be subjected to a variety of stresses. These stresses cause the asset to deteriorate by lowering its resistance to stress. Measurements for exposure to stress are in calendar time. Age-related failures also tend to be associated with fatigue, oxidation, corrosion, and evaporation, for example, pump impellers, valve seals, seals, machine tooling, screw conveyors, the inner surface of a pipeline, etc. Fatigue affects items such as mill components, crushers, and hopper liners, which are subjected to a high frequency of cyclic loads.

Scheduled overhaul entails remanufacturing a single component or overhauling an entire assembly at or before the specified age limit, regardless of its condition at the time. The frequency of a scheduled restoration is governed by the age at which the item or component shows a rapid increase in the conditional probability of failure. For power stations to carry out scheduled overhaul, reliable historical data must be available.

Scheduled restoration tasks are technically feasible in the following cases (McCall, 1965):

- There should be an identifiable age to which the machine is supposed to last, and the item shows a rapid increase in the conditional probability of failure.
- Most items of similar manufacture and servicing the same function survive up to that identified age, and as a result, the item starts posing both environmental and safety hazard when keeping it.
- They restore original resistance to failure of an item.

2.2.2.1.4 Effectiveness of scheduled overhaul

Once the historical data has been checked and consensus has been reached by management that scheduled overhaul should be carried out in a power station, it is of the utmost importance to consider the economic impact (benefits and drawbacks) of carrying out such a task. The cost impact of doing a scheduled overhaul should be less than the cost impact of allowing the failure to occur. Repetition of failures will dent the corporate image of the company brought about by repeated blackouts, and the shareholders' share capital will also lose its value.

If operational consequences occur as a result of machine breakdown, such breakdown may affect overall production. For a maintenance team to effectively carry out scheduled overhaul, it is likely to have the least effect on

power-generating utility, and the scheduled overhaul is likely to take less time than it would take to repair a failure because it is possible to plan more thoroughly for the scheduled task.

2.2.2.2 Predictive (condition-based) maintenance

White (1979) defines predictive maintenance as maintenance work initiated as a result of knowledge of the condition of an item from routine or continuous checking. Moubrey (1979) argues that condition-based tasks entail checking for potential failures, so that action can be taken to prevent the functional failure or to avoid the consequences of the functional failure. Both authors share the common notion that predictive maintenance recognises historical information about a component to plan and to prevent functional failure. The condition of the equipment is measured at predetermined intervals to determine when the component will fail. Before the equipment fails will a replacement or overhaul be scheduled.

EG&G Florida's KSC Predictive Maintenance Plan (1992) also highlights that the plant health of equipment is checked and monitored through the usage of computers and equipment monitoring instruments, eliminating too little or too much maintenance. Since the equipment is monitored on a regular basis, trend data analysis is projected for probable machine date maintenance.

Some of the major benefits expected from a condition (predictive) monitoring programme, according to EG&G's KSC Predictive Maintenance Plan (1992) include the following:

- Reduced expenditure on maintenance costs. Maintenance needs can be anticipated, and planned maintenance activities are more efficiently planned from the standpoint of manpower, spare parts, and tools.
- Unnecessary dismantling of plant items is avoided, since the condition of equipment under a predictive maintenance programme is known.
- Predictive maintenance measures equipment condition, so that corrective actions can be carried out, as such enhancing equipment performance.
- Energy saving in the form of elimination of high energy vibration. As a result, misalignment and imbalance will eventually reduce machine power consumption. Motor phase imbalance, which increases power consumption, can be corrected, resulting in savings in power and increased motor life.

Condition-based maintenance is carried out regularly, and its benchmarking is the forecast derived from analysis and evaluation of the significant parameters of the degradation of the power plant equipment. To successfully carry out condition-based maintenance, the Management of power station needs to fully understand the technology used in the power station and effective communication regarding the use of the technology to even the lowest level of the workforce, which could be semi-skilled. Such communication should be able to integrate all available equipment condition data, such as diagnostic and performance data, maintenance history,

operator logs, and design data, to make timely decisions about maintenance requirements of equipment, so as to prevent failure.

Predictive maintenance assists in the determination of plant health. All the important components of power stations, namely, standby feed pumps, boiler feed pumps, BFP turbines, turbine speed control, BFP fluid drives, BFP reticulation valves, cold reheat attemperator spray control valves, lube oil pumps, total feed water flow switches, turbine low vacuum switches, feed water heaters, secondary superheater attemperator spray isolation valves, and feed pump lube oil coolers, are all subjected to condition monitoring, which, in turn, informs the maintenance manager as to the individual status of these key components. This allows for predictive maintenance to be carried out when there are breakages, and if it comes to replacement, these strategic spares are usually kept in stock.

Condition monitoring also contributes to maintenance planning, maintenance cost reductions, health and safety programmes, and energy conservation. Maintenance planning is often assisted by advance warning of faults, so that corrective action can be planned in advance. Pre-planning allows for support to be organised in terms of access equipment, spare parts, technical information, and any specialised-skilled personnel who may be required. Proper planning and pre-planning, which occur as a result of predictive maintenance, ensure minimum work time and less overtime payment, thus reducing maintenance costs. Condition monitoring further contributes to

health and safety by recognising faults that may give rise to pollution or health hazards – also by indicating incipient faults that could produce dangerous conditions. Wasteful components of power station plant and inefficiency arising from faulty operation are then addressed.

The power industry's deficit of electricity supply and the collapse of economic markets have created the need to reduce costs because access to raising funds from international markets is very difficult. It is in this context that the objective is to better align our maintenance policy and plans with the operating context, to eliminate non-value-adding maintenance, and to implement the best maintenance practices, that is, predictive and time-based maintenance.

2.2.2.2.1 Levels of monitoring

In the case study, we will discuss four levels of monitoring in the baseload power station, according to EG&G's KSC Predictive Maintenance Plan (1992).

Level 1

Inspections carried out at this level are based on the human senses and are included in the daily and weekly activities. People who carry out such inspections are expected to use sight, hearing, touch, and smell and also to

obtain a sensory impression of the condition of the asset in order to determine the condition of the equipment or component. At this level, human observation plays a major role, despite fixed monitoring systems that provide alarms or even analog indications and trends.

Level 2

The inspector is assisted by a range of portable test equipment to make a variety of measurements. According to Eskom's Research and Technology Guidelines (Eskom,2007), the following types of equipment are used when carrying out tests in determining accurate readings on the equipment or plant:

Table 1: Types of equipment used for testing equipment/plant

Measurement	Equipment
Speed and running time	Tachometer
Electrical quantities	Test meter
Fits and tolerances	Proximity tester
Overheating and heat links	Thermography
Vibration wear	Shock pulse tester
Movement	Frequency analysis

Misalignment	Laser alignment
Level of degradation in electrical motor circuits	Motor analysis
Technology used to detect hidden flaws in materials, especially metals	Ultrasonics

Monitoring is applied to selected assets from the assets register of the power station plant, from which a condition history file is built up. Quantities are recorded, including characteristics, their variations are observed and interpreted, and predictive maintenance is carried out. This allows for functional failure to be detected, since the plant is being observed.

Level 3

In the case of Level 3 monitoring, the Eskom Maintenance Manual (2007) describes the process of lubricating items, which consists of checks on component wear and the level of contamination of the lubricant. Wear of components is usually indicated by metal particles and debris floating in the lubricant and these can be collected by magnetic devices. Contamination of the lubricant is detected by sampling and subsequent spectrometric analysis.

A list of analytical data reported includes:

- a) wear elements – iron, aluminium, copper, and chromic silicon dust;
- b) viscosity; and
- c) water content.

Level 4

Fixed monitoring systems are used at this level. These systems range from simple remote alarm systems to comprehensive data gathering systems based on minicomputers or microprocessors. Data is transmitted directly to the display screens, so that power station personnel can interpret the results and plan for maintenance if the need arises.

1. Condition monitoring applications
2. Permanent indicators are provided for the following:
 - a) Chilled water inlet temperature
 - b) Chilled water outlet temperature
 - c) Cold gas pressure and temperature
 - d) Hot gas pressure and temperature
 - e) Sea water inlet temperature
 - f) Sea water outlet temperature
3. Additional information is obtained from the following:
 - a) Motor currents – fixed ammeters
 - b) Bearing condition (three motors, compressor, and two pumps)
portable instruments for shock pulse or vibration monitoring
 - c) Lubricant condition (two pumps and compressor) oil sampling, particle detection, and analysis of oil samples
 - d) Temperature, fire, or smoke warning devices

All power station key assets in the boiler house, turbine house, ACC, FFP, auxiliary bay, and conveyor belt system are connected to a condition monitoring installation, and the maintenance department is able to apply the necessary monitoring techniques. Payback expectations will generally be exceeded because of the additional benefits from the reduction in consequential losses, production losses, and repair costs. The payback period is usually short, but it is extremely difficult to prove the connection between the new measures put in place and the losses that would have occurred had those measures not been put in place.

2.2.2.2.2 Cost benefits realised from planned maintenance

According to the proceedings of the EPRI (1996), it is widely recognised by maintenance people that maximum value in maintenance is generally obtained from a predictive maintenance programme. This would be much less expensive than, for example, letting the bearings run to failure, thus exacerbating the damage and the corrective maintenance cost. The power station is able to realise cost benefits as a result of having a good-quality planned maintenance programme in place.

Eskom uses maintenance effectiveness assessment, a blending review of existing preventive maintenance items, and the option of root cause analysis, through the sorting process resulting in a task that provides the maximum value. The process results in an optimised programme that includes

predictive and preventive tasks that are applicable and effective in preventing known failure modes. From the above-mentioned statement, it is clear that proper planned maintenance is likely to yield positive cost benefits and enhance the reputation of Eskom's power stations as reliable electricity-generating power stations.

Kelly and Harris (1978) hold that, in the simplest terms, profit is the difference between the income from the sale of the product and the costs of the manufacture and sale of the product. Costs can be classified as fixed (for example, the cost of raw materials) or variable, both used in the manufacturing of electricity as well as the sale of it. Profitability is influenced by many factors, such as customer demand, product price, equipment running costs, etc. Maintenance is related to profitability through equipment output and equipment running cost, meaning that with fewer disruptions to the equipment running and, as such, producing more electricity, more profit is realisable. According to Morrow (1966), any well-designed preventive maintenance is likely to yield positive benefits, which by far outweigh the actual cost of the maintenance itself. Nobody would argue against the benefits of such maintenance. Many men, Morrow argues further, he states that although several people had doubts before implementing the system but none thereafter. Wyder (1966) argues that the following are some of the major returns with which planned maintenance rewards its users:

- a) Less production downtime, with all its related savings and customer benefits, because of fewer breakdowns

- b) Less overtime pay for maintenance men on ordinary adjustments and repairs than for breakdown repairs
- c) Fewer large-scale repairs and fewer repetitive repairs – hence, less crowding of maintenance manpower and facilities
- d) Postponement or elimination of cash outlays for premature replacement of plant or equipment because of better conservation of assets and increased life expectancy
- e) Less standby equipment and fewer generators needed, thus reducing capital investment
- f) Identification of items with high maintenance costs, leading to investigation and correction of causes such as misapplication, operator abuse, and obsolescence
- g) Better spare-parts control, leading to minimum inventory
- h) Lower unit cost of manufacture

2.2.3 Routine work management

When generating electricity on a daily basis, it becomes routine work for the employees at power stations. It is very important to ensure that the equipment is used correctly, that is, doing the correct type of work for which the equipment is intended and that work is done in the right way and at the right times. The entire life cycle of the equipment should be considered when doing routine work, that is the lifespan and the scheduled maintenance on the equipment should also be considered.

By applying routine work management, the sustained cost-effective application of current asset management best practices is realisable, with the benefits being the support of long-term care and plant health. The Eskom Generation Manual (2007) defines routine work management as a combination of technical, administrative, and managerial actions aimed at ensuring that all work is properly identified, planned, scheduled, assigned, executed, and completed in pursuit of the work management objectives. This clearly simply requires proper planning and assessment before the work commences, so as to optimise production and sustain plant health.

The following objectives are outlined in the Eskom Maintenance Manual (2007) on routine work management:

- a) In order to be economically feasible, critical equipment failures should be greatly reduced in order to maximise power plant reliability.
- b) The maximisation of production by scheduling scarce resources very well. Routine work management forms the communication centre from which all maintenance activity is communicated and coordinated.
- c) Retention of employees as well as proper training is critical when carrying out routine work.
- d) A proactive approach to equipment reliability should be adopted, with critical failures analysed, tracked, and predicted and maintenance being carried out.

2.2.4 Outages

According to the section on outage management in the Eskom Generation Manual (2007), outages are predetermined repair/overhaul/maintenance endeavours undertaken during the project life cycle to ensure that the power station units have the capacity to produce electricity as per production plans. They are part of the preventive maintenance strategy. Since they can be planned long in advance, they have the potential to minimise disruptions of power supply by correcting defective equipment. Well-planned and -executed outages lead to shorter outages and improvement in the quality of work performed.

Effective outage management, according to the section on outage management in the Eskom Generation Manual (2007), plays an important role in the management of the life cycle of the equipment in the power stations. It is mainly concerned with a drastic reduction in outage durations and an increase in the duration between outages. The outage philosophy is based on the equipment manufacturers' recommendations in the operating manual, inspections, test plans, plant history, and statutory recommendations.

The power station outage philosophy is usually compiled by taking the following criteria into account (Eskom Generation Manual, 2007):

- Turbines and feed pumps are overhauled based on the running hours and number of start-ups.
- Boilers and high-pressure pipe work are mainly overhauled based on findings made during inspections and tests.
- The balance of the work on the power stations, that is, electrical, control and instrumentation, filter fabric plants, and auxiliary plants, is done to suit the outage philosophy of the turbine and boiler plant.

2.2.5 Strategic spares

Strategic spares are long lead items that are critical in case of breakdown, and it is of the utmost importance to ensure that they are available and in stock. The section on the management and reporting of strategic spares in the Eskom Generation Manual (2008), states that due to the unprecedented depletion rate of the generating reserve margin, the effect of unplanned generating plant outages has become more pronounced. Furthermore, generating units are required to operate at high load factors, leading to adverse component degradation and unpredicted failure rates. The fact that the majority of the power station key plants have either passed or reached the mid-life of their original design life means that preventive maintenance must be in full operation in order to avoid plant and equipment failure. Strategic spares need to be well managed to minimise the lead time it could take to replace a part. Some critical equipment has a very long lead time, meaning that, by the time preventive maintenance must be done; there

should be spares available in storage. Correct spares should be purchased and should be well maintained. Power stations should not wait for the breakdown to occur before attempting to purchase critical parts.

Some of the original parts are difficult to get due to some manufacturers no longer being in existence or parts no longer being manufactured; hence, it is important to plan for substitutions for such parts or components. This implies that such components or parts are usually not bought off the shelf.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Rationale for proposed method

The method and material used in this study are suitable for fulfilling the specific objectives of the study. The primary focus of the study is to assess the effectiveness of the preventive maintenance being used by Eskom on its generating plants and the extent to which it enhances plant reliability and security of supply. In this study, an attempt is made to shed light on what the current situation is like in terms of the maintenance philosophy being employed in keeping plant healthy.

Both qualitative and quantitative methods were used to gather information from maintenance and operational personnel of various power stations. Quantitative data was gathered by way of administering a structured questionnaire. The questionnaire used data collection that was pre-tested by removing all subjectivity prior to use. Qualitative data was also gathered in order to acquire information which was used to support the research. The principal data-gathering instrument used in the study was a structured questionnaire. At each power plant selected for study, the questionnaire was administered by a trained interviewer, whose main objective was to gather facts without misleading the interviewees. In addition to the questionnaire,

personal interviews using a tape recorder were conducted to collect data from each respondent who took part in the study.

There is no single method of data collection that is flawless. In this study, questionnaires and personal interviews were used for data collection. Since cost is an issue when doing research, personal interviews enable the process to be much faster, thereby cutting the overall cost of the study. Another advantage of conducting interviews is that guidance and clarification are usually offered as and when required by the participants, but it is critical to guard against bias when offering such guidance.

Since the questionnaires designed are the same for all the participants, the advantage is that all participants are exposed to the same questions. Each participant is expected to have a fairly good understanding of what research entails in order to make a meaningful contribution.

Both ordinal variables, such as gender (both males and females are employed on the plant), and nominal variables, such as understanding of maintenance (strongly agree, agree, not sure, disagree, strongly disagree), have been used for the study. With ordinal variables, the order does not matter, but with nominal variables, the order does matter. Included in the list of variables are indicators of preventive maintenance and whether it is followed, as well as the benefits resulting from such maintenance. The variables also include the planning of maintenance, decisions taken when

planning for such maintenance, and the overall sustainability of the maintenance in power stations.

3.2 Selecting the population and size

The population was selected based on geographical boundaries, that is, the Limpopo (Northern) and Mpumalanga (Eastern) provinces. The research was confined to load-based coal-fired power stations. Power stations were then grouped into clusters in terms of their performance and reliability – hence, the choice power plants with a similar type of operation. The choice of this population resulted from the fact that the Mpumalanga province had 71.43% of the available power stations and the Limpopo province 7.14% (Eskom, 2010).

They were further grouped into different age categories, that is, those built around the 1950s to 1960s and those built around the 1970s to 1980s. This assisted in analysing the performance plant health and performance output of older power stations in comparison to relatively newer power stations.

3.3 Sample selection

Polit et al. (2001:234) define a sample as a proportion of a population. The sample was chosen from employees at four power stations who were permanently employed at various levels. The researcher worked in

conjunction with power station management in choosing participants based on their level of experience in the operating and maintenance of power plants as well as their qualifications. There were 30 potential participants, of whom 24 participated in the study. From Majuba Power Station, three managers from Technical Support, Turbine, and Maintenance participated in the study. At the supervisory level, two employees from the Boiler and the Control and Instrumentation Sections took part in the study. There were also one planner responsible for scheduling, one maintenance technician from Maintenance, and one system engineer for Outside Plant. At Grootvlei Power Station, six employees out of 10 employees who had been sent the questionnaires participated in the study. The maintenance manager, two senior engineers from Electrical and Turbine, one maintenance support manager, and two supervisors from the Electrical Department participated in the study.

At Matimba Power Station, 14 questionnaires were sent out, and six people responded. Of the six, there were a mechanical maintenance manager, an operational manager, a maintenance planner, two supervisors from Auxiliary Plant, and a senior operator. At Hendrina Power Station, scheduled maintenance of two units was in progress; therefore, it was impossible to get the full response of the participants who had been sent questionnaires. Of the 12 participants, only four responded. These participants were the auxiliary manager, maintenance planner, auxiliary supervisor, and turbine supervisor.

Some of the employees were not available, as they were involved in outages, were involved in training, or were off sick, while others did not feel comfortable participating in the study.

3.4 Sampling procedure

Sampling of the participants was done as follows:

- The researcher was assisted by power station management in identifying potential participants.
- The employees who participated were pre-selected, and the research study was sent and explained to all potential participants.

3.5 Data collection technique

Systematic random sampling was used for selecting eligible personnel within the Eskom Generation business. Eligibility of the participants was determined based on their willingness to voluntarily take part in the study, their overall knowledge of the power plant in relation to their area of trade, and their willingness to provide accurate information and records to the interviewer. This technique was found to be suitable for carrying out the study, as I was able to meet face to face with the participants in their natural working environment. Through personal interviews, it was possible to explain and repeat questions on which respondents sought clarity. A suitable venue was selected to ensure that there was no interference. Of the 40

questionnaires issued, 24 were returned. During the interviews, a tape recorder was used to capture the participants' responses. The questionnaires were sent out to respondents before the actual interviews and were sent back to the researcher on the day of the interview. All of the personnel who were interviewed were sent the questionnaires.

3.6 Treatment of bias

The interviews were conducted at the interviewees' power station offices, which was conducive for this purpose. Each interview ranged from one to two hours. The conversation between the parties was tape-recorded and later transcribed. The questionnaire was structured in an open-ended way in order to avoid "Yes" and "No" answers. In order to validate the interview, all the responses from the interviewees were sent to them so that they could read and confirm that what was written down was representative of the discussion. Since the interviews were conducted in English, there was no need for the researcher to translate the questionnaire into the participants' mother tongue. Efforts were made to ensure that the interviewees' responses were as discreet as possible, so as to eliminate the researcher's subjective opinion on the 24 interviews conducted.

3.7 The research experience

The interviews were conducted over a period of two months. Since the researcher had a full-time job, the interviews happened intermittently rather than on a continuous basis. In setting up the appointments for interviews, some challenges were experienced in accessing interviewees. Appointments were set up telephonically and confirmed through e-mails. On the day of the scheduled interviews, the researcher would arrive, only to find that some respondents did not turn up. On finding out that this exercise was for academic purposes as opposed to Eskom's business requirements, some respondents were reluctant to participate. Since the project had two ways of acquiring data, the structured questionnaire and the face-to-face interviews, the latter was a more effective means of acquiring the data needed.

CHAPTER 4: DATA ANALYSIS AND INTERPRETATION

4.1 Data presentation

Data is presented in a simple, logical, and systematically tabulated manner from the research findings.

4.2 Findings and their analysis

4.2.1 Analysis of the interviewee responses

4.2.1.1 Analysis of Majuba respondents

Majuba is one of the flagship baseload power stations within the Eskom group, which was the last to be built. Majuba Power Station uses the Eskom Generation maintenance strategy, which is based on a preventive maintenance schedule for each of the different identified plants. Maintenance department uses a work management system to prioritise work into low, medium, and high priority. Defects that are Priority 1 in terms of the schedule are high level and cannot be ignored. Defects classified as Priority 1 cannot be deferred and should be addressed within 24 hours. Priority 2 defects have to be attended to within 72 hours because the Management of the station believes that this type of work has the potential for load losses

and health and safety risk. Through the work management system, the maintenance people and the operating teams are able to view the history of the plant and the trouble areas. There are structured meetings such as scheduling and cross-functional meetings where each department or line function offers feedback in relation to the performance of individual sections of its plants. There are a number of reports taken from the leading matrices in Workweek Management, and this is done on a daily basis. There are weekly reports on schedule compliance and reports on aging work orders and safety and statutory violations. The significance of the leading matrices process is to ensure notification to monitor planning work orders on turnaround, which shows how people are reacting to defects and closing time.

Majuba embraces a proactive maintenance strategy, according to which the need to uphold the units on hold does not compromise the criticality of ensuring regular maintenance of different plant components. This gives Majuba an opportunity for being 95% to 100% on load. Scheduled outages as given by the Eskom maintenance system are an added bonus on its part, as it is able to overhaul identified plants. The Majuba Power Station relies on keeping optimal critical spares to ensure an effective maintenance programme. In order to avoid over- or under maintenance, the philosophy applied at Majuba is that, for critical spares to be referred to as 100%, it means that one should be running and the other should be on standby. Majuba also uses the critical spares principle where, if you run the

component 3 x 50%, you need two to run at a time at a full load with one serving as a spare part, and if one breaks, then you have one on standby. These enable the maintenance team to be able to carry out maintenance in the event of breakage..

One of the critical issues affecting plant performance is related to inadequate training of personnel who are equipped to take decisions on when, where, and how to maintain or inspect the plant. Job hopping on the career path of young employees creates a problem because they do not stay in one post for long enough period to be capacitated and make them experts in their respective fields. Another reason is that, with Majuba being in a remote rural town, it does not attract a highly skilled pool of mobile employees. This creates a problem because, if you have employees who lack plant understanding with regard to operating the plant within the design parameters, then you will always be faced with unnecessary challenges related to plant failure.

4.2.1.2 Analysis of Grootvlei respondents

Grootvlei, unlike Majuba, is an old moth-balled power station, which was returned to service in 2009. The philosophy used when returning Grootvlei to service was to refurbish the existing equipment rather than to overhaul the entire power station. This had an effect on the reliability of the plant.

Most of the respondents felt that some of the plant components, even though they had been refurbished, constantly need to be maintained hence compromising performance of the plant. For the six month period between September and February every year, unit performance in line with the Eskom Generation Performance Index is reviewed, and boiler tube leaks contributed 80% of the unit losses.

Just as at Majuba (as at all Eskom Generation power stations in the same format), there are structured meetings such as scheduling and cross-functional meetings. The performance of plant is monitored through the computer system in the control room. Even though there are planned maintenance and prioritisation of the scheduled work, there is constant unreliability of the units as a result of refurbished components.

Similarly to Majuba, there is Workweek Management system, which assists in diagnosing plant conditions. Due to constant breakages, management of critical spares becomes almost impossible, and this has a bearing on reliability of the plant to be on load.

Most of the time, inadequate investigations are done to determine the root cause of plant failure. When the root cause is not identified correctly, the mitigating strategy becomes incorrect, and the failure will be repeated, which leads to compounding of the problem of the plant components.

4.2.1.3 Analysis of Matimba respondents

Matimba, just like Majuba Power Station, is the last in the fleet of power stations built in the late 1990s, with more capacity than previously build power stations. Matimba maintenance is based on planned maintenance, which is linked to the SAP system, in which it is possible to prioritise maintenance requirements for each plant. Reports are drawn weekly, monthly, quarterly, biannually, and yearly to assess plant health. Preventive maintenance reports are reviewed on an ad hoc basis, even though the management of the power station would like to review them on a yearly basis as it is likely to detect probable maintenance related problems and thereby recommending mitigating strategies. Based on the reviews from the power station personnel, planned maintenance that is still applicable is left, and that not required is revised. Generally, Matimba does not review much of the planned maintenance frequently, which is a sign that the station is quite happy with the present maintenance strategy.

Like all other power stations within the Eskom group, Matimba uses the maintenance principles of Workweek Management. Available resources are considered per section of work to be maintained, which also has duration. Added to the resources, availability of spares is considered. Criticality of the plant cannot be overemphasised.

Planned maintenance is categorised into corrective and condition-based maintenance. Corrective maintenance comes from actual breakdowns. Condition-based maintenance is done as a result of plant walks. For example, if vibration is identified as having a detrimental effect, then a plan is made to correct the prevailing condition. Due to the fact that Matimba is a relatively new power station, maintenance of boiler's and turbines are scheduled only once every six years.

Like all other power stations, Matimba uses weekly meetings as one of its strategic tools, while daily meetings are for plant-related topics. Matimba's projection is that it will never be satisfied with the way the system works, but would like to have continuous improvement of between 80% and 100% of its jobs being planned maintenance and as low as less than 20% of its jobs being breakdowns. Matimba believes that Workweek Management is a tool that will assist in getting the power station to record less than 20% and will lead to improved quality assurance. It is also looking into improving condition monitoring.

Matimba is able to maintain its competitiveness as a leading and reliable power plant within the Eskom group and is able to run the station with minimum power interruption. An added advantage of Matimba is that it is able to retain competent personnel, as a result of the manner in which employee career development is looked at as well as management incentives to their personnel, and as such, there is always continuity in terms of the

skills of the plant personnel. The area where it is located has quality coal, and that enhances the station's performance.

4.2.1.4 Analysis of Hendrina respondents

Hendrina is one of the oldest power stations within the Eskom group undergoing a capacity increment. Its strategy, as with the other power stations, is that it believes in having condition-based and preventive maintenance. Through the SAP system, information is drawn on a daily, weekly, monthly, biannual, and yearly basis to help assess the health conditions of the plant. The report being drawn depends on the nature of the failure. The defects are put against a particular department in the SAP system. That particular department has to fix the defect in terms of the Eskom Generation maintenance defect matrix.

The challenge that Hendrina faces as an old power station is that it is sometimes very difficult when doing maintenance to have a history of previous maintenance carried out on a particular plant before carrying out a particular activity. The dilemma is that there is no history in certain situations, with no detailed drawings, specifications, and operating manuals. In most cases where critical spares are concerned, Hendrina depends on nearby power stations of a similar age and design. Most of Hendrina's plant is old, and in case of the need for maintenance, some spares are obsolete.

The reliability of the Hendrina Power Station is compounded by flooding of the sumps. This is a frequent problem affecting plant reliability, which is why Hendrina has decided to explore the issue of submersible sumps as opposed to pedestal sumps.

The main contributing factor compounding plant reliability is related to poor-quality coal that affects the mills, which results in repeated breakdowns of the mills. Another contributing factor is that the coal Hendrina receives has too much moisture content, which this leads to tripping of the mills. Soot blowers are used to clean the boilers when the tubes are clotted with ash to maximise the heat transfer rate. In most cases, the operators fail to determine when the boilers need to be cleaned, and this contributes to operating parameters not being adhered to in order to determine when the boilers need to be cleaned. See Figure 1, which shows the boiler tube leak station trends for the financial years 2007 to 2010.

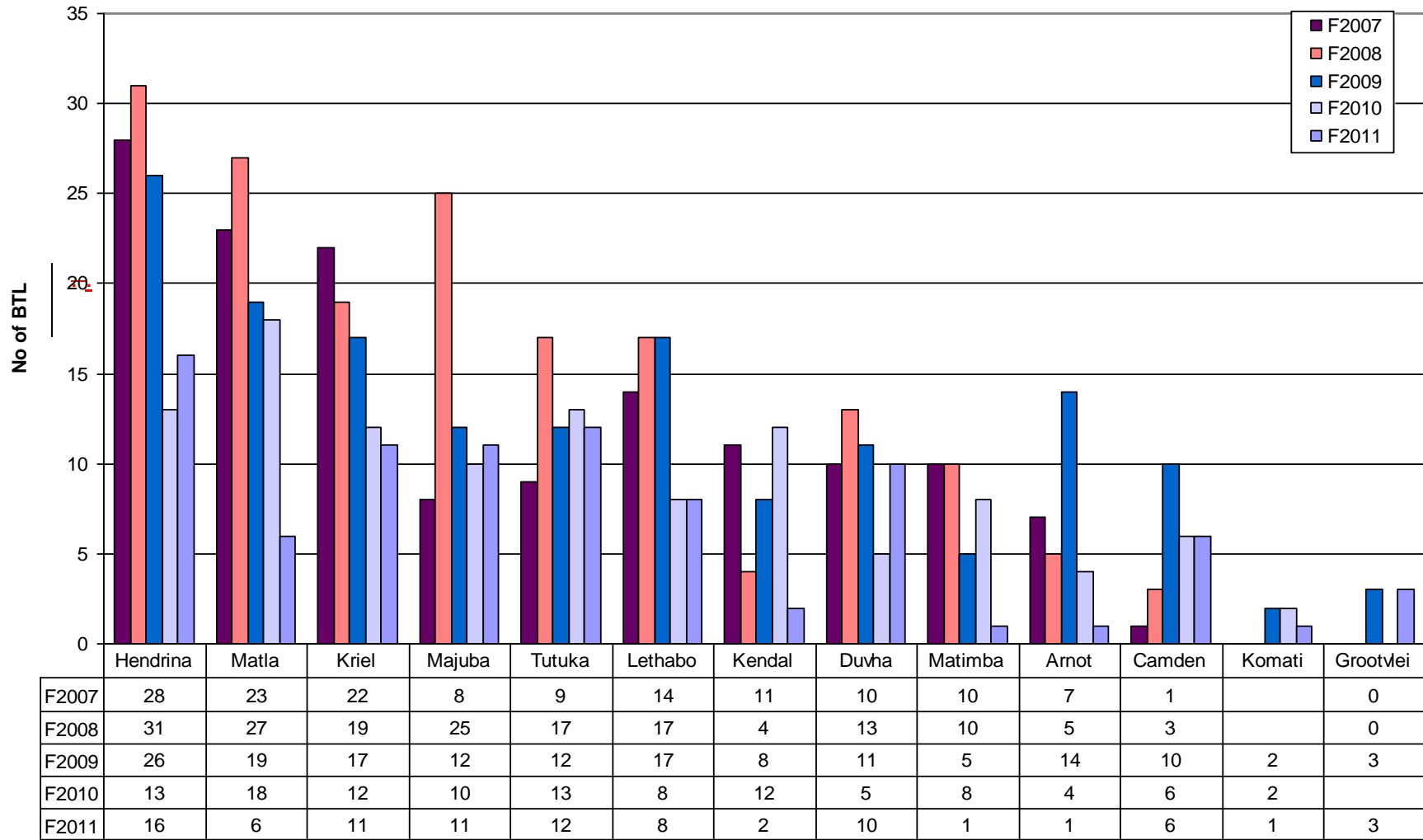


Figure 1: Boiler tube leak station trends (F2007-F2011 YTD 2011)

4.3 . The questionnaire was aimed at addressing the following

- The general understanding of what maintenance entails in terms of competitiveness of each generating unit within Eskom
- The sustainability and effectiveness of maintenance in Generation power stations
- Management’s and employees’ perceptions of the maintenance strategy being used in Eskom power stations

The results for each question in the questionnaire are shown in a separate table, as seen below.

Table 2: Understanding maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Maintenance refers to the plant running smoothly without stoppages	11	9	1	1	2
Frequency	11	9	1	1	2
Percentage	45.83%	37.50%	4.17%	4.17%	8.33%

Table 3: Asset management as part of maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Asset management is part of maintenance	9	13	2	0	0
Frequency	9	13	2	0	0
Percentage	37.50%	54.17%	8.33%	0%	0%

Table 4: Routine work management as part of maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Routine work management is part of maintenance	12	11	0	1	0
Frequency	12	11	0	1	0
Percentage	50%	45.83%	0%	4.17%	0%

Table 5: Outages as part of maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Outages are part of maintenance	15	7	1	1	0
Frequency	15	7	1	1	0
Percentage	62.5%	29.17%	4.17%	4.17%	0%

Table 6: Preventive maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Preventive maintenance is the most desired type of maintenance	17	6	1	0	0
Frequency	17	6	1	0	0
Percentage	70.83%	25%	4.17%	0%	0%

Table 7: Condition-based maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Condition-based maintenance forms part of the daily operation of the plant	8	14	2	0	0
Frequency	8	14	2	0	0
Percentage	33.33%	58.33%	8.33%	0%	0%

Table 8: Decision-making on strategic spares

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Decision-making on strategic spares does not include principles of maintenance	1	2	8	7	6
Frequency	1	2	8	7	6
Percentage	4.17%	8.33%	33.33%	27.17%	25%

Table 9: Meaning of maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Maintenance means that the overall cost of electricity will be reduced	5	11	2	4	2
Frequency	5	11	2	4	2
Percentage	20.83%	45.83%	8.33%	16.67%	8.33%

Table 10: Maintenance and profit

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
When thinking about maintenance, it is important to think about making a profit for Eskom and not to think about the electricity cost to consumers	3	7	2	11	1
Frequency	3	7	2	11	1
Percentage	12.50%	29.17%	8.33%	45.83%	4.17%

Table 11: Decision-making related to maintenance

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
The employees of power stations are involved in making decisions on maintenance	4	12	3	3	2
Frequency	4	12	3	3	2
Percentage	16.67%	50.00%	12.50%	12.50%	8.33%

Table 12: Meaning of effectiveness of planned maintenance

What do you think is the meaning of effectiveness of planned maintenance in power stations?
Out of the sample of 24 respondents, seven held the view that effective maintenance was based on reliability, reduction in emergent work, and less disruption in production.
Four respondents believed that effective maintenance entailed saving money and that resources were run sustainably.

Table 13: Preventive and condition-based principles

Does power station maintenance incorporate preventive and condition-based principles?	Yes	No	Don't know
Frequency	18	3	3
Percentage	75.00%	12.50%	12.50%

Table 14: Meaning of planned maintenance

Planned maintenance means that different units, that is, boilers, turbines, etc., plan their maintenance separately, with each unit presenting its plans at the strategic planning meetings	Yes	No	Don't know
Frequency	14	8	2
Percentage	58.33%	33.33	8.33%

Table 15: Planned maintenance and budgeting

Decision-makers consider the planned maintenance principles when drawing up the short-, medium-, and long-term budgets and overall plans for power stations	Yes	No	Don't know
Frequency	21	1	2
Percentage	87.50%	4.17%	8.33%

Table 16: End-users' involvement in planned maintenance

The end-users are involved in decision-making on planned maintenance	Yes	No	Don't know
Frequency	14	9	1
Percentage	58.33%	37.50%	4.17%

Table 17(a): Implementation of planned maintenance principles in previous projects

Taking the projects that Eskom successfully implemented in 2008, how were the principles of planned maintenance incorporated in the planning of these projects?
The respondents were non-committal on the status of the projects carried out in each power station.

Table 17(b): Execution of planned maintenance principles in previous projects

Taking the projects that Eskom successfully implemented in 2008, how were the principles of planned maintenance incorporated in the actual execution of the projects?
No information was provided by the respondents to clarify the above in response to the question asked in Table 17(a).

Table 18: Parties responsible for implementation of planned maintenance

Who, within the various power stations, is responsible for implementation of planned maintenance?
Maintenance manager = 6 Engineering = 3 Production = 2 Work management = 3

Table 19: Sustainability of planned maintenance principles

Are the principles of planned maintenance approved because of their sustainability?	Yes	No	Don't know
Frequency	16	1	7
Percentage	66.67%	4.17%	29.17%

Table 20: Sustainability of planned maintenance principles in relation to load-shedding

Please explain your answer in 19 above.
All respondents believed that they did not want to experience load-shedding.

Table 21: Monitoring of implementation of planned maintenance

Is there any monitoring of the implementation of planned maintenance within Eskom's power stations?	Yes	No	Don't know
Frequency	18	1	5
Percentage	75.00%	4.17%	20.83%

Table 22: Peer review mechanism, competency matrix, and centralised monitoring mechanism

If "Yes" or "No" to 21 above, please explain how it is done.
There is a peer review mechanism and competency matrix = 3
There is a centralised monitoring mechanism = 6

Table 23: Effectiveness of planned maintenance

Is Eskom concerned with the effectiveness of planned maintenance in power stations?	Yes	No	Don't know
Frequency	17	5	2
Percentage	70.83%	20.83%	8.33%

Table 24: Financial constraints related to planned maintenance

Is there any planned maintenance that is deferred due to financial constraints?	Yes	No	Don't know
Frequency	10	7	7
Percentage	41.66%	29.17%	29.17%

Table 25: Strategies employed by Eskom

Explain the strategies employed by Eskom in ensuring that planned maintenance is sustainable.
All respondents believed that there was a time schedule given to each power station to shut down and engage in overhaul without compromising power supply.

Table 26: Employees' participation in planned maintenance

How do various levels of employees, that is, skilled, semi-skilled, and managerial, participate in planned maintenance decision-making?
There are daily meetings, weekly meetings, and monthly meetings, and these are shared by all respondents.

Table 27: Programmes empowering employees

What kinds of programmes must Eskom implement that will empower employees to participate in making decisions pertaining to planned maintenance?
All respondents believed that information-sharing sessions were the tool they used.

Table 28: Monitoring of planned maintenance

Is progress towards the implementation of planned maintenance monitored?	Yes	No	Don't know
Frequency	14	5	5
Percentage	58.33%	20.83%	20.83%

Table 29: Progress reports on various activities

If "Yes", how?
The progress reports on various activities carried out. Management tracked the progress by looking at the maintenance programme, and this was a view shared by all.

Table 30: Indicators of planned maintenance

Are the indicators of planned maintenance available within the Eskom group?	Yes	No	Don't know
Frequency	16	4	4
Percentage	66.67%	16.67%	16.67%

Table 31: Reporting on planned maintenance progress

How is the progress towards the implementation of planned maintenance reported?
All respondents shared the same sentiment that reporting was done at daily production meetings.

Table 32: Information sharing with end-users on planned maintenance and benefits emanating from that

Are the end-users informed about progress pertaining to planned maintenance and any benefits emanating from that?	Yes	No	Don't know
Frequency	10	5	9
Percentage	41.67%	20.83%	37.50%

Table 33: Constraints Eskom has in implementing planned maintenance

What constraints does Eskom have in implementing planned maintenance?
All respondents believed that resources were constraints.

Table 34: Types of constraints experienced within Eskom power plants

Please explain the constraints with reference to Question 33.
Understaffed business units, financial constraints, and the tight margin of electricity supply.

In general, there seemed to be agreement among the respondents that preventive and condition-based maintenance was integral to the uninterrupted supply of electricity. There was also a general understanding of the different aspects and principles comprising planned maintenance.

The majority of the respondents were in the age group 40 to 49 years, with work experience of over 15 years.

CHAPTER 5: THE CHALLENGE TO UPHOLD THE BEST MAINTENANCE PRACTICE AGAINST THE PREVAILING AGEING PLANTS AND THE TIGHT MARGINS OF SUPPLY

Eskom was anticipating adding more power to the grid as a result of the three return-to-service power stations and the new build programme to relieve hard-pressed existing power plants. Since the intended addition of more power is unlikely to be realised before 2013, the increasing demand for more power will not be met, and this poses a critical challenge to the availability of much-needed electricity.

This brings the correlation between upholding a healthy plant and sustaining envisaged and planned maintenance to the centre of this discussion. Dhillon (2002) shares the view that preventive maintenance usually accounts for a major proportion of the total maintenance effort. Preventive maintenance may be described as the care and servicing by individuals involved in maintenance to keep the facilities in a satisfactory operational state by providing systematic inspection, detection, and correction of incipient failures prior to their development into major failures.

A high-performing power station such as Matimba has moved beyond the norm of reviewing its preventive maintenance report on a yearly basis and actually reviews its preventive maintenance report on an ad hoc basis. This gives it an added advantage in terms of identifying problematic areas and also minimises the cost of carrying out unplanned maintenance.

Since Majuba and Matimba are not as old as the other two power stations, personnel from Engineering, Maintenance, and Operating are able to access the historical data relative to each plant, which is unlikely with the older power plants. Personnel interviewed at all power stations identified a certain deficiency with regard to the unavailability of historical data related to the plant. In most cases, there are no drawings and procedures in place. This creates a problematic vacuum for the Engineering, Maintenance, and Operating personnel.

There is a gap between the new recruits and the personnel who are about to exit in terms of old age. There is also high staff turnover, which has a detrimental effect in terms of maintenance and operational skills.

Time-based and preventive maintenance are catered for in the Workweek Management programme. This programme serves as a tool to ensure that Eskom operates in line with best practices. As with any other management system, there will be problems that will occur from time to time within the power stations. When the problems arise, they must be investigated and

analysed, and adjustments must be made to ensure that the system yields the desired results. Where this is the norm, maintenance will be effective. With such effective maintenance in place, plants that were built in the early 1980s will not perform better than older generating plants that were built in the early 1970s.

Maintenance cost comparison amongst various base load power stations:

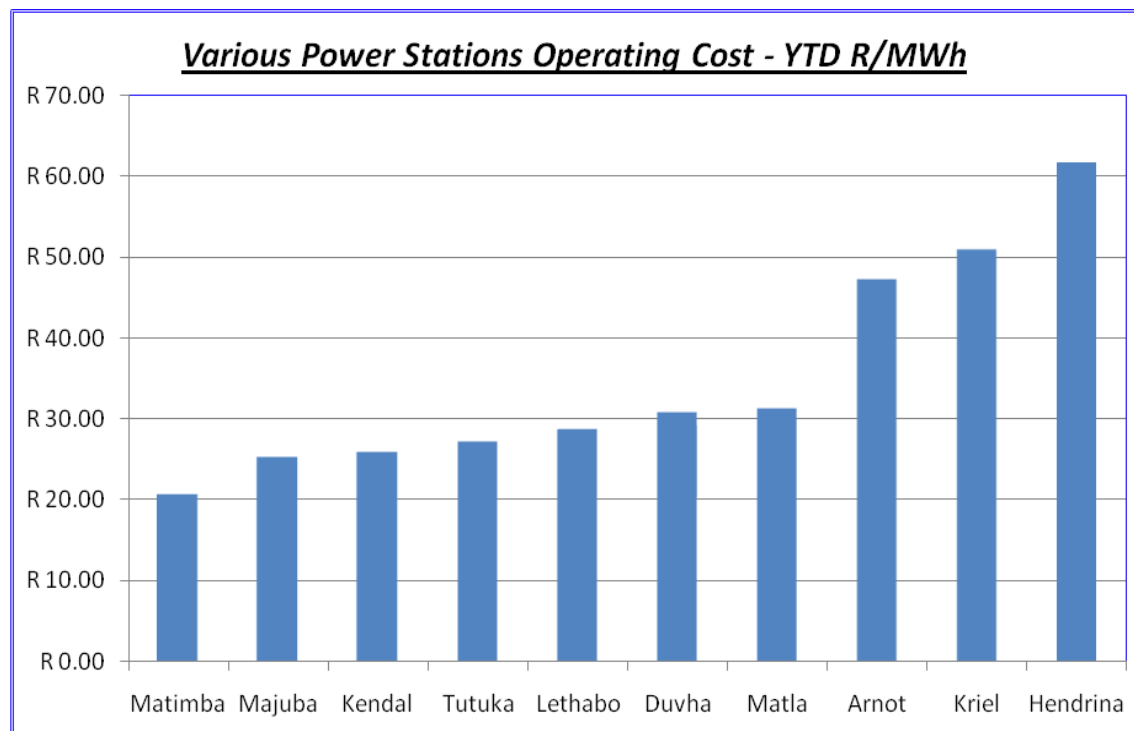


Figure 2: Various power stations – operating cost in relation to Rands per Megawatt hour – YTD R/MWh

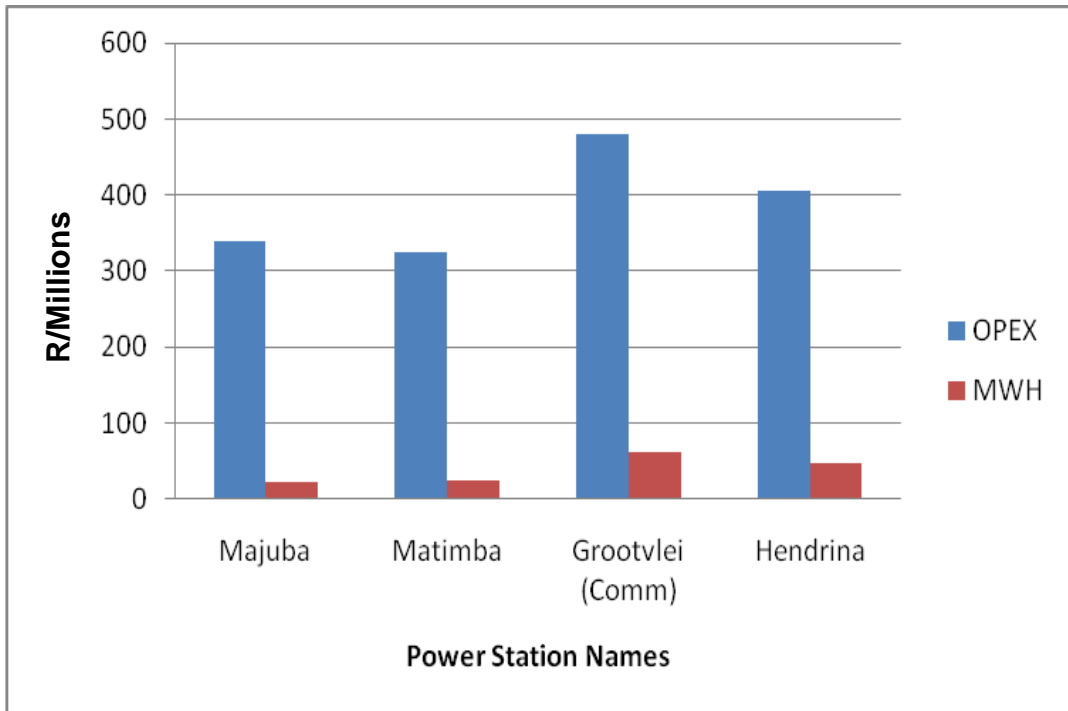


Figure 3: Various power stations – operating cost in relation to annual actuals

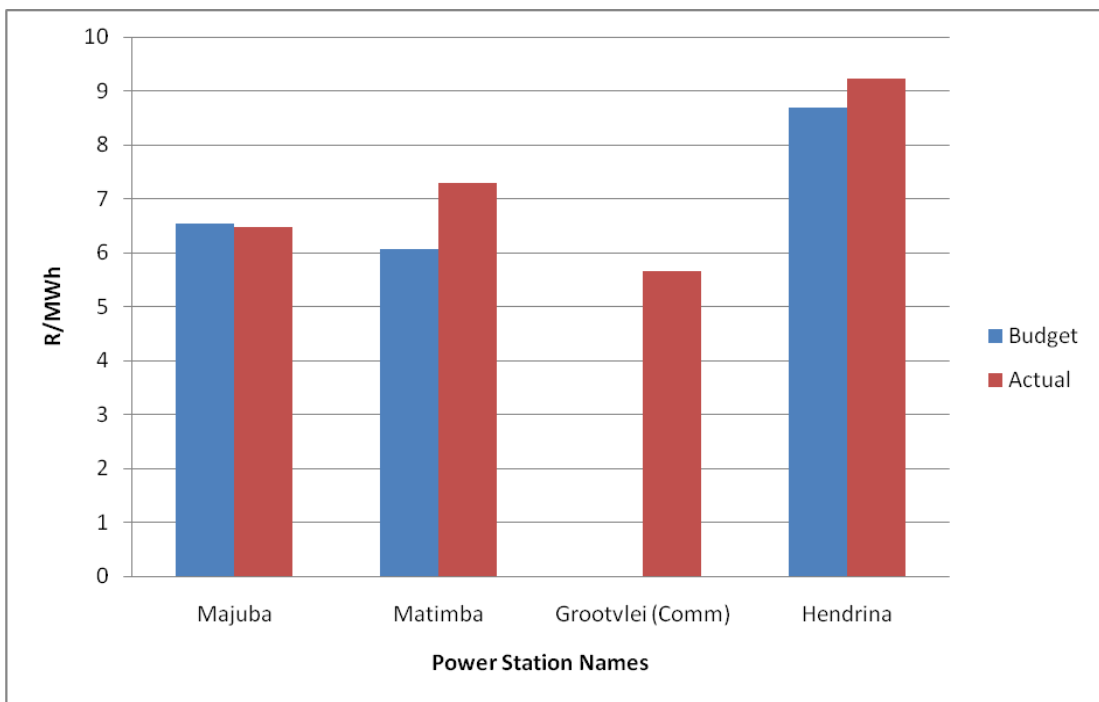


Figure 4: Planned budget MWh versus actual budget MWh

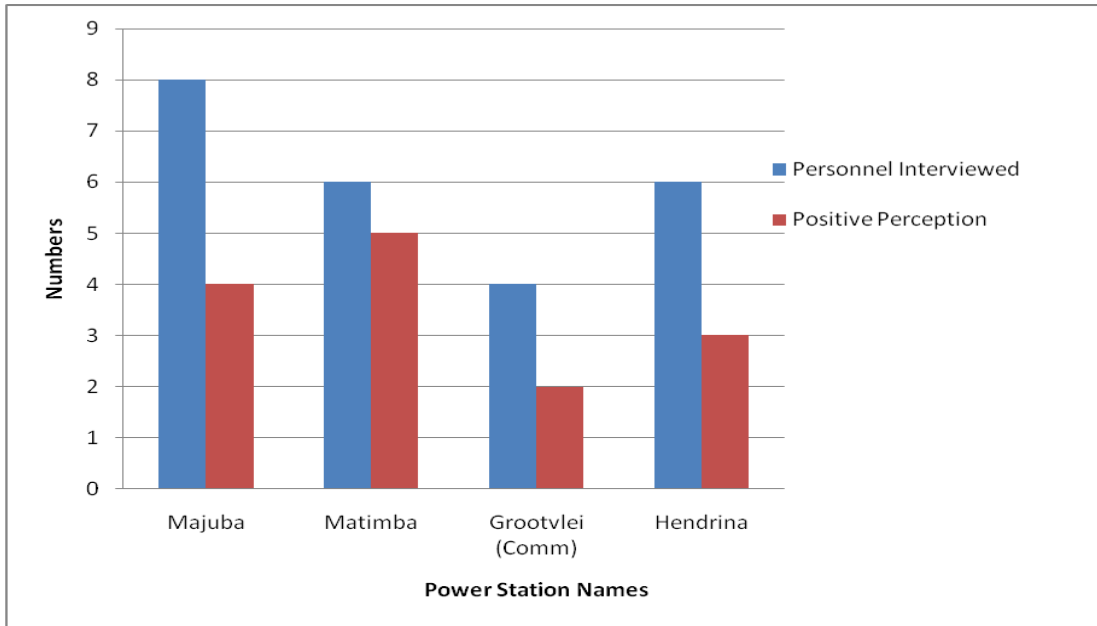


Figure 5: Perception of the existence of planned maintenance by the personnel interviewed

Percentage comparison of maintenance and operating cost of various baseload power stations of the overall budget for the entire Eskom group:

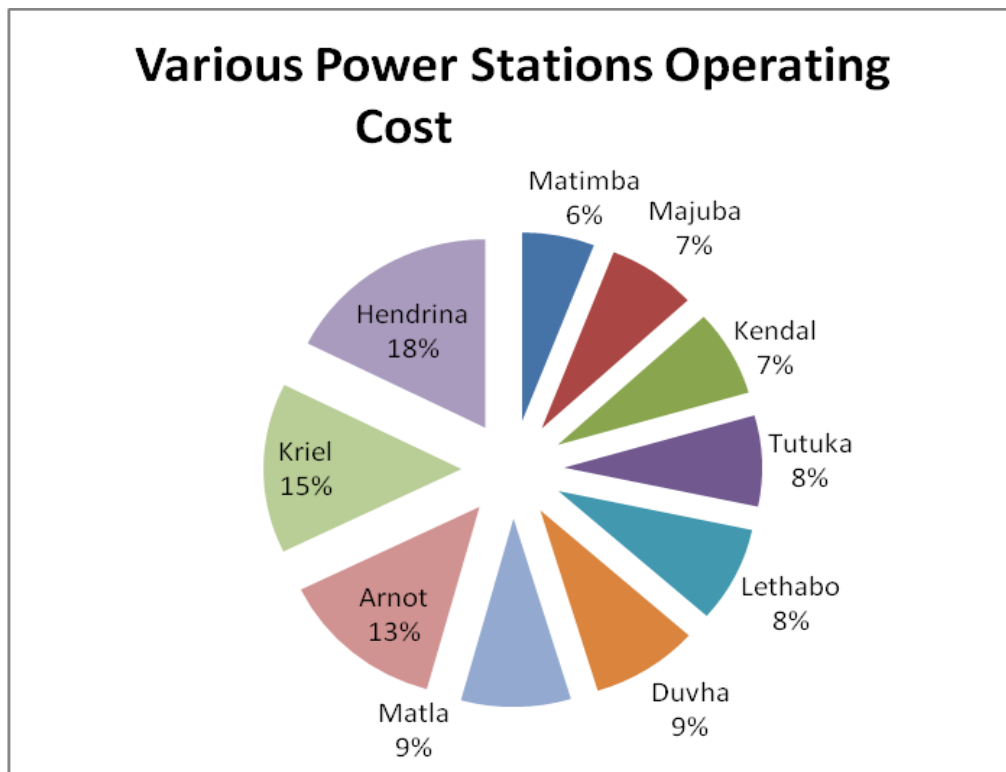


Figure 6: Various power stations – operating cost as percentage of the total power station operating cost

Percentage comparison of operating cost of various baseload power stations for the entire Eskom group:

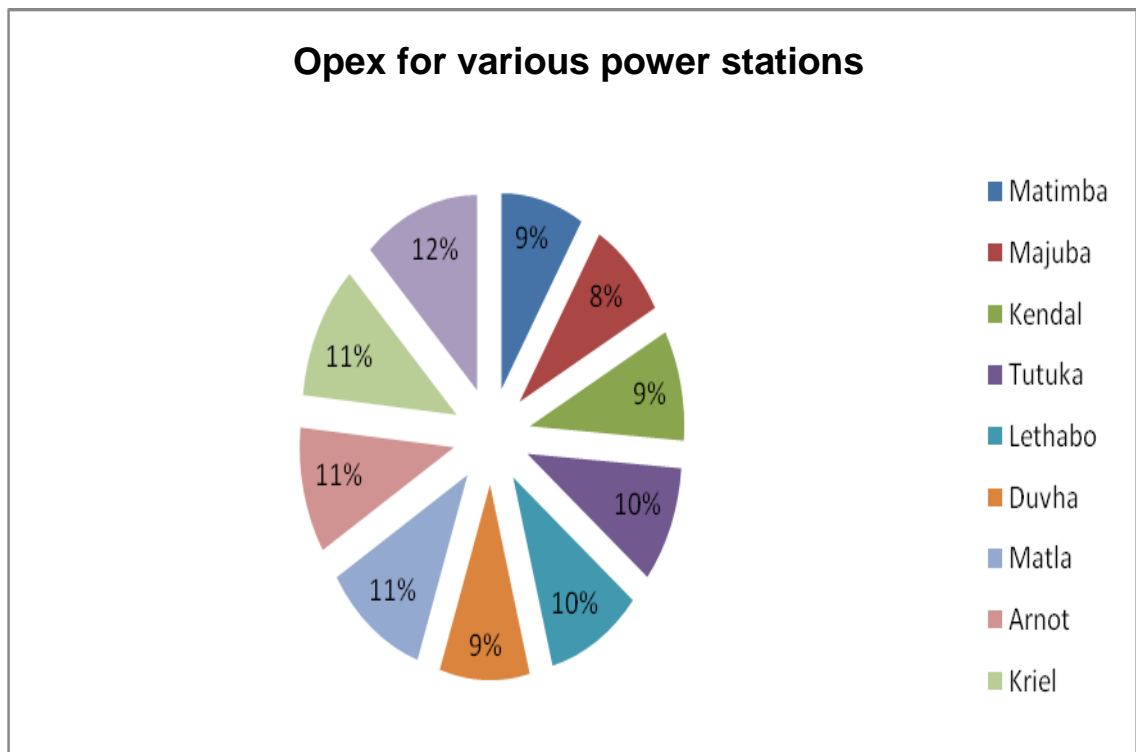


Figure 7: Operational expenditure (opex) of various power stations as percentage of the overall power station budget

Percentage contribution in megawatt-hour (MWh) output among various baseload power stations of the overall megawatt-hour for the entire Eskom group:

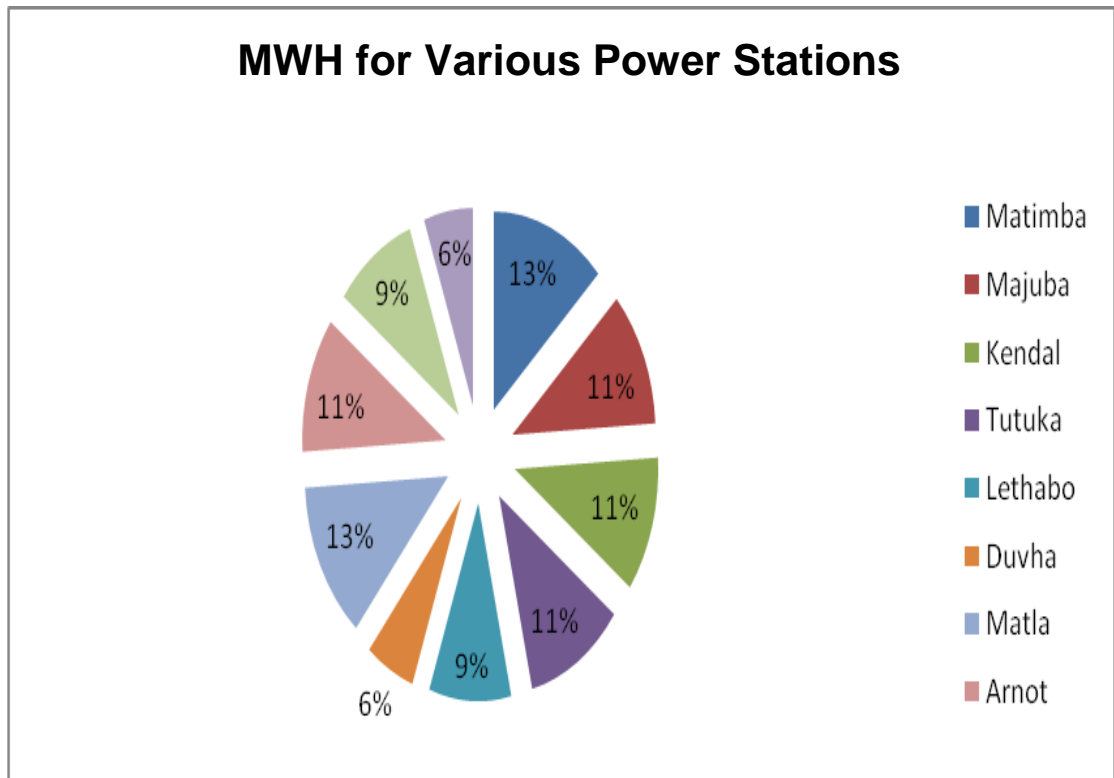


Figure 8: MWh for various power stations as percentage of the overall MWh

5.1 Correlation between cost and planned maintenance

Our study was focused on a few selected power stations. In Figure 6, total operating costs are depicted. Out of the eight people interviewed at Majuba Power Station, four had a strong belief that planned maintenance was followed, which constituted 50% of the personnel interviewed, while the other 50% were either uncertain or felt that there was no effective planned maintenance. For Majuba, being one of the last coal power stations built by Eskom in the late 1990s, 7% of the overall Eskom budget on operating cost is high when compared to Matimba in relation to its age. Matimba's last unit was commissioned around 1992, while Majuba's last unit was commissioned around 2002, meaning that Matimba has been in operation longer than Majuba, and as a new power station, its operational cost is expected to be relatively lower. This correlates with the perception of employees interviewed at Majuba Power Station: 50% of them were uncertain regarding maintenance activities taking place. With 50% of the employees being uncertain of maintenance activities taking place at Majuba Power Station, this correlates with the high operational costs as seen at the power station.

At Matimba Power Station, 83% (five of the six respondents) interviewed believes that Matimba had an effective planned maintenance programme, which was reflected in the lowest operating business cost per unit within Eskom Generation (6% of the overall annual budget).

Both Hendrina and Grootvlei are old power plants. At Hendrina, two out of four people interviewed held the view that there was preventive maintenance, but the criticality was as a result of the aging plant – hence, the lack of strategic spares, which gave the high percentage of 18% of the operating costs. With Grootvlei being one of the recently refurbished power plants, three out of six respondents held the view that preventive maintenance was not applied enough, as it could have reduced the operating cost due to the recently refurbished power plant. Hence, 30% felt that it could be as a result of the original parts being obsolete, while 20% believed that lack of skill was a contributing factor.

5.2 Summary of results

Some of the maintenance problems and reliability of the plants may be compounded by the poor coal quality. For example, most of the time, the percentage of rock in the coal content is as high as 70% and has a detrimental effect on the lifespan of the mills.

In the course of this research, it has been shown that all power stations have a common maintenance strategy based on condition-based and preventive maintenance. For Eskom to be one of the leading power utilities globally, it has to adopt the best global practice to ensure that it is in line with its peers in terms of maintenance. To become more competitive, it has to distinguish itself through its maintenance strategy and innovative ways of improving

plant reliability and security of supply to meet its mandate. There is a common belief at all power stations that the purpose of planned maintenance is to ensure reliability and reduction of operating costs.

5.3 Testing of hypotheses

5.3.1 The first hypothesis

Is there a positive relationship between planned maintenance and high performance and reliability of power station plants in South Africa?

For the purposes of analysis, the four power stations are first looked at together and then divided into two subgroups: Majuba-Matimba and Hendrina-Grootvlei. The data showed that the relationship between planned maintenance and the high performance of power stations was not a strict one. The overall results showed that more annual megawatt output per hour was achieved with more annual maintenance cost rather than with less. For instance, the annual maintenance cost of the Hendrina-Grootvlei Power Stations was more than that of the Majuba-Matimba Power Stations. The same was true of their annual megawatt output per hour. This implied a positive relationship between planned maintenance and performance and reliability of power stations. That being so, a closer look at the data revealed another pattern in the relationship between planned maintenance and power station performance.

Table 35: Summary of first hypothesis

	Annual operating cost (millions, R)	Annual MWh (MWh)	Planned maintenance	
			Employees' perceptions (%)	Annual maintenance cost (millions, R)
Majuba	325	20	50	252
Matimba	310	30	83	240
Hendrina	400	45	50	300
Grootvlei	480	60	50	264

The two power stations with greater maintenance cost out of the four, that is, Hendrina-Grootvlei, when looked at closely, showed that with less annual maintenance cost, greater annual megawatt output per hour could still be attained. Of the two power stations, Grootvlei was able to produce more annual megawatts per hour than Hendrina, which boasted a greater annual maintenance cost overall. The same results were also observable for the other two power stations, Majuba-Matimba, with less annual maintenance cost out of the four power stations. Matimba managed to produce more annual megawatts per hour than Majuba; yet its annual maintenance cost was less. What the results indicated, therefore, was that it did not necessarily take an increase in the annual cost for planned maintenance for greater annual megawatt output per hour to be attained; more could still be achieved with less. This proved an inverse relationship between planned maintenance and power station performance and reliability.

The other element influencing the operating cost was the reliability of supply of coal, which had a detrimental effect on the lifespan of the power plant. Comparatively, it was found that Matimba had a good reliable thermal coal supply compared to Hendrina and Majuba. At most other power stations, the quality of coal supply was very poor, as most of the suppliers preferred to give Eskom low-quality coal due to the good returns on exporting higher-grade coal.

5.3.2 The second hypothesis

The second hypothesis was to test whether there was a high level of planned maintenance taking place at the power stations.

The findings partially supported the hypothesis. The view shared by the respondents was that well-trained and skilled employees contribute positively to enhancing and maintaining the reliability of the plant. Employee perceptions regarding the existence of planned maintenance at power stations showed interesting results. Overall, there was no high perception that planned maintenance was taking place at power stations. Matimba Power Station was the exception, since it showed a high level of employee perception regarding planned maintenance.

5.3.2.1 Maintenance procedures at various power stations

5.3.2.1.1 Maintenance procedure at Majuba Power Station

Majuba has a maintenance strategy, and from the strategy, there is a preventive maintenance schedule for each different identified power plant. Servicing of equipment will result in optimal performance of that particular equipment.

Majuba has a system in place according to which the Planning Department prioritises its work through the schedule, and defects are identified and prioritised in terms of their levels of criticality. Priorities 1 and 2 are high level, cannot be ignored, and require immediate action. Both Priorities 1 and 2 have the possibility of load losses and safety hazards, and as such, they should be attended to within 24 and 72 hours, respectively. Priority 3 is similar to planned maintenance and will only be carried out at the appropriate time. Priority 4 is considered the least important and will only be done when the resources and plant are available.

The Workweek Management system is utilised for all the departments. The purpose of the system is for all the departments to share information related to the work to be done as identified and prioritised by the operation team. A

number of reports are drawn from SAP on leading matrices in Workweek Management on a daily basis.

a. Aging work orders

They are drawn on a weekly basis, the purpose being that they explain the date on which maintenance was supposed to be carried out.

b. Production meetings

Production meetings are held on a daily basis, and their purpose is to track Priority 1 and 2 progress, that is, whether these priorities have been done and closed out.

c. Leading metrics

Workweek Management uses seven leading metrics:

1. Schedule compliant – tracking whether the maintenance was carried out following the schedule.
2. Emergent work (Priorities 1 and 2) – how quickly were they carried out.
3. Statutory violation – jobs that are seen as safety-related, and they pose a risk of the plant being closed by Government agencies.
4. Backlogs – jobs that are to be carried out during outages.
5. Close-out of notification (turnaround time) – time taken to close an event.
6. Resource utilisation – how the manpower is utilised; the 80/20 rule is used where, out of eight hours, six hours are used for planned maintenance, and the other two hours are for breakdowns.

7. PM (planned maintenance) compliant – monitoring the actual execution of the work.

When planning for the availability of the plant, the following is considered: manpower, spares, resources required, and tools, depending on the planned maintenance to be carried out.

The line managers participate in the Workweek Management Forum. The line managers also attend the Electrical and Maintenance Managers Forum on behalf of Majuba, where working experience is shared among various power stations, and lessons learnt are discussed. The support manager assists with the history of the power station where similar problematic items are encountered.

The criticality of the components of the plant is also considered. In some components, there is redundancy; that is, there are two components where one is running and the other one is on standby, which means that the power station can afford to maintain one while the other component is running. In some instances, there is no redundancy, and it becomes critical to schedule the maintenance of such components properly.

5.3.2.1.2 Maintenance procedure at Matimba Power Station

Matimba Power Station has a fairly good maintenance process. The maintenance strategy was established by the Engineering Department. The overall maintenance strategy encompasses the maintenance strategy for each plant, and that is how the planned maintenance was developed. Each maintenance strategy is linked to the SAP programme, which assists with the drawing of the reports as well as preserving the history of the plant. The role of the Engineering Department is to come up with the maintenance strategy. The strategy outlines how a particular plant is to be maintained, the frequency of maintenance, and the generation of the maintenance task list. If revision of the existing strategy is needed, that task is carried out by the system engineers.

Planned maintenance is carried out on a regular basis, and there is weekly, monthly, quarterly, six-monthly, and yearly maintenance. This planned maintenance is well established and is reviewed on an ad hoc basis.

Matimba categorises planned maintenance as follows:

1. Corrective maintenance – this comes as a result of breakdowns in the plant.
2. Condition-based maintenance – this occurs as a result of plant not performing to its optimal level; for example, during a site walk, one recognises that the sound of a vibrating machine is not usual, and such occurrence will be reported and fixed.

3. Preventive maintenance – this is usually an outage happening after six years, and it is for major overhauling of the plant.

Before any maintenance is carried out, the priority or urgency of the plant is looked at. Priorities are classified as follows:

1. Priority 1 – work that must be done immediately within 24 hours, indicating the criticality of the plant.
2. Priority 2 – the work must be done within 72 hours.
3. Priority 3 – this is usually planned maintenance.
4. Priority 4 – the breakdowns or work orders that can be done only during outages; they are usually urgent, but the plant cannot be stopped.

The parts of the plant that are obsolete are those areas where there are recurrences of the problem. Feedback is given to the System engineer, and new measures are put in place to improve the prevailing conditions. Work management meetings are held once a week and the stakeholders represented are Operating, Production, Procurement (Stores), Maintenance, and Engineering Departments.

Matimba Power Station has a principle that says that each job done on the plant must start as a system; that is, all maintenance work is reported and is loaded on the system (SAP); once the task has been carried out, it is closed out on the system.

Matimba's aim is that it will never be satisfied with the way the system works, but would like to have continuous improvement, with more than 80% of its jobs being planned maintenance and with the breakdowns being as low as 20%.

5.3.2.1.3 Maintenance procedure at Grootvlei Power Station

In order to run the equipment for its useful life, that is, to ensure the longevity of the plant and exceed it, where possible, preventive maintenance must be in place. Most of the systems require a preventive maintenance strategy to be in place before any maintenance work is carried out. Usually, maintenance personnel contact their counterparts at other power stations with a similar history and operating on a similar principle, called Production Unit 3 (namely, Camden, Komati, Hendrina, and Arnot), to see whether their present prevailing maintenance case has ever been encountered at any of the said power stations, so that lessons learnt can be shared. Before carrying out the planned maintenance, the following aspects are usually taken into account:

1. Availability of the spares – the necessary replacement spares are available.
2. Availability of the plant – since Eskom has a central control point for determining the supply to the grid as opposed to the demand at that point in time, before any maintenance is carried out, Grootvlei Power Station makes a formal request to carry out maintenance – hence, the plant

availability – and can only continue with the maintenance if the plant becomes available.

3. Personnel availability – the right mix of personnel with the required experience should be available to ensure the minimum of mistakes when carrying out the work. Planners ensure the proper sequencing of activities take place and that the time allocated is realistic. Proper tools should enable the technicians in carrying out the work, and technicians will prepare reports on the maintenance carried out as well as lessons learnt. The information contained in the report includes the date of maintenance, the time, the number of people involved, and the spares utilised.

System engineers determine the frequency at which different plant components must be maintained. Long-term components are those that have a maintenance period of six months, three years, and six years. Short-term components are those that require daily monitoring.

Grootvlei Power Station uses a work management system where the Planning Department is notified of maintenance to be carried out. Notification of work to be carried out is usually determined by the operators. A meeting will then be arranged where planners and supervisors agree on what must be maintained and do the actual planning of the maintenance schedule.

5.3.2.1.4 Maintenance procedure at Hendrina Power Station

Planned maintenance at Hendrina Power Station is classified as preventive and corrective maintenance. Planned maintenance is carried out in order to prevent breakdowns, extends the life of plant components, and assists with the productivity as well as management of overtime costs. The Operating Department is the department most affected by maintenance carried out; if the problem persists, it is then passed on to the Engineering Department to again look into the maintenance philosophy. The Engineering Department is the custodian of the plant, and it is responsible for both the design and the type of maintenance to be carried out.

When carrying out the maintenance, people are likely to be subjected to overtime, and it is very important to plan their overtime in line with what the Labour Relations Act requires. When carrying out maintenance, the following should be considered:

1. Plant availability – the availability of the plant is considered, and the timing of when to carry out maintenance is very important.
2. Availability of spares – spares need to be considered according to the scope of work compiled. Procurement of long lead items is extremely important and should be properly included in the schedule.
3. Personnel availability – skilled people trained to execute those tasks in order to be able to meet the required time frame.

4. History of the plant – the history of the plant includes the drawings and the specifications for the component to be maintained. Previous work done on the plant is considered, and the work done on similar-plant power stations is also considered, if available.
5. Tools available – the right tools required to carry out the tasks should be in place.

Hendrina uses Work Management, a system developed to plan future maintenance. Preventive maintenance inspections are done, and defects are recorded in the SAP system, so that they can be rectified. The report from SAP system is analysed, and risk assessment is carried out. The planning and the actual execution of the task follow, while mitigating factors are put in place in the event of any failure. There is a log-down meeting where emergency work and its prioritisation are done. Emergency work is prioritised as follows:

1. Priority 1 – maintenance that must be carried out within 24 hours; it has a statutory violation connected to it and cannot be deferred. Even if there is planned maintenance, Priority 1 will take precedence over that planned maintenance.
2. Priority 2 – just like Priority 1, it has a statutory violation, it cannot be deferred, and it must be carried out within 72 hours.
3. Priority 3 – the normal planned maintenance.

At the daily morning meetings, there is a toolbox talk where tasks to be carried out are discussed and employees are encouraged to be authorised in order to take permits to work on a particular work to be carried out to ensure safety and that the correct work is carried out.

Once tasks have been completed, reporting on SAP is done by clearing the permit on the system, clearing the work order registers, signing off, and then sending the permit it to the planner for closing. Key areas contained in the reports are the cost of maintenance/repairs, the type of material used, the time it took to complete the task, and the personnel used. Reporting is done daily, weekly, and monthly and is shared by the entire maintenance team. Operating supervisors share the reports with the artisans who do not have access to SAP.

5.3.3 The third hypothesis

The third hypothesis was to test whether planned maintenance had an effect on operational costs.

Dividing the four stations into two groups – Majuba-Matimba and Hendrina-Grootvlei – showed that greater annual maintenance cost went with greater operating costs. This indicated a positive relationship. A closer examination within the two groups, however, revealed further interesting patterns. In the case of the Hendrina-Grootvlei Power Stations, an inverse relationship was observable between annual maintenance cost and operational costs.

Grootvlei Power Station had less annual maintenance cost, with a greater annual operating cost, while – comparatively – Hendrina Power Station had greater annual maintenance cost, with less annual operating cost.

In the case of the Majuba-Matimba Power Stations, a positive relationship between annual maintenance cost and annual operating cost was observable. Matimba Power Station had less annual maintenance cost and less operating cost when compared to Majuba Power Station, which had more of both annual maintenance cost and annual operating cost. It can, therefore, be safely concluded that the effect of planned maintenance on operational costs is a mixed one. In some cases, it results in less operating cost, while, in other instances, increased annual maintenance cost has no such positive effect on operational cost.

Table 36: Maintenance versus operational cost

	Annual maintenance cost (millions, R)	Annual operating cost (millions, R)
Majuba	252	325
Matimba	240	310
Hendrina	300	400
Grootvlei	264	480

Table 37: Megawatt output of individual power stations and year of commissioning

	Annual Megawatt Output	Date When Commissioned
Majuba	4110	1996
Matimba	4800	1982
Hendrina	2000	1970
Grootvlei	1200	1969

The table above shows annual megawatt output per station in relation to the date when each station was built. The Grootvlei–Hendrina duo, with a difference of one year between them, is almost of the same age. The average age difference between all the four power stations is 9 years. What the table reveals is that the relatively two older power stations of Grootvlei and Hendrina produce less megawatt output per annum compared to the relatively younger power stations of Matimba and Majuba. Age can therefore be argued to be an important factor in what power stations are able to produce. This however needs to be qualified since a close look in the Matimba-Majuba group shows that it is the relatively older of the two power stations that is producing more megawatt out per annum. It could therefore be alternatively argued that age has nothing to do with what power stations are able to produce in megawatt output. Rather it is the capacity that each power station was enabled to handle when they were constructed. Effective planned maintenance appears not to play any significant role here

CHAPTER 6: SUMMARY, RECOMMENDATIONS, AND CONCLUSION

6.1 Summary

This project set out to find whether planned maintenance was applied within Eskom power stations. The project also sought to establish the general understanding of planned maintenance and its different facets by Eskom staff. The findings indicated that planned maintenance was a crucial part of the daily operations of power station. Eskom, like its global competitors, has positioned itself in terms of adopting sound maintenance practices based on value adding to its operations, as opposed to reactive measures. This is reflected in the way maintenance programmes are executed across the Generation business, while maintaining security of supply. Eskom employees also understood the critical importance of planned maintenance as a tool for preventing load-shedding and enhancing the lifespan of a plant. This innovative adopted maintenance practice being applied is yielding the desired benefits to the company, as there is an acceptable level of breakdowns in terms of the global norm.

6.2 Recommendations

The following recommendations are suggested:

- Preventive maintenance strategies should be implemented for all of Eskom's baseload power stations to increase plant health.
- The tight electricity margin under which South Africa is operating can be managed as long as preventive and time-based maintenance is adopted within the power stations.
- Cost benefits emanating from the planned maintenance fully justify that there should be a dedicated budget and a fully operational maintenance department.
- Greater inventory control should be implemented, as it will result in better procurement and management of spare parts.
- Lessons learnt on all maintenance issues should be shared across the whole Eskom business.
- Critical areas should not be outsourced, since they have a negative effect on skills retention and ownership of knowledge regarding the particular plants or equipment.

6.3 Conclusion

In the final analysis, the importance of planned maintenance cannot be overstated. For one, there is the likelihood that, with planned maintenance, there will be sustainable plant health, which will result in lowering of the tariff costs, which can be passed on to end-users. This is a win-win situation, as there will be benefits for both Eskom and end-users. Moreover, investors' confidence is likely to be restored in the Southern African region as a result of an increased reserve margin, meaning that more electricity can be used for new developments. This will place South Africa on a higher growth path.

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A SURVEY TO INVESTIGATE THE EFFECTIVENESS OF PLANNED MAINTENANCE IN POWER STATIONS

The aim of this questionnaire is to research the effectiveness of planned maintenance in power stations. The information obtained will assist in determining whether planned maintenance is effective. The information you supply will be treated with strict confidentiality. The findings from the research will be shared with you and the entire organisation.

Please take time to answer the following questions, which should not take much of your time. All answers will be appreciated; that is, there are no correct or incorrect answers.

I. GENERAL INFORMATION

Name and surname				
Designation				
How long have you been in this position?				
Years of service				
Gender				
Age range (please tick the correct age range)	20 – 30 years	31 – 40 years	41 – 50 years	51 – 65 years
Highest educational qualifications				
Power station age cluster	1950s – 1960s	1960s – 1970s	1970s – 1980s	
Date of interview				

II. MAINTENANCE PRINCIPLES

The Eskom group is committed to providing electricity to its customers in a sustainable and reliable manner. Please indicate your response to each by placing a circle around the heading that best describes your response.

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
Maintenance refers to the plant running smoothly without stoppages	1	2	3	4	5
Asset management is part of maintenance	1	2	3	4	5
Routine work management is part of maintenance	1	2	3	4	5
Outages are part of maintenance	1	2	3	4	5
Preventive maintenance is the most desired type of maintenance	1	2	3	4	5
Condition-based maintenance forms part of the daily operation of the plant	1	2	3	4	5
Decision-making on strategic spares does not include principles of maintenance	1	2	3	4	5
Maintenance means that the overall cost of electricity will be reduced	1	2	3	4	5

Scale	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
	1	2	3	4	5
When thinking about maintenance, it is important to think about making a profit for Eskom and not to think about the electricity cost to consumers	1	2	3	4	5
The employees of power stations are involved in making decisions on maintenance	1	2	3	4	5
What do you think is the meaning of effectiveness of planned maintenance in power stations?					

III. PLANNING FOR MAINTENANCE

Please tick the box that best explains your views about planned maintenance.

Does power station maintenance incorporate preventive and condition-based principles?	Yes	No	Don't know
Planned maintenance means that different units, that is, boilers, turbines, etc., plan their maintenance separately, with each unit presenting its plans at the strategic planning meetings	Yes	No	Don't know
Decision-makers consider the planned maintenance principles when drawing up the short-, medium-, and long-term budgets and overall plans for power stations	Yes	No	Don't know
The end-users are involved in decision-making on planned maintenance	Yes	No	Don't know

IV. PLANNING FOR MAINTENANCE

<p>Taking the projects that Eskom successfully implemented in 2008, how were the principles of planned maintenance incorporated in:</p> <ul style="list-style-type: none"> • the planning of these projects? • the actual execution of the projects? 			
<p>Who, within the various power stations, is responsible for implementation of planned maintenance?</p>			
<p>Are the principles of planned maintenance approved because of their sustainability?</p>	<p>Yes</p>	<p>No</p>	<p>Don't know</p>
<p>Please explain your answer in 19 above.</p>			
<p>Is there any monitoring of the implementation of planned maintenance within Eskom's power stations?</p>	<p>Yes</p>	<p>No</p>	<p>Don't know</p>
<p>If "Yes" or "No" to 21 above, please explain how it is done.</p>			
<p>Is Eskom concerned with effectiveness of planned maintenance in power stations?</p>	<p>Yes</p>	<p>No</p>	<p>Don't know</p>
<p>Is there any planned maintenance that is deferred due to financial constraints?</p>	<p>Yes</p>	<p>No</p>	<p>Don't know</p>
<p>Explain the strategies employed by Eskom in ensuring that planned maintenance is sustainable.</p>			

How do various levels of employees, that is, skilled, semi-skilled, and managerial, participate in planned maintenance decision-making?			
What kinds of programmes must Eskom implement that will empower employees to participate in making decisions pertaining to planned maintenance?			
Is progress towards the implementation of planned maintenance monitored?	Yes	No	Don't know
If "Yes", how?			
Are the indicators of planned maintenance available within the Eskom group?	Yes	No	Don't know
How is the progress towards the implementation of planned maintenance reported?			
Are the end-users informed about progress pertaining to planned maintenance and any benefits emanating from that?	Yes	No	Don't know
What constraints does Eskom have in implementing planned maintenance?			
Please explain the constraints with reference to Question 33.			

INTERVIEW SCHEDULE

PREVENTIVE MAINTENANCE

How does the concept of preventive maintenance apply to your power station?

What do you consider when planning for preventive maintenance?

How does your power station relate to other power stations within Eskom Generation Division with regard to preventive maintenance?

What measures are in place to encourage participation of all role players in your power station?

Is the level of involvement of role players in the power station in terms of preventive maintenance satisfactory? If not:

- What are the problems that you encounter?
- What can be done to improve the situation?

How is reporting on preventive maintenance done, and what are the key areas covered in the report?

How often is reporting done relative to the number or types of maintenance carried out?

Who are the recipients of preventive maintenance reports?

Is the preventive maintenance sustainable in the power station? Please explain.

Suggest what preventive maintenance measures can be implemented to improve the sustainability of plant reliability.

COST MEASURES

How do you measure financial benefits in terms of planned maintenance for your power station?

What is the role of the Financial Department, Quantity Surveying, and the Maintenance Team in ensuring that maintenance requirements are provided and executed in a sustainable manner?

Is maintenance planning carried out in a manner that supports financial forecasting, the cash flow, and the financial sustainability of the power station?

What strategies are employed to monitor the sustainability of plant maintenance in the power station?

How is the productivity/fruitfulness of the maintenance measured, thus distinguishing its lows, or failures, from its successes in order to make clear areas for improvement?

What tools are used to measure financial sustainability of maintenance in power stations?

What suggestions do you have for the power station to improve on implementation of sustainable preventive and condition-based maintenance?