5. APPLICATION EXAMPLES

5.1 INTRODUCTION

Energy conversion models have been developed and verified for different components in a water reticulation system that could be found in a deep-level gold mine. It has also been verified that they operate together successfully. What becomes important now, is to demonstrate what use these models actually are to us by using examples of how they can be employed to save electricity costs to the mine.

This chapter uses case study data presented in the previous chapter to show examples of how the models can be used to reduce the cost of electricity. This is not only done by adjusting schedules, but also by showing the effect on the cost of pumping that changing physical parameters could have. Depending on the cost of changing physical components, it becomes possible to decide if it will be viable making such changes. This also extends to how these models can be used to evaluate different proposed systems for future installations.

In installations where data of flow rate and power consumption are available, these models can be altered to have the efficiency as an output. This will aid the mine in determining the condition of the pumps by monitoring the efficiencies of the pumps. Once the efficiencies drop below a specified level, the pumps would need to be seen to. This may used to indicate the need for routine servicing or damage to the pump.

The examples used in this chapter are all based on data obtained from the Tshepong mine case study of 27-28 July 1999. For demonstration purposes, in each example, all variables will be kept constant apart from the variables that are specifically being changed.

The variables that have been used as inputs to the models for this chapter are summarised in the following table. Naturally the variables relevant to each example are not kept constant.

Table 5.1: Summary of variables used in examples

COMPONENT	VARIABLE	SYMBOL	VALUE
Shaft Bottom Pumps	Constant	f	0.02
	Pipe Length	L	640.1 m
	Flow Rate	Q	0.250 kl/s
	Pipe Diameter	D	0.35 m
	Number of Pumps	No	3
	Water Density	ρ	1 kg/l
	Gravitational Constant	g	$9.81\ m/s^2$
	Efficiency	η	65%
	Natural Head	h	640.1 m
3CPF	Flow Rate	Q	0.295 kl/s
	Pipe Length	L	1372 m (x2)
	Water Density	ρ	1 kg/l
	Gravitational Constant	g	$9.81\ m/s^2$
	Constant	f	0.02
	Natural Head	h	0 m
	Efficiency	η	69.1%
	Pipe Diameter	D	0.35 m

The pumping profiles used for all the examples presented in this chapter are the same as those shown in figure 4.5, which represents two days' actual data. The only variations to the profiles will be in the illustration of savings, which can be brought about by schedule changes.

5.2 THE EFFECT OF PIPE DIAMETER ON ELECTRICITY COST

Tshepong mine has 350 mm pipes installed up and down the shaft for its water transportation. According to Darcy model shown in figure 3.1, the friction head incurred by these pipes is proportional to the 5th power of the diameter. The following figure demonstrates the effect that changing this would have on the cost of electricity at a mine such as Tshepong. All other variables and schedules remain the same.

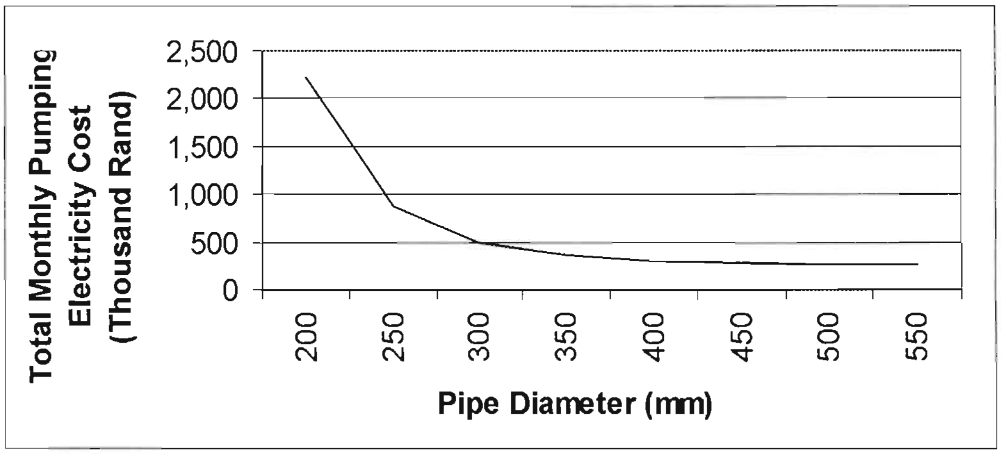

Figure 5.1: Total monthly pumping electricity cost as a function of pipe diameter

As can be seen from the figure 5.1, the 350 mm pipes, which Tshepong have installed are reasonably efficient. Depending on the cost of changing the diameter of the pipes, they can now decide if it would be worthwhile doing this. Once the pipe diameter is above 300 mm, the friction head becomes reasonably small compared to the natural head. It is also very informative to notice how enormous the cost of electricity for pumping would be if the pipe diameter were too low.

5.3 THE EFFECT OF EFFICIENCY ON ELECTRICITY COST

McKechnie [42, p. 3.2/5] mentions that dirty water pumps in underground operations are very large consumers of electrical energy. This can be explained by the low efficiencies of such pumps.

In the water reticulation system of Tshepong mine, two efficiencies are identified, which have the greatest effect on the cost of electricity. These are the efficiencies of the shaft bottom pumps, which are assumed to be identical and the efficiencies of the pumps driving the three chamber pipe feeder system. The efficiencies listed in table 5.1 were determined in the model verification process. For the purpose of this example, the two efficiencies will be varied individually while keeping the one not being varied constant at the value shown in table 5.1.

5.3.1 Shaft Bottom Pump Efficiency effect

The following figure shows the effect of varying the efficiency of the shaft-bottom pumps on the total cost of electricity for pumping.

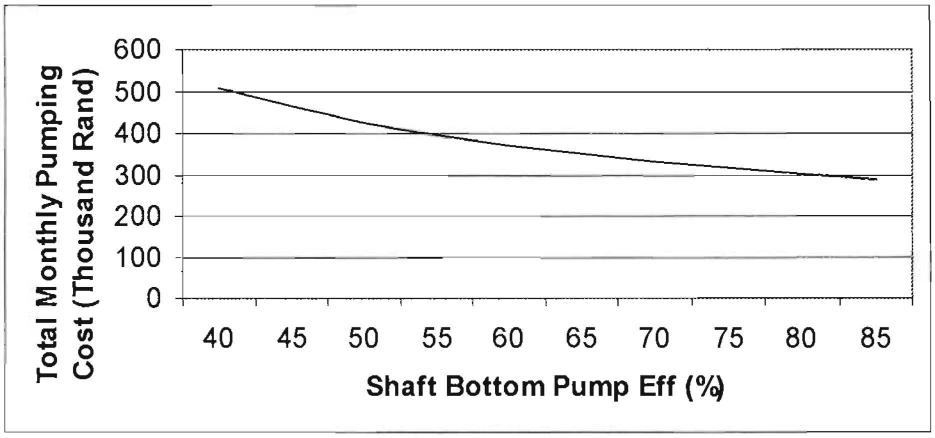

Figure 5.2: Total monthly pumping cost as a function of shaft bottom pump efficiencies

By ensuring that there is no wear on the pumps and that they are using very efficient impellers, a rather significant difference can be made to the monthly pumping costs. Presently the pumps are operating at approximately 65%. If this efficiency could be raised to the region of 75%, approximately R35,000 could be saved per month. Again the investment of implementing any such changes should be weighed against the returns.

5.3.2 Three Chamber Pipe Feeder Efficiency

Changing the efficiency of the entire three chamber pipe feeder system is not possible. For this reason the efficiency of the pumps alone will be varied, as this is the only realistic variable that can be changed.

The three chamber pipe feeder has a single pump on surface as well as a single pump on the mine's 43-level. The effect of varying the efficiencies is investigated by varying the efficiencies of the two similar pumps simultaneously.

The following figure is a graphical representation of the effect of varying the efficiency of the three chamber pipe feeder pumps on the total electricity cost of pumping in the mine.

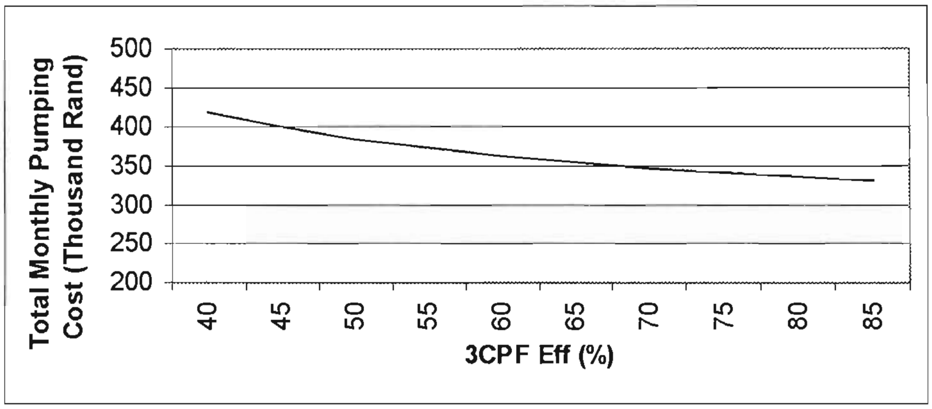

Figure 5.3: Total monthly pumping cost as a function of 3CPF efficiency

Figure 5.3 shows that varying the efficiency of the three chamber pipe feeder pumps, has a similar effect to that of varying the efficiency of the shaft bottom pumps. Presently the three chamber pipe feeder pumps are operating at approximately 70%, which is reasonably good. If the efficiency were to be increased to for example 75% as speculated in the last example, a saving of approximately R7,000 per month would be achieved. This is much less than that of the savings which could be achieved by making the shaft bottom pumps more efficient, it is however still a considerable sum. If both sets of pumps had their efficiencies raised, the total monthly saving would be approximately R42,000. Again, a decision would need to be taken keeping the capital expenditure in mind that any efficiency improvements would require. Investment criteria were also dealt with in section 1.4.4.

The reason that the efficiencies of the three chamber pipe feeder pumps do not have nearly the same effect on the total pumping cost as that of the shaft bottom pumps, is that the pumps are much smaller. The whole idea behind the 3CPF system is that it does not need to pump against a natural head. It thus uses much less energy than the shaft bottom pumps, even though there is a natural head of more than double that which, the shaft bottom pumps have to pump against.

5.4 EFFECT OF NUMBER OF SHAFT BOTTOM PUMPS ON ELECTRICITY COST

Investigating the effect of the number of shaft bottom pumps operating in parallel is perhaps not as useful as the other studies because the constraints present make changing the number of pumps rather difficult. The pumps, which have been installed, have been installed for a certain designed flow rate. Keeping all variables (including flow rate) the same while varying the number of pumps, implies that the pumps will not be operating in their most efficient area in their respective pump curves.

The following figure indicates how the total cost of electricity for pumping will vary when the number of pumps are varied.

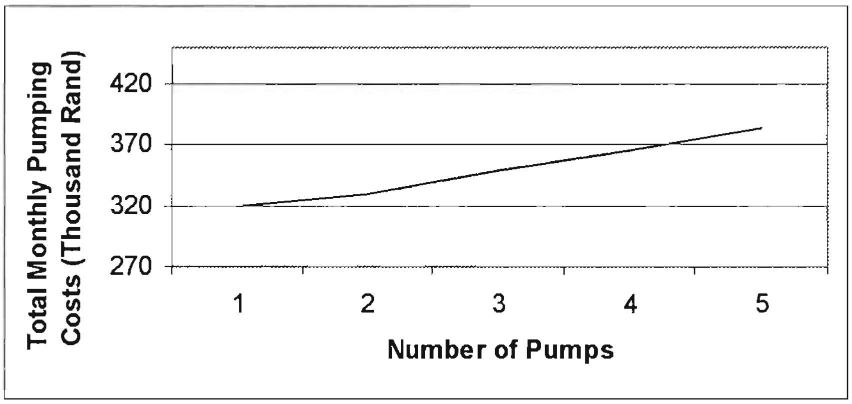

Figure 5.4: Total monthly pumping cost as a function of number of shaft bottom pumps while maintaining the same flow rate

Figure 5.4 shows that as more pumps are used, the cost of electricity also increases. For this reason it is important that there is a balance between the number of pumps (and so the electricity cost) and size of the pumps (initial costs). Efficient pumps that can handle much larger water volumes obviously cost much more than smaller pumps, which would be used in parallel. It is also pointless simply adding pumps in parallel due to the fact that the flow rate increases in a bounded exponential fashion as described in section 3.4.

Tshepong mine typically runs three shaft bottom pumps in parallel, so obtaining a reasonable balance between energy cost and initial pump cost.

5.5 TYPE OF ENERGY RECOVERY AND TARIFF COMPARISON

Using the models that have been developed, it has become possible to examine different kinds of energy recovery systems that can be used within a certain water reticulation system. For the purpose of this example, the system used in Tshepong mine was used. The simulation was done using the three chamber pipe feeder system as well as turbines and finally with no energy recovery. The entire system remains the same apart from the energy recovery system changing. As is the case in many mines where turbines are used, it was accepted that a system such as this would use three turbines in parallel and three pumps pumping the water to surface in parallel.

For the purpose of the example, it was accepted that the mine-wide maximum demand occurs at 9:30. The costs listed in the following table are based on Eskom's Nightsave and Megaflex tariffs as in 1999. The reason for this being that the case study's profile used for this simulation was measured in July 1999.

Table 5.2: Energy recovery and tariff comparisons

	3CPF	TURBINES	NO RECOVERY
Energy (Total Monthly)	1,865,559 kWh	3,478,699 kWh	3,776,007 kWh
Maximum Demand	4,366 kW	8,477 kW	10,561 kW
Monthly Nightsave Cost	R349,495	R667,238	R788,588
Monthly Megaflex Cost (Summer)	R283,200	R445,078	R599,961
Monthly Megaflex Cost (Winter)	R305,480	R457,897	R629,983

Table 5.2 demonstrates a further benefit of the modelling in that it can be used to evaluate different tariffs for the same or different systems. If for example Tshepong mine was a proposed mine, it would now be possible to determine how much power would cost for different installations and then decide in the energy recovery configuration while keeping available tariffs in mind.

One can furthermore determine how much power would be saved by the different energy recovery systems and use this information to decide if it would be economically viable to install the various systems. In the example shown in figure 5.2, one can see that using Nightsave, which is the tariff Tshepong are presently using, a typical saving of R439,093 per month is brought about by using the three chamber pipe feeder system. A saving of R121,350 per month would have been realised if they had installed turbines.

Naturally one must keep in mind that the figures mentioned assume that the maximum demand occurs at a given time. This is not necessarily the case, and may vary due to many other factors in the mine. The water reticulation system of a mine is not billed separately to the rest of the mine and so the choice of tariff must take the entire mine load profile into consideration. The values presented in table 5.2 are given as an indication of what the cost contribution of the water reticulation system would be if the mine had to be on the Nightsave or Megaflex tariffs.

5.6 SCHEDULING

Using the models developed, it is possible to use flow schedules as an input to the system of models to determine the electricity cost for that particular schedule. Once again the Eskom Nightsave and Megaflex Tariffs are of interest [22].

5.6.1 Nightsave Tariff

Apart from the basic charge, monthly rental, voltage discount and transmission percentage surcharge, Nightsave charges customers for total energy used per month as well as a maximum demand charge for either kW or kVA integrated over a 30 minute period. The maximum demand charge for Nightsave is only applicable between 6:00 and 22:00 on weekdays.

A customer such as a mine naturally has reasonably high maximum demand on this tariff as their main production shift occurs within the Nightsave peak time. This means that if the water reticulation system, which as can be seen from figure 4.7 is operating for most of the day, including the peak times, it is contributing a substantial amount to the maximum demand of the mine. From table 5.2 it can be seen that a typical maximum demand for the water reticulation system of Tshepong mine is 4,366 kW.

Theoretically, if the mine were to avoid using the water reticulation system at all during the times that they experience maximum demand, they could realise a potential saving of R213,628 (based on 1999 rates). Naturally this is only possible if there is absolutely no contribution to the mine's maximum demand from the water reticulation system.

Apart from this no saving can be made from scheduling changes. The energy used for pumping a certain amount of water remains constant and so Nightsave cannot be of any further benefit.

5.6.2 Megaflex Tariff

Customers using the Megaflex tariff are subject to a basic charge, monthly rental, reactive energy charge, voltage discount and transmission percentage surcharge. In addition they have to pay an active energy charge as well as a maximum demand charge. The main difference between Megaflex and Nightsave is that the energy cost varies depending on the time of use. The maximum demand is applicable all the time and varies according to two set seasonal rates. The time of use rates also vary according to two respective set seasonal rate groups. The two seasonal rate groups broadly represent winter and summer.

In order to use Megaflex most economically, it is not only important to minimise the contribution to the mine's maximum demand, but also to avoid using energy at all during expensive times. In summer as little energy as possible should be used between 7:00 and 12:00. In winter energy usage should be avoided between 7:00 and 10:00 as well as between 18:00 and 20:00. Energy is typically the cheapest in the evenings and so as much load as possible should be shifted to night time (after 22:00).

Again referring to table 5.2, if Tshepong were on Megaflex, they would typically be spending R283,200 for pumping in summer and R305,480 on pumping in winter. Potentially, this figure can be reduced to R244,207 for summer and R271,478 for winter rates. Again, these figures are based on the 1999 figures. Furthermore the amounts represent only the potential saving that can be brought about by shifting load to reduce energy costs. In addition to this saving, a saving can also be made by avoiding operating the components of the water reticulation system at mine-wide maximum demand times.

The 4,366 kW of maximum demand from the water reticulation system of Tshepong, represents a potential saving of R52,000 in summer and R57,675 in winter. One must keep in mind that this saving is dependent on when the mine-wide maximum demand occurs and that one may need to weigh up the cost effectiveness of shifting load to avoid maximum demand or to avoid high energy costs. Typically Megaflex has its expensive energy charges during a mines production shift. For this reason, it may be possible to avoid high energy costs and maximum demand contribution be reducing pumping during the main production shift as far as possible.

5.6.3 Constraints

For any schedule changes that are brought about for electricity cost reduction, it is imperative that the buffers in the system are checked. This means that schedules can only be adjusted once it has been established that there will be sufficient water for production when it will be needed and that none of the dams in the system will overflow. Depending on the particular system, it may be necessary to compromise on some of the potential cost savings to ensure that the system operates properly. The constraints must ensure that an acceptable safety tolerance is adhered to in all cases as well.