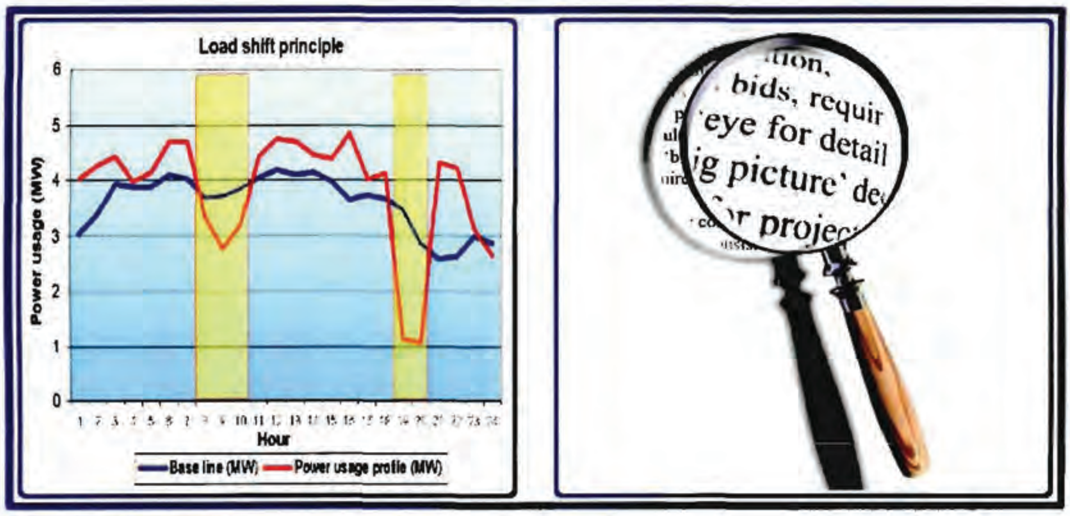
4. Verifying the new system



The newly developed system was implemented and tested on 13 sites. Load shifting of 37 MW and savings of R 5,7 million proved its success.

4.1. Prelude

This chapter focuses on how REMS was verified and benchmarked. The best way to verify a system like REMS is to implement it in a real-world environment and closely monitor its progress. This was done on various South African deep level gold mines. Each mine is unique as described in section 4.4.

REMS was used to control the water pumping system in these mines. See section 1.2.2 for a full explanation on water pumping systems. Section 4.3 gives a summarised explanation on how REMS is implemented to control the water pumping system of a mine.

4.2. Success measurement

In order to measure the success REMS achieves on a mine, the way success will be measured must be defined. Looking at the problem statement of this thesis in section 1.2.5, it can be concluded that REMS must be benchmarked on the following:

1. Running Electricity Cost comparison: Calculating the drop, if any, in the running electrical cost of the system after the implementation of REMS.

2. Electrical Load Shift comparison: Calculating the electrical load shifted by the system since it was controlled by REMS.

3. Comparing simulated potential: REMS was used to predict the load shift potential of each project before implementation. This was then compared to the actual load shifted after implementation.

4.2.1. The baseline

For all three successful measurement methods, a baseline for the electrical system is needed. A baseline consists of 24 points representing the average electrical power usage of a system for a typical day averaged over a period of time of three months or more. The baseline for every project is drawn up before the implementation of REMS.

The baseline of a system is calculated from status profiles and running power usage data from the electrical components of that system. The status profiles for electrical equipment are the data that shows when the equipment was running/operational. During the case study we had three sources for the status profiles of the electrical equipment.

1. The first is the SCADAs on the mines itself. The status profiles of electrical equipment are logged for sustainability investigations.

2. Data is logged by contractors. In some cases data management and logging contractors provide a service to the mine.

3. Thirdly, REMS logs this data. REMS dump all this data in a private database, allowing full access to it.

In the water pumping system the electric pumps are the only significant electricity users. Consequently, the explanation on the baseline will be focussed on the pumps.

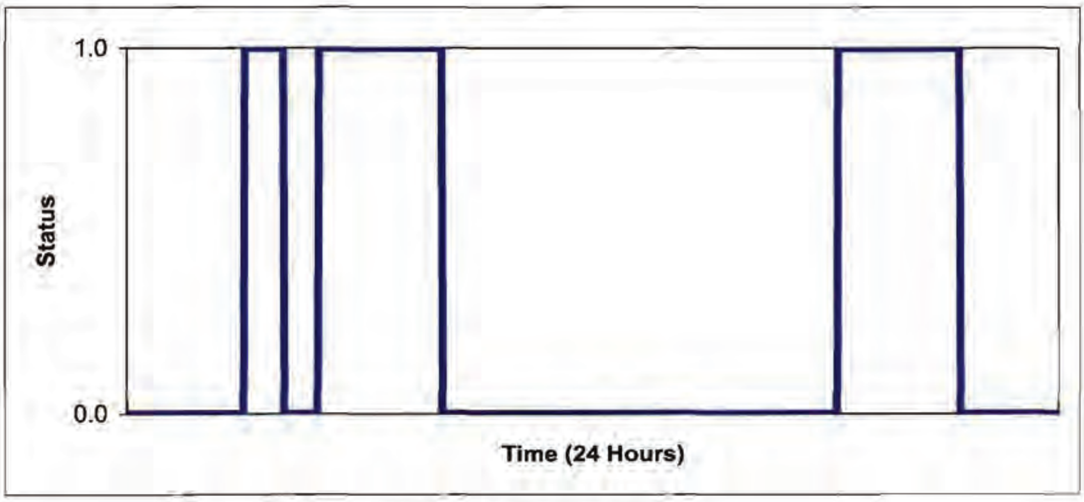


Figure 4-1 Pump status profile

Figure 4-1 is an example of a pump status profile plotted on a graph. From this profile one can determine that this particular pump started at 03h03 and was stopped at 04h10. It was started at 04h58 and stopped at 08h09. It was then started again at 18h20 and stopped at 21h29.

Now, multiplying the pump status profile with the running power usage of the pump yields the power usage profile of the pump. Adding the power usage profiles of the individual pumps of the water pumping system, results in the daily power usage profile for that system. The baseline for the water pumping system is calculated as the average of the daily power usage profiles over a period of time. Figure 4-2 shows the baseline for a typical gold mine water pump system.

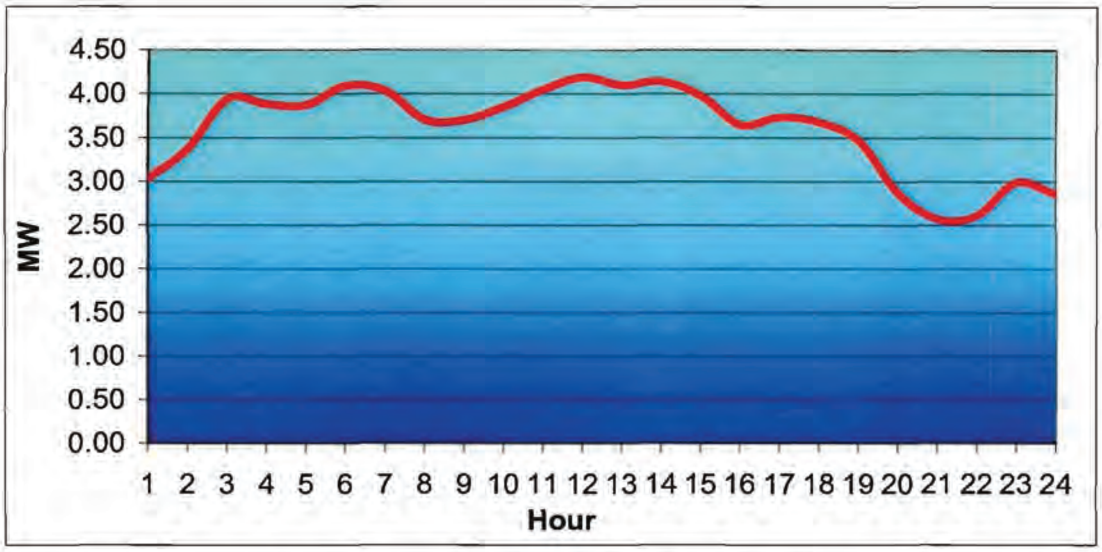


Figure 4-2 Baseline of a typical water pumping system

4.2.2. Electrical load shifted

As explained, electrical load shifted describes the amount of electrical demand lowered in peak periods and rescheduled to off-peak periods. The electrical load shifted on a system after REMS was installed is calculated as follows.

Before REMS is implemented, the baseline for the system is drawn up as described in section 4.2.3. After REMS is implemented a new power usage profile is set up. This is done for every day. Like the baseline, the power usage profile consists of a 24-hour profile that gives the electricity usage of a system.

The peak period where electrical load can be shifted is between 18h00 and 20h00 as decided by ESKOM. To calculate the load shifted the baseline and the power usage profile is needed. The amount of load shifted for a specific day is equal to the average power used by the system between 18h00 and 20h00 before implementation (baseline), minus the total power used by the system after implementation.

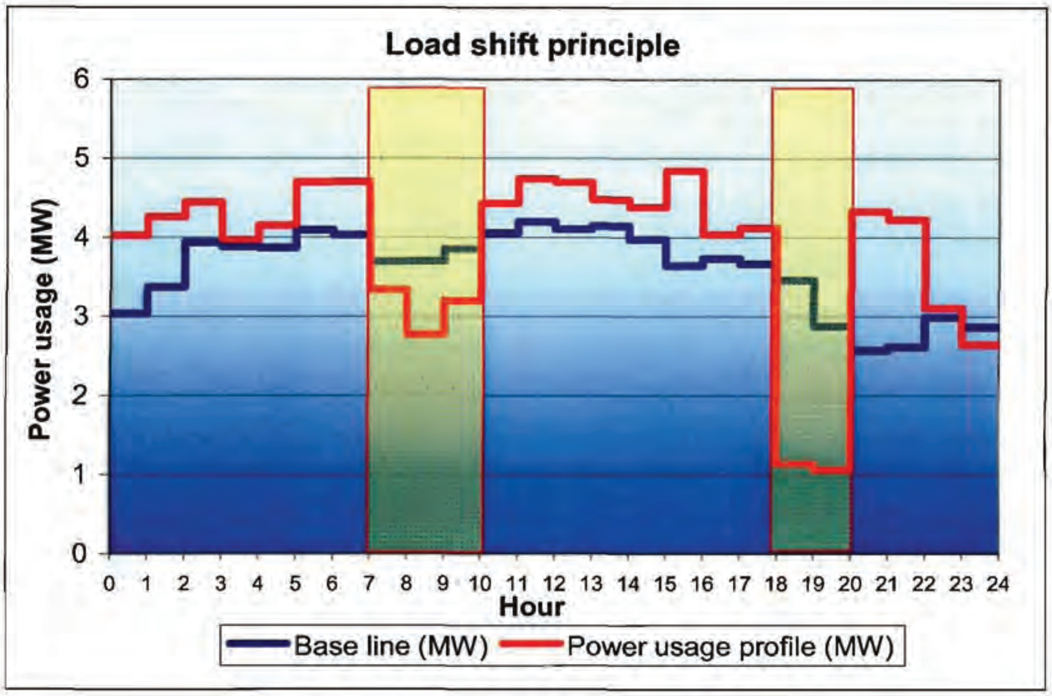


Figure 4-3 Load shift principle

Figure 4-3 shows how this is done. Consider the yellow marked square representing the period for 18h00 to 20h00. This is the period where the evening load shifted is calculated. The blue line represents the baseline of this particular mine. The red line represents the power usage profile after REMS was implemented for this specific day.

The graph shows that the new profile averages about 2 MW lower than the baseline for those two hours. This means that about 2 MW of load was shifted in the 18h00 to 20h00 peak. For monitoring purposes the amount of load shifted was calculated every day for the remainder of the case study and the results thereof is given in section 4.4, for each mine individually.

Load shift success is usually presented in the average load shifted during the period of a month. This figure, for a specific month, is calculated by taking the average load shifted for every day of that specific month excluding the condonable days.

Condonable days are defined by the presence of external factors over and above the control of the REMS that prevented REMS in shifting load. These days are not included in the success measurement of REMS, as it is not REMS' fault that no load was shifted.

Following are some examples of condonable days:

1. **Column burst**. Consider one of the columns bursting in the mine, preventing some of the pump stations to be functional. This seriously affects the whole water pumping system layout, and usually in a case like this, REMS is switched off and the system is controlled manually until the problem is fixed of rectified.

2. **Pump breakdowns**. In the event of a pump breakdown, REMS loses its capacity to optimise workload during the inexpensive off peak hours. These days are therefore also seen as condonable.

3. **Power failures**. These days are considered as condonable. It can happen that the power failure happened during the inexpensive off-peak periods. When power supply resumes, dams are usually full and have to be emptied regardless the time of day.

4. **Communication disruptions.** Communication loss between REMS and pumps or dams can happen when the network cables running into the mine are damaged or when the network is undergoing maintenance. During these days REMS is unable to ascertain dam levels and pump statuses and it is unable to control the pumps. These days or periods are also considered condonable.

5. **Scheduled pump maintenance**. Scheduled pump maintenance implies the unavailability of a pump for a period of up to three days. During this time REMS does not have all the infrastructure it needs to its disposal to achieve load shifting and running cost reductions. These periods are considered as condonable.

6. **PLC failure or breakdowns**. The PLC's are an integral part of the communication chain between the water pumping system components and REMS. When these PLC's are dysfunctional, no communication is present, and no control can be achieved.

7. **Too much water in system.** In some cases, usually after pump downtimes or power failures, the total amount of water in the system is very high due to underground fissure water that accumulated in the mine system. When this happens, the first priority is to pump all excess water out of the mine.

4.2.3. Electrical cost savings

Running electricity cost comparison is fairly simple. The running electricity cost of the water pumping system was determined before and after REMS was implemented. These two figures are then compared.

To work out the electrical cost of a system, a full understanding of the electricity billing system is necessary. All the mines in this case study make use of Eskom as their electricity supplier. During this case study the mines were billed according to the Megaflex pricing structure. A full explanation of the Megaflex pricing structure is presented in section 1.1.5.

From here, calculating the water pumping cost is simple. The electricity billing system is known. Furthermore, the power usage profile of the water pumping systems is calculated as described in the previous sections.

Multiplying the power usage profile of the water pumping system with the pricing profile, yields the electricity cost profile. Adding the values of this profile gives the total electricity cost of the system for a given day. Multiplying the baseline with the pricing profile results in the cost base load.

Every day's saving is calculated by comparing that day's cost profile with the cost base load. This is done over a period of a month and the savings realised on the system is expressed in savings per month. The results for the electrical cost comparison is given in the following section for each mine individually.

4.2.4. Simulated project potential

Before implementation of any project, the load shift potential was predicted using the REMS' simulation engine. To test the accuracy of these predictions it was compared to the actual savings and load shifting that were realised after implementation.

Every case study presented in the next section, shows the predicted potential against the actual load shift realised. This yields an indication of the success and accuracy of the simulation engine's ability to predict the potential of projects before implementation.

4.3. Implementation

Quite a number of REMS implementations on mines were conducted during the last two years. A thesis on the implementation procedures of REMS was written by Nico de Kock [95].

The implementation of any project is basically done through the following steps. Keep in mind that this is only a short description of the steps taken to identify and implement the project.

The first step is to identify projects that have load shift and savings potential. This is done by doing a simulation investigation with the use of REMS to predict these values. Visits are made to the mine to investigate the water pumping system. During these visits, information regarding the water pump system is gathered.

This information is needed to build up the simulation model in the REMS environment. Once the system build-up is mimicked in the simulation, investigations are done by simulating different scenarios and underground conditions.

If the simulation shows a feasible project potential, the project will be continued. The next step is to hand in a project proposal at ESKOM-DSM. If successful, this will result in an agreement between the ESCO, the mine, and ESKOM, that will dictate the detail of the project.

If the mine lacks certain hardware and infrastructure such as PLC's, valves or centralised SCADA control, it is implemented. This work is usually outsourced to sub-contractors. After the necessary SCADA and PLC infrastructure is in place, the implementation of REMS can start.

The implementation of REMS consists of establishing communication to the relevant mine SCADA. The components in the REMS build-up are linked to the actual system components by using the OPC tags provided by the SCADA. REMS is now able to monitor the actual components on the mine.

Implementation engineers will then do the control algorithm set-up. Alarm conditions are set up and discussed with mine officials. At this point training of the mine control room operators are done.

After this REMS is ready for automated control.

4.4. *Case studies*

Eight case studies are discussed in detail in this section. These case studies were chosen because they were all implemented more than a year ago. This implies that the information that is gathered from the case studies is sustainable and proved over a period of a year or more.

4.4.1. Basic pump systems

<u>Kopanang mine</u>

Background

Kopanang is included in this case study because this project not only proves that the implementation of REMS can result in both electrical running cost reduction and load shifting, but it also sheds light on the sustainability of the REMS system. REMS was implemented on Kopanang's water pumping systems in April 2004 and has been operational since then.

Mine setup

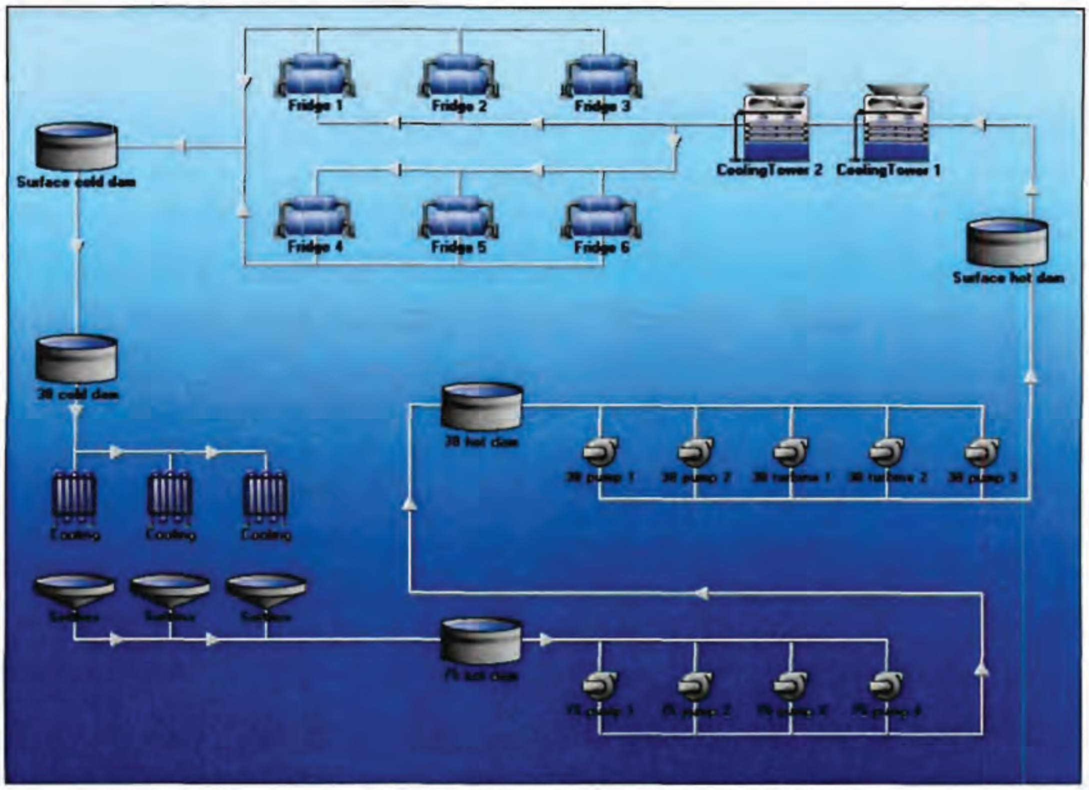


Figure 4-4 Kopanang water cycle

Figure 4-4 is a representation of the Kopanang hot water cycle, starting with the two cooling towers (marked "Cooling Tower 1" and "Cooling Tower 2") and the six refrigeration plants (marked "Fridge 1" to "Fridge 6"). Water is cooled down to about 3.5 °C where it is sent down into the mine and distributed to bulk air coolers (marked "Cooling"). These bulk air coolers are used to cool the air in the mine itself. After this the water is re-collected into settlers (marked "Settlers") from where it is pumped through different stages back to the surface for re-cooling.

The components responsible for delivering this used hot water back to the mine surface are referred to as the hot water pumping system. These are the components controlled by REMS. They are:

1. '75 hot dam',
2. all the '75 level pumps',

3. '38 hot dam',

4. all the '38 level pumps'

5. and the 'surface hot dam'

The running power usages of each of the pumps in the hot water pumping system are as follows:

Pump name	Running power usage
P 75 - 1	1500 kW
P 75 - 2	1500 kW
P 75 - 3	1500 kW
P 75 - 4	1500 kW
P 38 - 1	1500 kW
P 38 - 2	1500 kW
P 38 - 3	1500 kW

Table 4-1 Running power usage of pumps on Kopanang mine

Electricity cost savings

The electricity cost savings realised on the mine are calculated monthly and presented in a REMS monthly performance report. An example of a monthly performance report as generated for Kopanang is shown in appendix 7.1. This report shows the savings that were realised on a specific mine for a specific month. The saving for a month is calculated as described in section 4.2.2 of this thesis.

Table 4-2 shows the electricity cost saving realised on Kopanang mine for the period of April 2004 to September 2007. The saving for each month may vary due to the availability of the equipment that makes up the hot water pumping system. The total savings made during the first year of the case study was approximately R 1.5 million.

Load shifted

The load shifted on the mine is calculated daily and is represented in REMS' daily performance reports. An example of a daily performance report generated for Kopanang mine is shown in appendix 7.2. This report shows the electrical load shifted for a specific day. The amount of load shifted is calculated as described in section 4.2.2 of this thesis. Table 4-2 shows the electrical load shifted and electrical running cost savings achieved on Kopanang mine for the period April 2004 to September 2007.

Kopanang performance summary Apr 2004 - Sep 2007		
Month	Load shifted (MW)	Savings achieved
Apr-04	2.70	R 278,098
May-04	2.50	R 26,282
Jun-04	4.29	R 105,572
Jul-04	3.87	R 105,572
Aug-04	3.01	R 105,572
Sep-04	4.18	R 19,703
Oct-04	3.92	R 19,703
Nov-04	4.81	R 19,703
Dec-04	4.73	R 19,703
Jan-05	4.31	R 20,305
Feb-05	2.59	R 19,388
Mar-05	3.39	R 19,651
Apr-05	3.37	R 19,914
May-05	3.69	R 20,567
Jun-05	2.90	R 104,374
Jul-05	4.75	R 104,374
Aug-05	3.58	R 109,177
Sep-05	4.08	R 21,221
Oct-05	3.51	R 20,568
Nov-05	4.98	R 21,221
Dec-05	4.50	R 19,914
Jan-06	4.33	R 20,305
Feb-06	4.35	R 19,388
Mar-06	4.87	R 19,651
Apr-06	4.98	R 19,914
May-06	4.83	R 20,568
Jun-06	4.57	R 145,572
Jul-06	0.78	R 9,783
Aug-06	1.21	R 38,441
Sep-06	0.00	R 534
Oct-06	0.00	R 0
Nov-06	0.00	R 75
Dec-06	3.11	R 2,663
Jan-07	3.12	R 3,378
Feb-07	3.20	R 3,471
Mar-07	3.23	R 2,869
Apr-07	1.70	R 39,173
May-07	1.99	R 2,444
Jun-07	3.88	R 28,444
Jul-07	4.00	R 44,272
Aug-07	4.37	R 54,115
Sep-07	3.06	R 3,216
Monthly average	**3.36**	**R 39,973**

Table 4-2 Kopanang performance summary

The load shifted for each month may vary due to the availability of the equipment that makes up the hot water pumping system. The average load shifted during the first year of the case study was approximately 2.6 MW. This proves that REMS succeeded in its goal in realising electrical load shifting at Kopanang mine.

Note the Megaflex high-demand seasons, June, July, and August that are marked on the table. The savings realised during these months are higher than the low-demand seasons due to the rise in tariffs during the high-demand months. See section 1.1.5 on a discussion on the Megaflex pricing structure.

Predicted potential

Before the implementation the load shift potential of Kopanang was predicted to be 3.00 MW using REMS. Using the average load shifted for the duration of the study, which is 3.36 MW, the accuracy of the prediction is calculated as 89%.

Mponeng mine

Background

Mponeng mine is included in the case study because this mine differs from the other case studies in the amount of water being pumped via the water pump system and the sheer depth of the mine. Mponeng, which is currently the leading production mine in South Africa, is the second deepest gold mine in the world at 3372 m and produced 14 tons of gold in 2005 .

The water pumping system on Mponeng is responsible for delivering 45 ML of used water from the mine per day. The water pump system has an installed capacity of 47.2 MW.

Mine setup

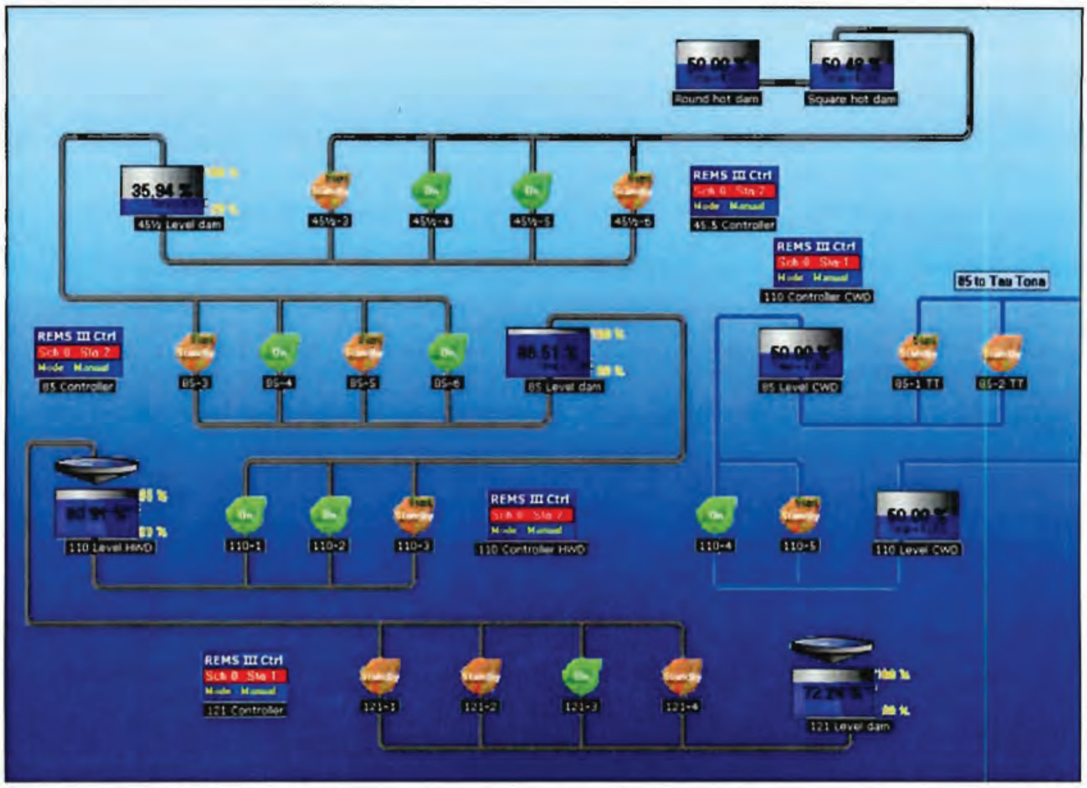


Figure 4-5 Mponeng water pump system

Mponeng's water pump system, as shown in Figure 4-5, has four pump stations. The complete system includes 15 electrical water pumps and six dams.

Performance summary

Mponeng performance summary June 2004 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Dec-05	11.29	R 44,245
Jan-06	12.32	R 51,691
Feb-06	11.56	R 45,652
Mar-06	11.00	R 44,775
Apr-06	12.09	R 37,513
May-06	14.00	R 55,973
Jun-06	15.00	R 479,005
Jul-06	14.13	R 418,937
Aug-06	13.69	R 428,127
Sep-06	13.57	R 0
Oct-06	12.72	R 0
Nov-06	11.46	R 54,527
Dec-06	12.33	R 43,699
Jan-07	13.32	R 67,203
Feb-07	13.64	R 54,745
Mar-07	13.64	R 70,886
Apr-07	13.62	R 48,931
May-07	13.80	R 66,922
Jun-07	12.59	R 371,199
Jul-07	12.63	R 408,657
Aug-07	11.90	R 370,982
Sep-07	15.44	R 84,777
Monthly Average	**12.99**	**R 147,657**

Table 4-3 Mponeng performance summary

Table 4-3 shows the performance of REMS on Mponeng mine for the period December 2005 to September 2007. These results show that REMS was successful in its implementation on this mine.

Note that there is a drastic increase in the savings realised during June 2006, and August 2006, and June 2007, and August 2007. This is due to the fact that June and July fall into the Megaflex high-demand season. The running cost of the system is higher during these high-demand months, but the potential savings also rise.

Predicted potential

The predicted load shift potential for Mponeng was calculated at 12 MW. Using the average load shifted since the implementation of REMS, the accuracy of the prediction was calculated as 92 %.

Previous load shift attempts on Mponeng mine

Before REMS was installed on Mponeng mine, manual load shifting was attempted. The success the mine achieved by this manual load shifting is shown by the profile of the Mponeng base line, which is shown in Figure 4-6 Mponeng base line.

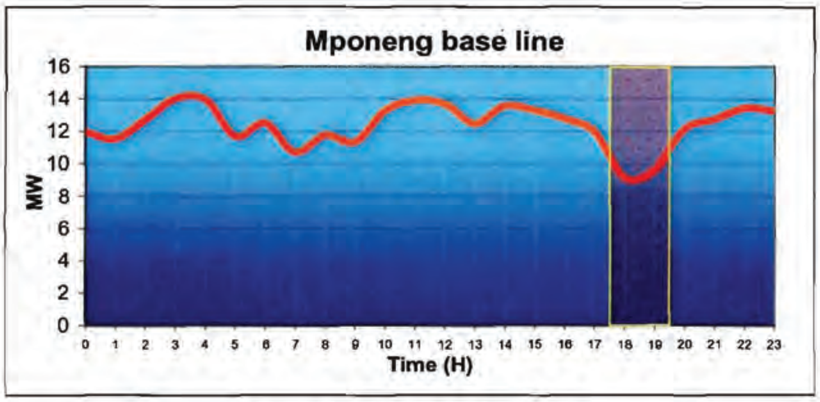


Figure 4-6 Mponeng base line

The success achieved by REMS on Mponeng mine was additional savings and load shifting achieved over and above the savings and load shifting achieved by the mine. This indicates how much more effective REMS is in shifting load and reducing running cost than that of a manual operator driven system.

4.4.2. Intricate pump systems

Elandsrand mine

Background

Elandsrand is included into this case study as it proved to be one of the most complicated mines to control. This is because of the internal water cycling in the water system and because of the small dam capacities. The smaller the dam's capacity, the quicker it fills up. This requires a much faster and more responsive control system. Again REMS proved successful in this case study, proving its capability to control complicated systems.

Mine setup

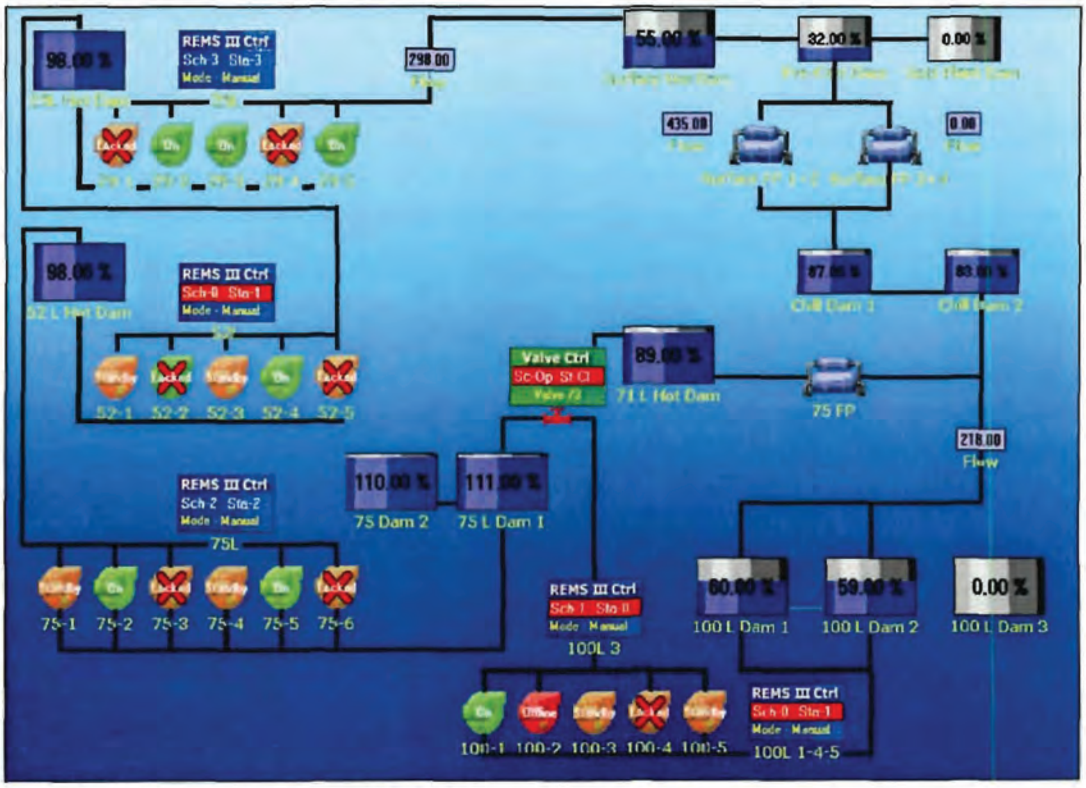


Figure 4-7 Elandsrand water pump system

Elandsrand's water pumping systems consist of four pumping systems situated on levels 100, 75, 52 and 29 containing a total of 21 pumps and 7 dams.

Performance summary

Elandsrand performance summary June 2004 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Jun-04	5.27	R 91,552
Jul-04	4.32	R 73,877
Aug-04	4.04	R 136,358
Sep-04	3.77	R 19,102
Oct-04	3.03	R 21,854
Nov-04	3.18	R 15,301
Dec-04	2.06	R 9,446
Jan-05	3.53	R 14,004
Feb-05	2.68	R 13,188
Mar-05	3.33	R 7,342
Apr-05	3.27	R 601
May-05	2.35	R 3,772
Jun-05	3.05	R 58,290
Jul-05	4.25	R 30,278
Aug-05	3.78	R 16,961
Sep-05	2.74	R 3,052
Oct-05	2.70	R 7,723
Nov-05	3.49	R 9,192
Dec-05	4.36	R 8,500
Jan-06	4.26	R 4,634
Feb-06	**0.00**	**R 1,531**
Mar-06	**0.00**	**R 0**
Apr-06	**0.00**	**R 1,043**
May-06	**0.00**	**R 1,126**
Jun-06	**0.00**	**R 22,339**
Jul-06	**0.00**	**R 0**
Aug-06	**0.00**	**R 661**
Sep-06	**0.00**	**R 775**
Oct-06	**0.00**	**R 0**
Nov-06	**0.00**	**R 142**
Dec-06	**0.00**	**R 50**
Jan-07	**0.00**	**R 105**
Feb-07	**0.00**	**R 0**
Mar-07	**2.44**	**R 1,801**
Apr-07	**0.00**	**R 552**
May-07	**0.00**	**R 2,809**
Jun-07	**0.00**	**R 4,575**
Jul-07	**0.00**	**R 1,136**
Aug-07	**3.47**	**R 25,215**
Sep-07	**0.00**	**R 0**
Monthly average	**3.47**	**R 27,251**

Table 4-4 Elandsrand performance summary

Table 4-4 shows the performance of the Elandsrand project for the duration June 2004 to January 2006. During the months of Feb 2006 to September 2007 Elandsrand entered a phase in which the dams of the water pumping system were cleaned. This resulted in REMS being disabled most of the time. No load was shifted and the relative saving realised during these periods are small. The normal operation of REMS will commence after dam cleaning is concluded.

The averages at the bottom of Table 4-4 was calculated omitting the months during which dam cleaning was done. This does not reflect any information on the ability of REMS as it was not activated during this months.

During Megaflex high-demand seasons (June, July, and August), marked on Table 4-4, higher savings were achieved. This is because of the high electricity cost during these months. See section 1.1.5 on a full explanation on Megaflex.

Predicted potential

Elandsrand's load shift potential was calculated at 3.00 MW prior to implementation. Using the actual average load shifted since implementation as 3.47 MW, the accuracy of the prediction is calculated at 86 %.

Bambanani mine

Background

This mine is included in the case study because of the complexity of its water cycle. Water is re-circulated within the cycle below ground and the cycle includes two water cooling plants, both underground. The water cycle splits into two loops at the bottom of the mine where the loops interchange water at various levels. As much as 65 ML water is pumped at Bambanani every day.

Mine setup

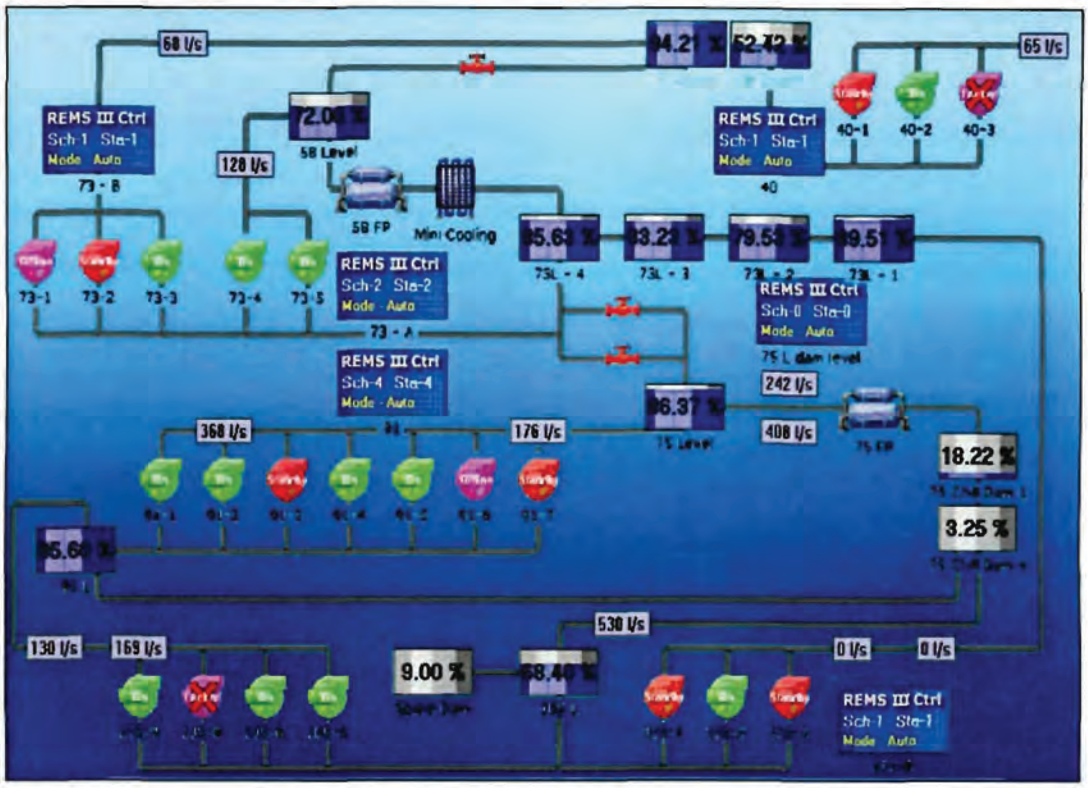


Figure 4-8 Bambanani water pump system

Similar to many other deep level gold mines in South Africa, water is used to cool the underground working environment. At Bambanani the water cooling plants are situated underground, which differs from other mines where the cooling plants are situated on the surface. Also different from other mines is the fact that water is re-circulated in-between the pump station levels, depending on where water is needed or where dam-capacity is available. This makes the Bambanani's water pump cycle a complex cycle to control.

Performance summary

Bambanani performance summary June 2004 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Apr-05	6.85	R 29,233
May-05	6.30	R 34,088
Jun-05	5.78	R 159,374
Jul-05	5.61	R 154,995
Aug-05	5.80	R 118,936
Sep-05	6.31	R 26,232
Oct-05	5.83	R 26,599
Nov-05	6.65	R 29,114
Dec-05	6.18	R 23,148
Jan-06	5.90	R 24,813
Feb-06	5.91	R 25,538
Mar-06	5.87	R 28,581
Apr-06	5.84	R 19,112
May-06	5.54	R 23,263
Jun-06	5.87	R 133,049
Jul-06	2.04	R 80,174
Aug-06	5.61	R 100,585
Sep-06	5.81	R 17,042
Oct-06	5.40	R 23,393
Nov-06	5.76	R 22,556
Dec-06	6.30	R 15,407
Jan-07	5.48	R 20,757
Feb-07	5.96	R 22,547
Mar-07	6.28	R 2,073
Apr-07	0.00	R 6,800
May-07	3.14	R 20,727
Jun-07	0.00	R 58,811
Jul-07	5.93	R 56,180
Aug-07	5.95	R 29,977
Sep-07	5.97	R 26,002
Monthly average	**5.33**	**R 45,304**

Table 4-5 Bambanani performance summary

Table 4-5 shows the performance of REMS on Bambanani mine for the duration April 2005 to September 2007. These results show that REMS was successful in its intention at this mine.

Note the Megaflex high-demand seasons, June, July, and August that are marked on the table. The savings realised during these months are higher than the low-demand seasons due to the rise in tariffs during the high-demand months. See section 1.1.5 on a discussion on the Megaflex pricing structure.

Predicted potential

The predicted load shift potential for Bambanani was calculated at 5.80 MW. Using the average load shifted since the implementation of REMS, the accuracy of the prediction was calculated as 91 %.

4.4.3. Intricate pump systems integrated with three-pipe systems

Tshepong mine

Background

This mine is included in the case study as it tested and proved REMS effectiveness in working in a unique environment. Tshepong incorporated a three pipe pumping system into their water pump systems. REMS therefore had to incorporate the working of this system into the overall control of the water pumping system. This implementation was published in the Journal of Energy [101].

A three pipe water pumping system is used, much like normal pumps, to pump water out of the mine. The three pipe system does not use electricity as its main source of power, but extracts potential energy from the water being fed down and into the mine, and uses this energy to pump used water out of the mine. The full working and integration of the three pipe water system into the water pumping system of Tshepong is explained in a thesis by myself, as referenced [102].

Mine setup

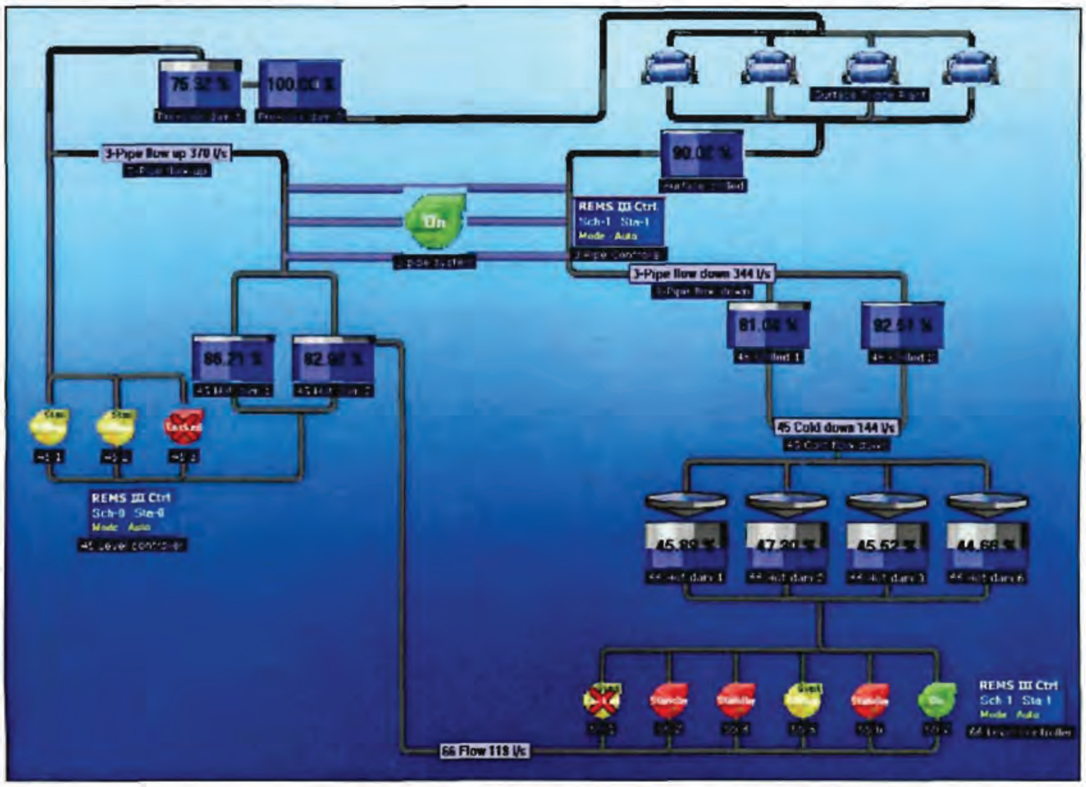


Figure 4-9 Tshepong water cycle

Figure 4-9 shows the Tshepong water cycle. It starts with the refrigeration plants (marked "Surface Fridge Plant") where the water is cooled down to about 3°C. From there the water is channelled down into the mine via a series of dams (marked "Surface Chilled" and "45 Chilled"). The cooled water is then used mainly for cooling air in the mine as it is passed through bulk air coolers. Most of the water is re-collected, first into settlers to remove most of the mud, and then into the four dams situated on 66 level (marked "66 Hot Dam 1" to "66 Hot Dam 4").

Here the water pumping system begins, starting with the 66 pump-station consisting of the six pumps (marked "66-1" to "66-7"). 66 pump-station pumps water from 66 level to two dams situated on 45 level (marked "45 Hot Dam 1" and "45 Hot Dam 2"). From there the water is pump via 45 Pump Station, which consists of three pumps (marked "45-1" to "45-2") and the three-pipe system (marked "3 pipe system"), to a dam on the surface (marked "Pre-Cool Dam 1").

The three-pipe system and 45 pump station work in parallel. REMS had to be set up to work around the availability and status of the three-pipe system. Switching the three-pipe system on and off is more complicated than controlling normal electrical pumps.

Performance summary

Tshepong performance summary October 2005 - Sep 2007		
Month	**Load shifted (MW)**	**Savings achieved**
Oct-05	4.11	R 95,802
Nov-05	4.26	R 80,572
Dec-05	4.07	R 86,121
Jan-06	3.84	R 41,730
Feb-06	3.93	R 17,600
Mar-06	3.18	R 11,588
Apr-06	3.20	R 34,379
May-06	3.40	R 61,854
Jun-06	3.74	R 51,347
Jul-06	4.32	R 80,174
Aug-06	3.88	R 79,528
Sep-06	3.21	R 2,970
Oct-06	4.43	R 8,289
Nov-06	4.51	R 73,843
Dec-06	3.39	R 78,131
Jan-07	4.00	R 70,178
Feb-07	4.46	R 90,836
Mar-07	3.38	R 117,866
Apr-07	3.87	R 121,062
May-07	3.83	R 111,136
Jun-07	4.91	R 328,104
Jul-07	4.69	R 337,404
Aug-07	4.65	R 355,599
Sep-07	4.97	R 130,560
Monthly average	**4.01**	**R 102,778**

Table 4-6 Tshepong performance summary

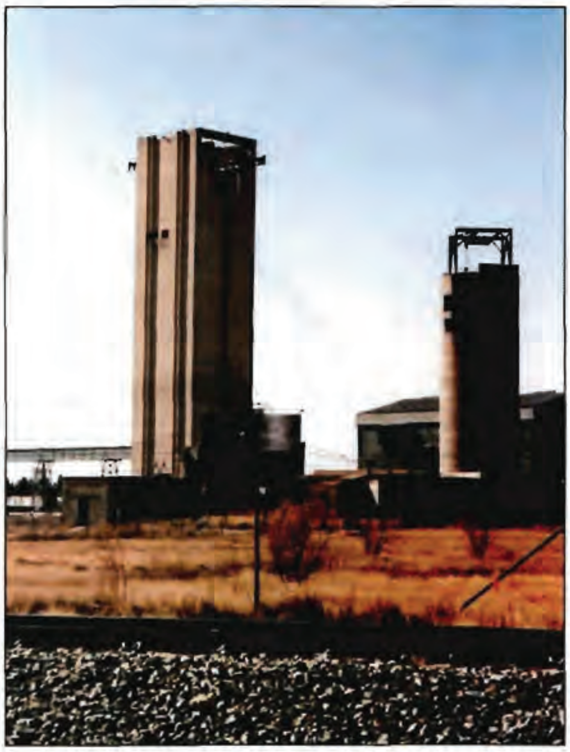
Table 4-6 summarise the success of the project for the period October 2005 to September 2007. The savings realised, plus the load shifted, show the success of REMS on Tshepong.

Predicted potential

Prior to implementation the load shift potential of Tshepong was calculated at 3.10 MW. Using the average load shifted since the implementation of REMS as 4.01 MW, the accuracy of the prediction is calculated as 77 %. This prediction was so poor because of a very conservative approach to incorporating a three-pipe pumping system into the workings of REMS. This three-pipe water pumping system proved to be more reliable than assumed during the preliminary load shift potential predictions.

4.4.4. Other pump systems

Masimong 4#



Background

Masimong 4#, a Harmony Gold mine, is situated near Welkom in the Free State. This shaft is used to pump excess underground water to surface to prevent the surrounding mines from flooding. This mine has an approximate depth of 2,250 meters with only two pump stations. The pump levels are situated at levels of 2,180 and 1,200 meters below ground level. 11 ML of water is pumped daily with the water pumping system with an installed capacity of 18.8 MW.

Mine set-up

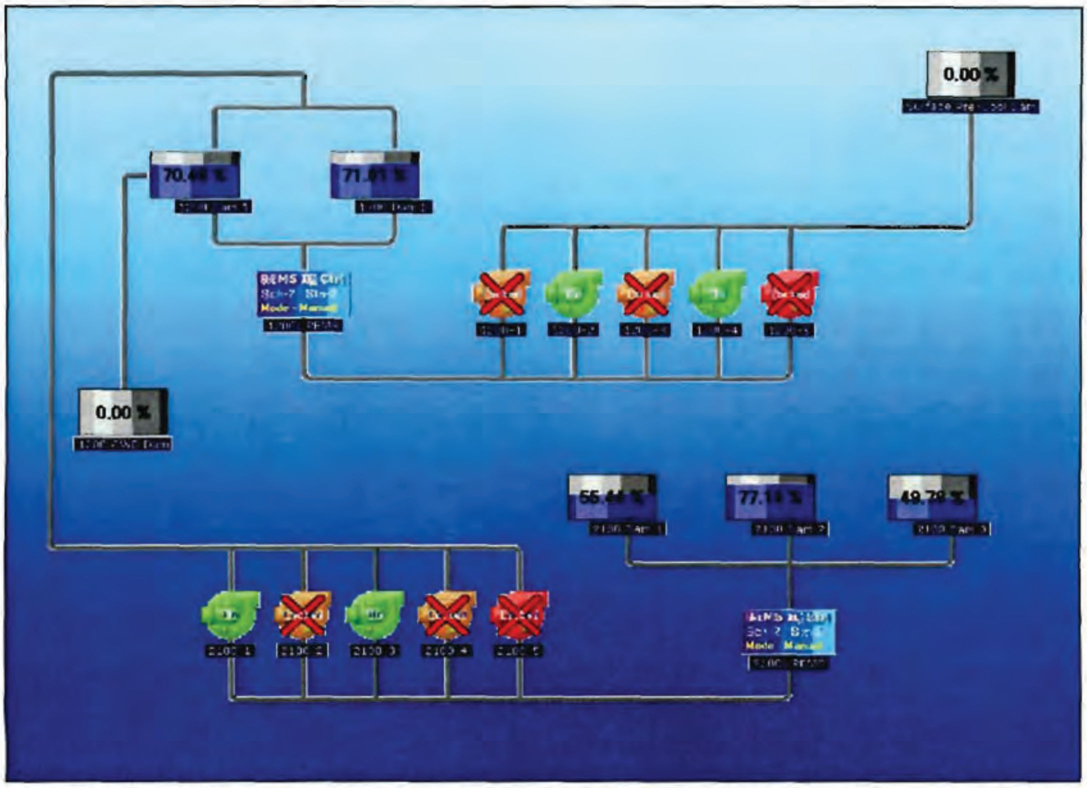


Figure 4-10 Masimong water cycle

The water pumping system at Masimong, as shown in Figure 4-10, consists of only two pump stations, each containing 5 pumps. Water enters the water pumping system into the three dams marked "2180 Dam 1" to "2180 Dam 3". From there the water is pumped via the bottom pump station (marked "2180-1" to "2180-5") to the two dams on '1200 level' (marked "1200 Dam 1" and "1200 Dam 2"). The water is then pumped via '1200 pump station (marked "1200-1" to " 1200-5") to the surface.

Performance summary

Masimong 4# performance summary Aug 2005 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Aug-05	4.04	R 70,978
Sep-05	4.53	R 25,060
Oct-05	4.75	R 24,670
Nov-05	4.83	R 27,147
Dec-05	4.78	R 19,962
Jan-06	3.94	R 17,698
Feb-06	4.45	R 14,859
Mar-06	3.91	R 17,850
Apr-06	4.40	R 18,114
May-06	3.97	R 18,283
Jun-06	4.30	R 133,049
Jul-06	4.10	R 115,010
Aug-06	4.09	R 62,802
Sep-06	3.83	R 8,735
Oct-06	3.95	R 21,734
Nov-06	4.13	R 16,788
Dec-06	4.09	R 19,044
Jan-07	4.19	R 21,327
Feb-07	4.40	R 22,131
Mar-07	4.54	R 24,587
Apr-07	4.15	R 19,273
May-07	4.15	R 19,486
Jun-07	4.26	R 121,139
Jul-07	4.07	R 122,669
Aug-07	4.20	R 136,407
Sep-07	4.14	R 20,530
Monthly average	**4.24**	**R 43,820**

Table 4-7 Masimong 4# performance summary

Note that there is a drastic increase in the savings realised during the months of June, July and August. This is due to the Megaflex high-demand season. The running cost of the system is higher during these high-demand months, but the potential savings also rise. See section 1.1.5 on a discussion about Megaflex demand seasons.

Predicted potential

The predicted load shift potential for Masimong 4# was calculated at 3.90 MW. Using the average load shifted since the implementation of REMS, the accuracy of the prediction was calculated as 91 %.

Harmony 3#

Background

Harmony 3# is a Harmony Gold mine located close to Virginia in the Free State. Little mining activity takes place at Harmony 3#, but the mine is still responsible for pumping huge amounts of water to the surface. The water comes from Merriespruit 1#, Merriespruit 2#, and Harmony 2#. The water table of these mines are interconnected. If Harmony 3# is to stop pumping water, the mining activities at Masimong 4#, Masimong 5#, Merriespruit 1# and Merriespuit 3# would be in jeopardy.

The Harmony 3# water pumping system has an installed capacity of 11 MW. The system pumps 19 ML of water from underground to the surface per day.

Mine set-up

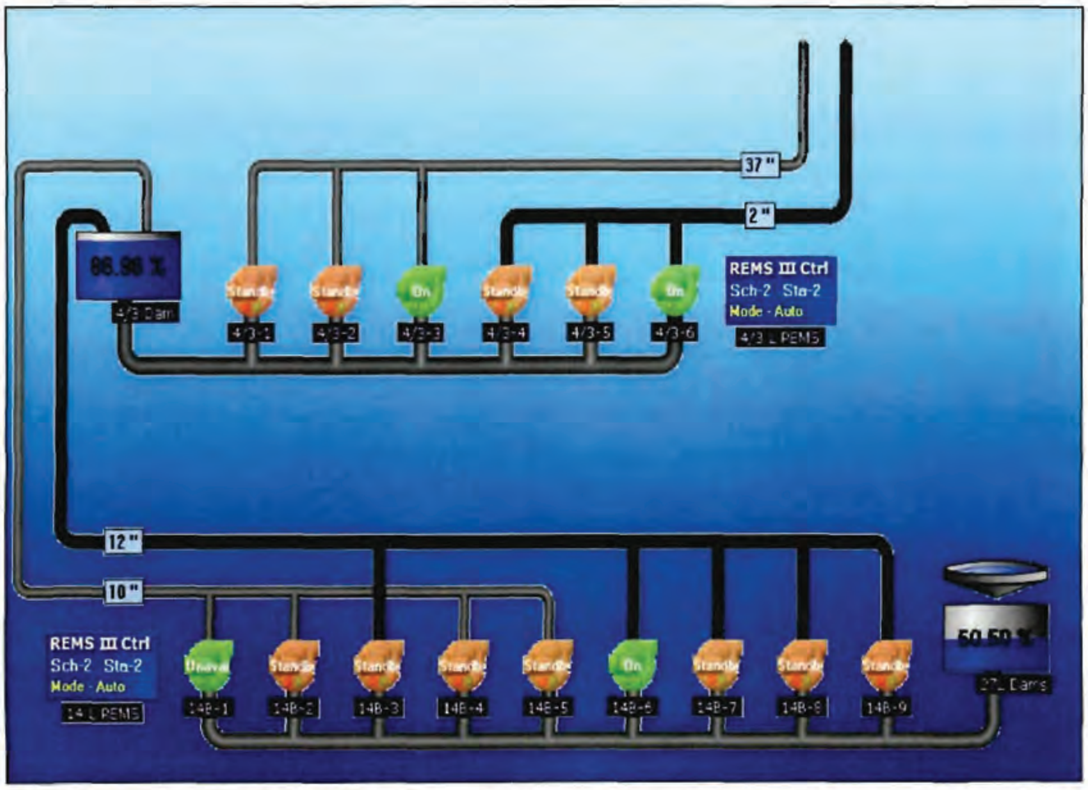


Figure 4-11 Harmony 3# water pumping system

Harmony 3# water pump system consists of only 2 pump stations. The bottom pump station consists of 9 water pumps of which 4 pumps deliver water into one column and the other five into a second column.

This situation where two water columns are available, posed a new opportunity to REMS. Always distributing the flow between the columns will ensure optimum efficiency of the pumps. REMS was set up to do this and proved successful in this regard.

Performance summary

Harmony 3# performance summary Sep 2005 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Sep-05	4.15	R 18,882
Oct-05	4.31	R 15,886
Nov-05	4.17	R 14,566
Dec-05	4.98	R 7,620
Jan-06	3.86	R 13,888
Feb-06	4.98	R 19,869
Mar-06	4.00	R 22,087
Apr-06	4.00	R 20,795
May-06	3.92	R 7,268
Jun-06	3.82	R 52,924
Jul-06	3.80	R 81,294
Aug-06	5.33	R 127,507
Sep-06	5.14	R 16,045
Oct-06	4.00	R 10,387
Nov-06	3.80	R 2,175
Dec-06	**0.00**	**R 4,394**
Jan-07	**0.00**	**R 2,441**
Feb-07	**1.60**	**R 4,583**
Mar-07	**0.00**	**R 2,852**
Apr-07	**0.00**	**R 2,206**
May-07	3.96	R 10,397
Jun-07	4.18	R 60,962
Jul-07	4.54	R 88,348
Aug-07	4.35	R 77,487
Sep-07	3.83	R 5,828
Monthly average	**4.26**	**R 33,711**

Table 4-8 Harmony 3# performance summary

REMS achieved no load shifting and cost saving during the months of December 2006 to April 2007. This is due to scheduled maintenance performed on all the pumps in the water pumping system. REMS was disabled during this period and these value are not taken into account in calculating the average success of the case study.

Predicted potential

The predicted load shift potential for Harmony 3# was calculated at 3.80 MW. Using the average load shifted since the implementation of REMS, the accuracy of the prediction was calculated as 89 %.

Target

Background

Target, a Harmony Gold mine, is situated near Allanridge in the Free State. The water pumping system of Target has an installed capacity of 7.8 MW. The water pumping system is responsible for pumping around 7 ML of water daily.

Mine set-u

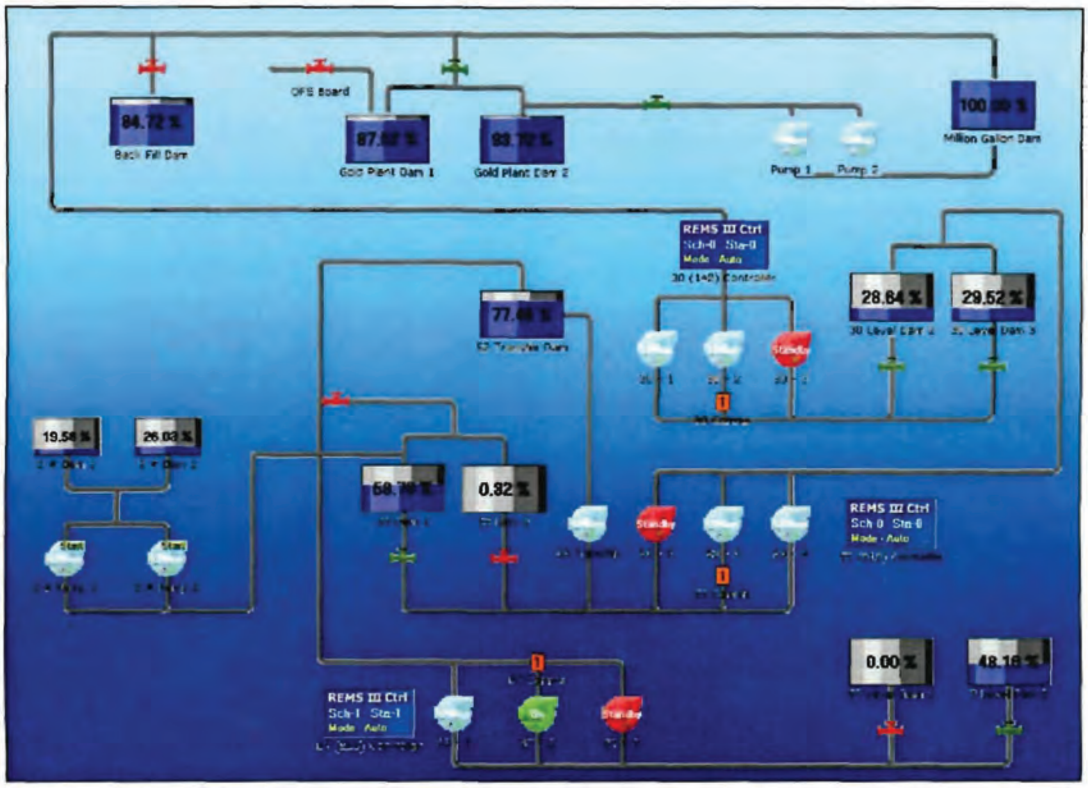


Figure 4-12 Target water cycle

The Target water cycle, as seen in Figure 4-12, is one of the more intricate cycles. The water pumping system has three pump stations. The water in this system is re-circulated underground. Valves that are also controlled by REMS dictate the circulation.

Performance summary

Target performance summary Nov 2005 - Sep 2007		
Month	**Load shift (MW)**	**Savings achieved**
Nov-05	1.93	R 11,697
Dec-05	1.86	R 9,309
Jan-06	1.83	R 9,273
Feb-06	1.81	R 8,428
Mar-06	1.82	R 10,759
Apr-06	1.78	R 8,738
May-06	1.78	R 9,948
Jun-06	1.88	R 20,346
Jul-06	1.89	R 65,545
Aug-06	1.83	R 48,347
Sep-06	1.72	R 7,754
Oct-06	1.73	R 11,819
Nov-06	1.69	R 10,827
Dec-06	1.62	R 8,370
Jan-07	1.80	R 10,364
Feb-07	1.91	R 11,702
Mar-07	1.80	R 11,031
Apr-07	1.82	R 8,891
May-07	1.90	R 8,112
Jun-07	1.88	R 42,324
Jul-07	1.86	R 35,755
Aug-07	1.91	R 47,760
Sep-07	1.82	R 9,975
Monthly average	**1.82**	**R 18,568**

Table 4-9 Target performance summary

Predicted potential

The predicted load shift potential for Target was calculated at 2.35 MW. Using the average load shifted since the implementation of REMS the accuracy of the prediction was calculated as 77 %.

4.5. Summary of results

Case study results summary				
Mine	Average load shifting (MW)	Average monthly savings	Potential prediction accuracy (%)	Time since implementation
Kopanang Mine	3.36	R 40,000	89	4 years
Mponeng Mine	12.99	R 147,700	92	2 year 4 month
Elandsrand	3.47	R 27,300	86	3 years 9 months
Bambanani	5.33	R 45,300	91	2 year 11 months
Tshepong	4.01	R 102,800	77	2 year 5 months
Masimong 4#	4.24	R 43,800	91	2 year 7 months
Harmony 3#	4.26	R 33,700	89	2 year 6 months
Target	1.82	R 18,600	77	2 year 4 month
Total	39.48	R 459,200		

Table 4-10 Case study result summary

Table 4-10 summarises the results of the case studies chosen for this research. The combined monthly savings of these projects is nearly R 460,000. The total load shifted on these eight projects comes to almost 40 MW.

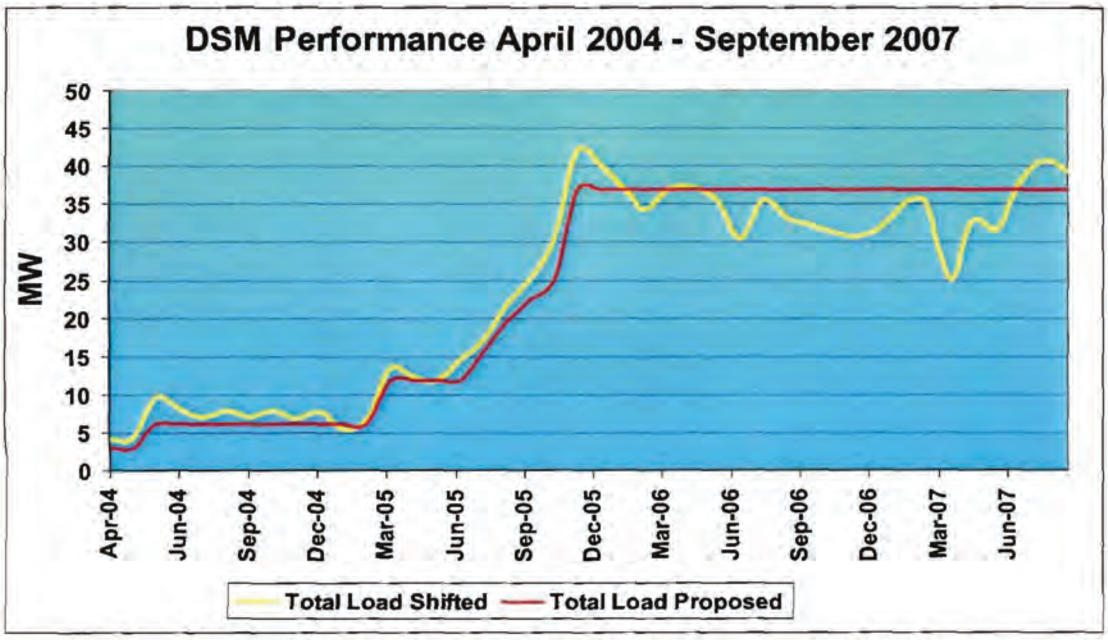


Figure 4-13 Accumulated load shifted April 2004 - September 2007

Figure 4-13 shows the total accumulative load shifted by optimised control performed by REMS. The figure shows the accumulation of load shifted on all the REMS pumping projects that were operational during this period, and included in this case study. The projects are Kopanang, Elandsrand, Bambanani, Masimong 4#, Harmony 3#, Tshepong, Target and Mponeng.

Figure 4-13 also shows the accumulative contractual load shift i.e. the load that is agreed upon between the ESCO and ESKOM that has to be shifted. It shows that REMS over-performed in comparison to the contractual target during this period.

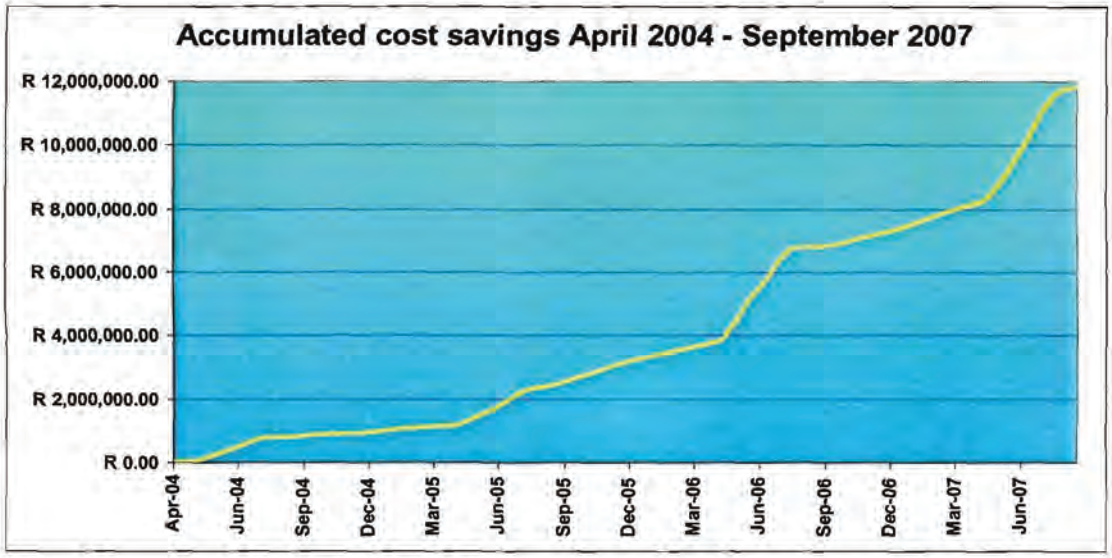


Figure 4-14 Accumulated cost savings April 2004 - September 2007

Figure 4-14 shows the accumulated savings REMS generated during the period April 2004 to September 2007. On April 2004 the first implementation of REMS was completed on Kopanang Mine. During the 34 months that followed, REMS generated an accumulated saving of R 11,800,000 on the eight mines included in this case study.

4.5.1. Electrical load shifting

One of the requirements set to this proposed invention, REMS, was that it should be able to shift electrical load as set out in section 1.2.5. Looking at the results listed and discussed, it is clear that REMS was successful in this regard. It can therefore be concluded that REMS is able to shift electrical load.

4.5.2. Electrical running cost savings

Section 1.2.5 stated that REMS must also be able to realise electrical running cost reduction during the control of a water pump system. The results in the previous section show that REMS was in fact able to realise electrical running cost reductions in all the described case studies. This concludes that REMS is able to realise electrical running cost reductions in the control of an industrial water pump system.

4.5.3. Predicted load shift potential

REMS was also developed with the ability to predict the load shift potential of any given project before implementation. The above results show the predicted potential against the actual load shifted, indicating the accuracy of the predictions made in using REMS. The accuracy of the predictions was in the region of 86.5% suggesting the reliability of REMS to predict the potential load shift potential of a project.

4.5.4. Sustainability

The case studies proved the sustainability of the system. REMS has been in control of seven mines for more than a year now. Five more projects have been controlled by REMS for a period of four months or more. REMS was not terminated on one of these mines.

4.5.5. Compatibility

The diversity of the case studies shows the sustainability of REMS in a wide variety of pump stations. REMS achieved successes in all these case studies, many of them very unique in comparison to the amount of water being pumped, the age of the pump system, the size of the pump system, the depth of the mine, the type of equipment used, set-up of the pump system, etc.

This proved that REMS is feasible in a wide range of pumping system set-ups. This gives an indication of the feasibility of this new invention in the South African mining industry and the impact it could have.