

# Implementation of DSM strategies at the Kopanang Mine

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## **Abstract**

*This paper describes the implementation of Demand Side Management (DSM) strategies at AngloGold's Kopanang Mine, for a period of three months during 2001. Since the unit price of electricity was very high during certain hours of the day, it was endeavoured to save costs by scheduling the operation of specific high power drawing equipment, (such as the clear water pumps and bulk air coolers), to operate mainly outside of peak hours. This objective was achieved by modelling and calculating a daily optimum operation schedule, which was supplied daily to the mine. As a result, an amount of R335 000 in electricity costs was saved during this period. It was also demonstrated that an additional R273 000 could have been saved if the supplied schedules had been complied with consistently.*

*Keywords: Kopanang Mine, demand side management, optimum operating schedule*

## **1. Introduction**

A previous study (Den Boef 2004) consisted of modelling three mines in order to determine whether demand side strategies on the ventilation, cooling and pumping systems of the mine, could save electricity and money. The study successfully demonstrated this.

Optimisation together with integrated simulation was used to study the possible cost savings and the impact on the operating limits of the different operating strategies. The preliminary study showed the potential of saving R1.47 million on the electricity bill, without compromising safety and comfort (Den Boef 2004).

The mine management was approached with these results for approval on the actual implementation of the proposed strategies. Kopanang's management agreed to the implementation of the pro-

posed strategies for a trial period of three months.

## **2. Implementation**

### **2.1 Implemented strategies**

The following strategies were implemented through the use of a daily operating schedule:

- On the underground pumping system, scheduling was used to shift load from the peak electricity tariff hours to cheaper hours.
- On the underground cooling system, the underground wet bulb temperature was used as the set point controlling the number of bulk air cooler (BAC) pumps active. This demand in turn, governed the amount of cooling required from the chillers.

### **2.2 Infrastructure**

A dedicated phone line was required to deliver the daily operating schedules. Fortunately, an extra phone line was available for this purpose in the control room. A modem was connected to the operator's computer to allow secure remote access to download condition data from the supervisory control and data acquisition (SCADA) system. Lastly, a fax machine was placed in the operating room as a backup for e-mails.

### **2.3 Software implementation**

To accomplish these functions, two new software programs were installed on the operator's computer. The first was a program that securely granted remote access to this computer and gave the off-site user the option to take complete control of the keyboard. The remote control functionality was turned off by default and was only used in the case where some maintenance to the software needed to be done. This piece of software was used to download SCADA data weekly for ongoing calibration of the optimisation model, and for reporting on the operator's ability to follow the daily operating schedule.

The second piece of software was a program

added to the SCADA system that displayed the operating schedule for the current day on the computer. This program highlighted the current hour and showed in red where there were deviations from the operating schedule as shown in Figure 1. This is done to help the operators to comply with the operating schedule.

This piece of software also recorded all the relevant SCADA measurements on a five-minute interval basis in a text file that was remotely downloaded once a week for calibration and reporting.

**2.4 Optimisation model calibration**

The boundary conditions as well as the component models used in the optimisation to calculate the optimum operating schedule, needed to be recalibrated to ensure accuracy due to the time span between the simulation model calibration (Den Boef 2004) and the actual implementation. This time span was just less than a year. A day calibration was done using the measured condition data as well as the on/off status of each of the components. Only slight adjustments to the component models were required. The flow of spilled cold water, used for drilling and cooling, through the mine into settlers and finally to the hot water dams on Level 75 was, however, not as predictable. This boundary was therefore calibrated once a week for the following week during the trial period (Den Boef 2004). The other components were only calibrated once a month.

**2.5 Daily operating schedule**

A daily optimisation had to be done to calculate the optimum operating strategy for the day. To deliver this service, an optimum schedule had to be calculated in advance to enable the operators to follow

the schedule from the start of the day. The daily RTP (Real Time Pricing) price signal was available from Eskom from 16:00 on the previous day. This meant that the optimum operating schedule for the next day could be generated after 16:00, and then be sent to the operators.

The generation of the optimum operating schedule consisted of the following steps:

*2.5.1 Downloading price and weather information*

The RTP price was downloaded daily, anytime after 14:30, from the following website: [www.enerweb.co.za/ftp/pub/ftp/rtp2p/latest\\_rtp2p.csv](http://www.enerweb.co.za/ftp/pub/ftp/rtp2p/latest_rtp2p.csv). The predicted minimum and maximum temperatures had to be downloaded, anytime after 16:00, from the following website: [www.weathersa.co.za/fcast/maxmin.htm](http://www.weathersa.co.za/fcast/maxmin.htm). This data then had to be combined into one file to facilitate its use in the optimisation process.

*2.5.2 Calculation of the climate data*

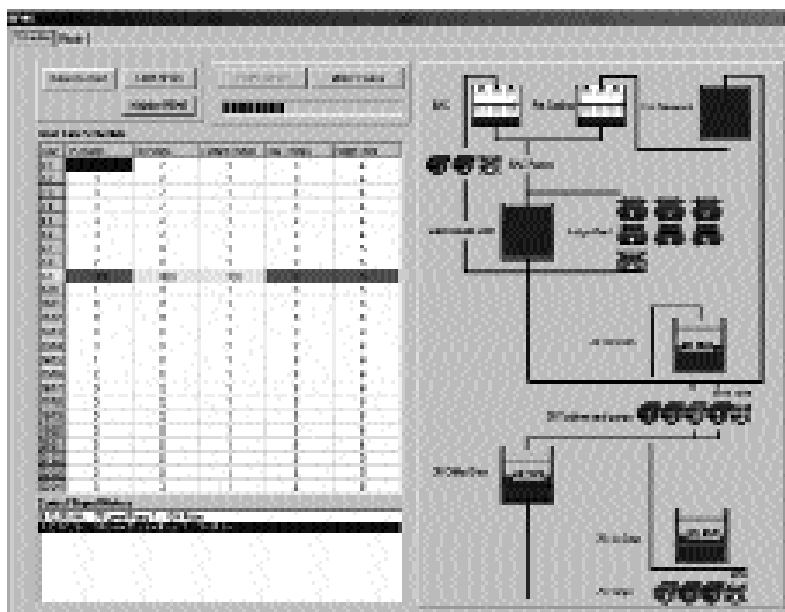
From the downloaded minimum and maximum temperatures, the hourly dry bulb and wet bulb temperatures were calculated.

*2.5.3 Optimisation*

All the variables were then reset to zero, and the optimisation of each of the subsystems was done. The newly calibrated boundary and component data was fed to a commercial solver for the optimisation (Frontline Systems). After the optimisation, the number of components active every hour needed to be rounded down or up to integer values.

*2.5.4 The final operating schedule*

This calculated number of components active every hour was then summarised in a report that was sent to the mine. In Figure 2 an example of such a report



**Figure1: The display of the operating schedule on the SCADA interface**

## RTP operating schedule

Client:  Date:  Consultant:   
 Day:  Predicted cost:

| Time  | 75 level elec pumps | 38 level elec pumps | 38 level turbine pumps | DMC pumps    | Chilled water plant | Rock winders |
|-------|---------------------|---------------------|------------------------|--------------|---------------------|--------------|
| Hours | Units active        | Units active        | Units active           | Units active | Units active        | Active hours |
| 0-1   | 3                   | 1                   | 1                      | 1            | 5                   | ON           |
| 1-2   | 3                   | 2                   | 1                      | 3            | 5                   | ON           |
| 2-3   | 3                   | 2                   | 1                      | 3            | 5                   | ON           |
| 3-4   | 3                   | 1                   | 1                      | 3            | 5                   | ON           |
| 4-5   | 3                   | 2                   | 1                      | 3            | 5                   | ON           |
| 5-6   | 3                   | 1                   | 1                      | 3            | 5                   | ON           |
| 6-7   | 3                   | 2                   | 1                      | 3            | 5                   | ON           |
| 7-8   | 1                   | 0                   | 1                      | 0            | 3                   | OFF          |
| 8-9   | 0                   | 0                   | 1                      | 0            | 3                   | OFF          |
| 9-10  | 0                   | 0                   | 1                      | 0            | 3                   | OFF          |
| 10-11 | 3                   | 2                   | 1                      | 3            | 6                   | ON           |
| 11-12 | 3                   | 0                   | 1                      | 3            | 6                   | ON           |
| 12-13 | 0                   | 0                   | 1                      | 3            | 6                   | ON           |
| 13-14 | 3                   | 2                   | 1                      | 3            | 6                   | ON           |
| 14-15 | 1                   | 0                   | 1                      | 3            | 6                   | ON           |
| 15-16 | 3                   | 0                   | 1                      | 3            | 6                   | ON           |
| 16-17 | 3                   | 0                   | 1                      | 3            | 6                   | ON           |
| 17-18 | 3                   | 0                   | 1                      | 3            | 6                   | ON           |
| 18-19 | 1                   | 2                   | 1                      | 0            | 3                   | ON           |
| 19-20 | 0                   | 0                   | 1                      | 0            | 3                   | OFF          |
| 20-21 | 0                   | 0                   | 1                      | 0            | 3                   | OFF          |
| 21-22 | 3                   | 0                   | 1                      | 2            | 4                   | ON           |
| 22-23 | 3                   | 1                   | 1                      | 2            | 4                   | ON           |
| 23-24 | 3                   | 2                   | 1                      | 2            | 4                   | ON           |

38 level hot water dam limits: 30%-60%  
 38 level chilled water dam limits: 30%-80%  
 75 level hot water dam limits: 30%-60%

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Tel: 012 881 5111

Use the hours 22:00-24:00 of the previous day for the following (override sc Cell: 083 377 3055)

MIMIC  
 Tel: 018 478 0201/02  
 Fax: 018 478 9219

Begin this day with 38 level hot water dam between 60%-70%  
 Begin this day with 38 level chilled water dam between 80%-90%  
 Begin this day with 75 level hot water dam between 60%-70%

**Figure 2: Optimum operating schedule as faxed to the operator**

is shown.

### 3. Results

#### 3.1 Load prediction model

##### 3.1.1 Previous operating strategy pumping profiles

Average daily pumping profiles were calculated for each day of the week, for the summer and winter seasons from the 2000 data supplied. The same philosophy was utilised in calculating the daily customer base line (CBL) profiles (Den Boef 2004; Kern 1998). The profiles can therefore be seen as pumping CBLs. Figure 3 shows these profiles.

##### 3.1.2 Previous operating strategy refrigeration profiles

Daily summer and winter refrigeration profile equations were derived from 2000 data, as a function of daily minimum and maximum ambient temperatures. (Hourly energy =  $f(T_{min}, T_{max})$ ).

##### 3.1.3 Actual measured total load

The actual cost was calculated on the actual total load profile measured at Koppanang. The refrigeration plant and the underground pumping systems

electricity consumption, was measured separately. This enabled the calculation of a daily base load known as the *actual base load* in the rest of the paper.

##### 3.1.4 Predicted total load

The implemented strategy on the pumping system only contributed to load shifting. This means that to pump the same amount of water, the total daily electricity consumption of the predicted and actual pumping profiles had to be the same. The predicted profile was scaled up or down, using the difference in total daily pumping electricity consumption divided by 24 for every hour. This scaled predicted pumping profile and the predicted refrigeration profile were then added to the actual base load profile to obtain the predicted total profile.

The predicted profile cost was then calculated from this predicted total load profile. Figure 4 illustrates this calculation.

##### 3.1.5 Calibration and verification of model

This model was then used to predict the electricity load for each of the months of 2000. The predicted load was then compared with the actual measured

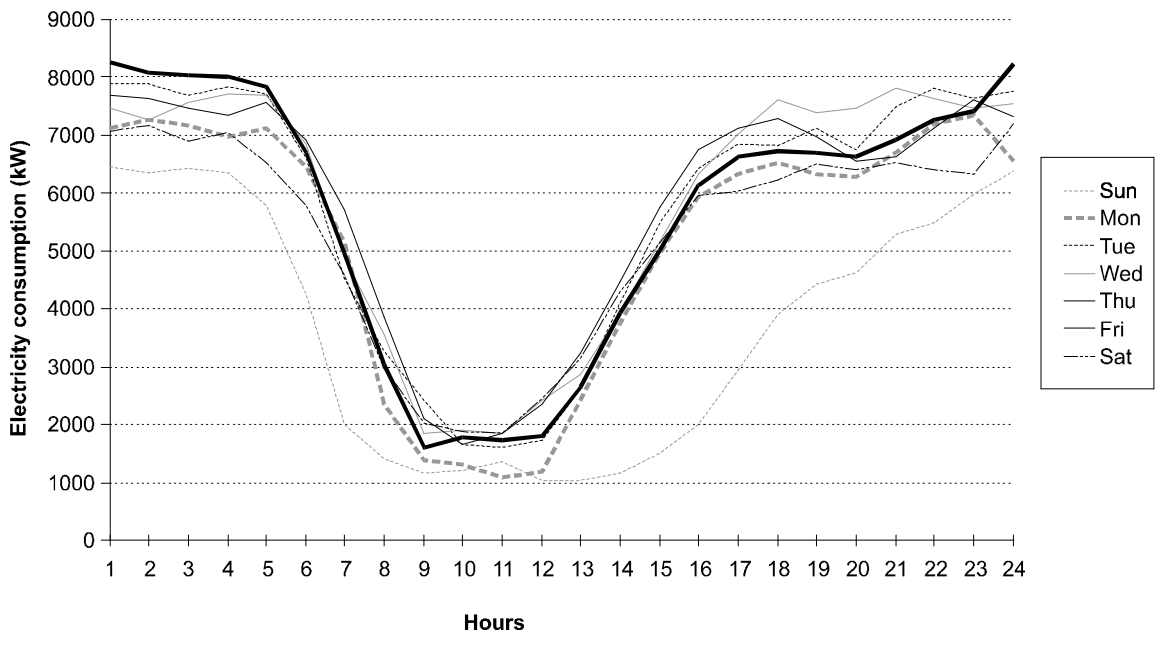


Figure 3: Summer pumping CBL's for Kopanang

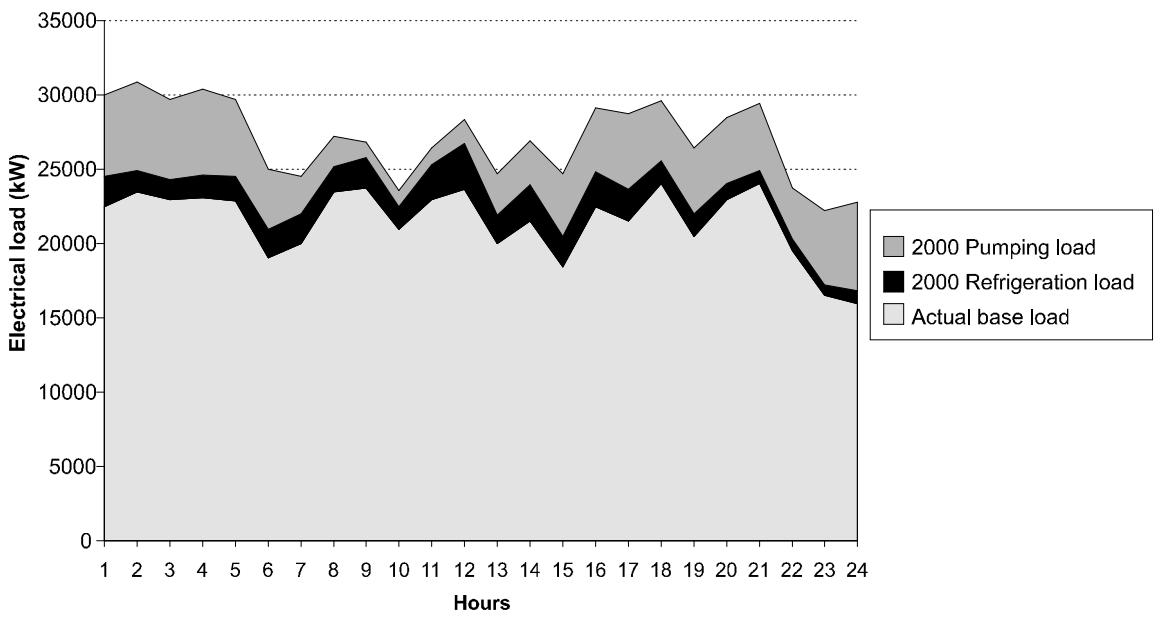


Figure 4: The composition of the predicted total load profile at Kopanang

load, in order to verify the accuracy of the prediction model. The total daily electricity costs of the predicted and measured load profiles were compared in order to gauge the accuracy of the load prediction profile. Figure 5 shows an extract of the daily electricity cost verification done on the load prediction model. The figure shows a stretch of 90 days extracted from the complete year verification. The absolute average error between the actual electricity cost and the modelled electricity cost was smaller than 1%. The load prediction model was accepted to be accurate enough to prove the actual

cost savings during the trial period by the mine management.

**3.2 Calculated savings**

In total, R335 446 was saved in the three-month period. An additional R273 101 could have been saved, if the operating schedules were followed 100% of the time as shown in Table 1.

The largest amount of this unrealised potential occurred in the first month, due to insufficient contact between the operators that had the schedules on the one hand, and the operators that had to con-

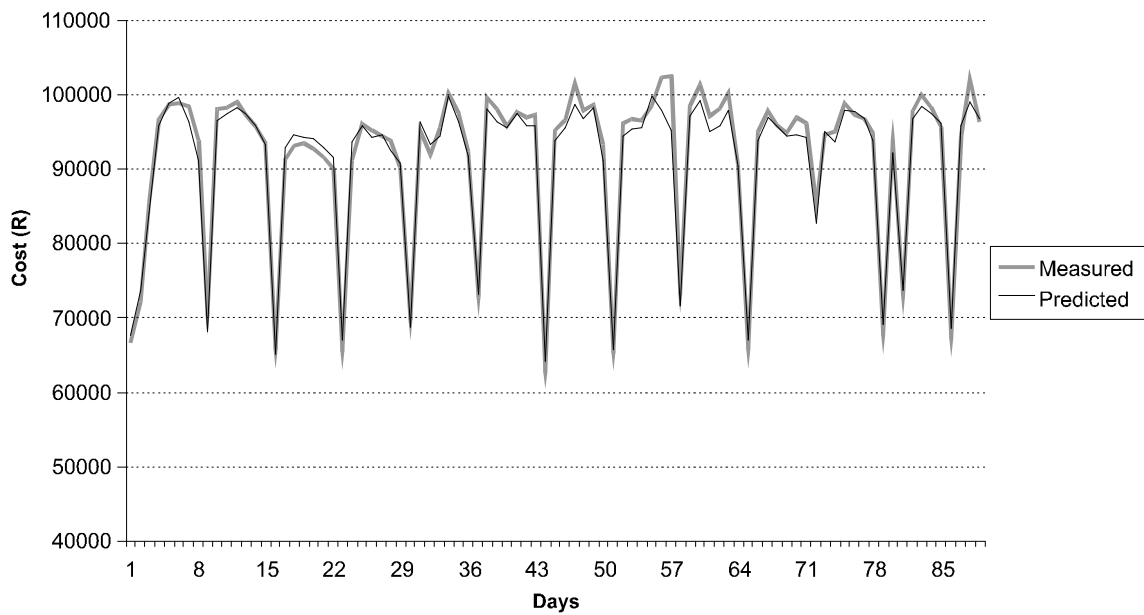


Figure 5: Load prediction model verification at Kopanang

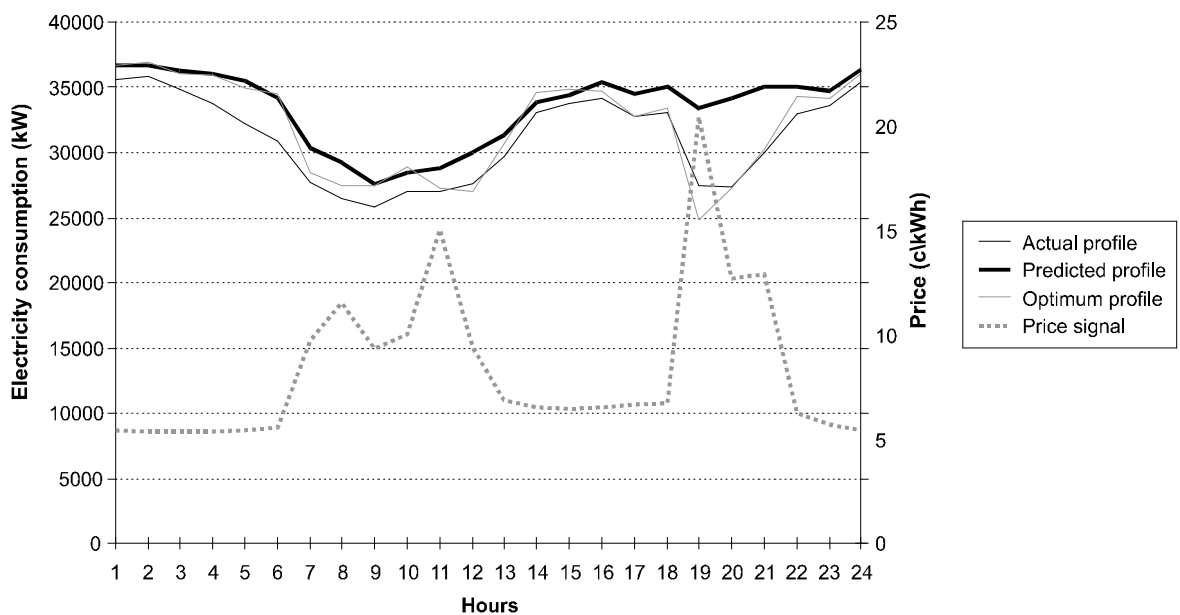


Figure 6: Average weekday demand profiles during September 2001 at Kopanang

Table 1: Summarised measured savings (in rands)

| Month          | Actual savings | Unrealised savings | Total possible savings |
|----------------|----------------|--------------------|------------------------|
| September 2001 | 188 808.50     | 214 000.79         | 402 809.29             |
| October 2001   | 69 250.83      | 41 677.45          | 110 928.28             |
| November 2001  | 77 386.80      | 17 422.86          | 94 809.66              |
|                | 335 446.13     | 273 101.10         | R 608 547.23           |

trol the refrigeration plant and the BAC's on the other. In addition, the electricity prices were extremely high during this time. After this was resolved, there was a steady decrease in the unrealised potential during the remaining two months.

Graphical representations of the average week-day profiles are shown in Figure 6. It can be seen that not all the required load was shifted during the peak price periods of the day, especially between 18:00 and 19:00. This was largely due to the refrigeration plant and BAC's.

#### **4. Conclusion**

The implementation consisted basically of a daily service, providing the mine operators with an hourly operating schedule. The infrastructure requirements were minimal. It consisted only of two phone lines and a modem. On the software side, a program was added to the current SCADA system to display the operating schedule, and any deviations from it. This program also stored the required condition data for the calibrations and reports.

A load prediction model was required to simulate the electricity demand according to the previous operating strategies, as a function of the RTP price and climate conditions. This model was within 1% of the total measured electricity cost for the year 2000.

The predicted, measured and optimised cost was compared for each of the months to calculate the actual saving achieved during the trial period. In total, R335 446 was saved during the three-month period. An additional R273 101 could have been saved if the operating schedules had been followed 100% of the time. The actual saving is very close to the predicted saving of R367 500 as calculated in the previous study (Den Boef 2004).

After three months, Kopanang decided to continue with the service. Currently the control is done automatically using the SCADA system and specifically designed optimisation software.

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