AN AUTOMATED SOLUTION TO FACILITATE SUSTAINABLE DSM IN THE MINING ENVIRONMENT

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Abstract

Title: **An automated solution to facilitate sustainable DSM in the mining environment.**

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Keywords: **DSM, ESCO, Sustainability, Automation**

South Africa is experiencing a serious electricity supply problem. This problem is expected to persist until at least 2012. During the winter of 2006 load shedding and electricity supply-cuts started occurring in the Western Cape. These spread to the rest of the country during the summer of 2007. By January 2008 daily load shedding was a common occurrence across South Africa.

In the 1990s the Department of Minerals and Energy (DME), the National Energy Regulator of South Africa (NERSA) and Eskom started a national demand side management (DSM) programme with the help of energy services companies (ESCOs). The aim is to reduce demand peaks and to promote the efficient use of electricity. These projects can be implemented much faster than building new power stations and are also more cost-effective. In 2008 an accelerated DSM program was launched to address the electricity shortage in South Africa.

Unfortunately, South African DSM projects experience the same sustainability problems as their counterparts overseas. These projects have been shown to be unsustainable over the five year

projected life-span. There are various reasons for this, including client mismanagement and maintenance problems.

An automated and rapid feedback system was identified as the best solution to address this problem. If plant personnel could be informed as soon as a DSM project's performance starts to decline, they would be able to respond much faster to rectify the problem. Reporting on DSM performance is difficult to achieve as these reports and the processing of measured data are time-consuming and presently no system exists to automate the process.

A new feedback solution was developed to fully automate the process of data gathering, processing and reporting. The implemented solution reduced the number of man-hours spent by ESCOs' project engineers dramatically. In addition, project performance increased by 13% and showed an increase in over-performance of 12.8%, while financial savings for clients improved by an average of 12%.

The feedback solution also provides the client with an accurate maintenance reporting system. This system can be implemented on all DSM projects, maximising Eskom's DSM investment.

Samevatting

Titel: **‘n Geoutomatiseerde stelsel om die volhoubaarheid van DSM in die mynboubedryf te verbeter.**

Outeur: **JP Steyl**

Promoter: **Prof M Kleingeld**

Sleutelwoorde: **DSM, ESCO, Volhoubaarheid, Outomatisering**

Suid-Afrika ondervind tans ‘n ernstige elektrisiteit verskaffingsprobleem. Die verwagting is dat hierdie probleem tot ten minste 2012 sal voortduur. Daar het reeds gedurende die winter van 2006 lasverminderings in die Wes-Kaap begin plaasgevind. Die probleem het verder versprei na die res van Suid-Afrika gedurende die somer van 2007. Teen Januarie 2008 was lasvermindering ‘n algemene verskynsel regoor Suid-Afrika.

In die 1990s het die Departement van Minerale en Energiesake (DME), die Nasionale Energie Reguleerder van Suid-Afrika (NERSA) en Eskom ‘n nasionale aanvraag bestuursprogram of *demand side management programme* (DSM) geloods. Die projek doel is om die energie-aanvraag pieke te verminder en ook om die effektiewe gebruik van elektrisiteit aan te moedig. Hierdie projekte kan baie vinniger geïmplementeer word as om nuwe kragstasies te bou en die koste daaraan verbonde is laer.

Ongelukkig blyk dit dat Suid-Afrikaanse DSM projekte dieselfde probleme ervaar as soortgelyke projekte oorsee. Die uitkomste is nie volhoubaar oor die vyf jaar geprojekteerde leeftyd nie. Daar is verkeie redes hiervoor, waaronder instandhoudingsprobleme en dat die kliënt belangstelling verloor.

'n Geoutomatiseerde terugvoerstelsel is geïdentifiseer as 'n manier om die probleem die hoof te bied. Indien die personeel gewaarsku kan word sodra die projek tekens begin toon van swak lewering, kan hulle vinniger regstellende stappe neem om die probleem op te los. Ongelukkig is dit baie moeilik vir 'n energiebestuursmaatskappy of *energy services company* (ESCO) om doeltreffende terugvoer te gee. Dit neem baie tyd in beslag om sulke verslae te skryf en huidiglik bestaan daar geen stelsel om die proses heeltemal te outomatiseer nie.

'n Nuwe terugvoerstelsel is ontwikkel om die proses te outomatiseer. Dit sluit in om die data in te samel, dit te verwerk en die verslae te skryf. Die geïmplementeerde stelsel het die ESCO baie man-ure gespaar. Verder het die piek las met 'n gemiddeld van 13% verminder en het projekte oorprestasie met 12.8% verhoog. Finansiële besparings vir die kliënte het verbeter met 'n gemiddeld van 12%.

Die nuwe terugvoerstelsel bied ook aan die kliënt 'n akkurate instandhoudingsverslaggewing-stelsel. Die stelsel kan nou saam met alle DSM projekte geïmplementeer word om Eskom se opbrengs op die belegging in DSM projekte te vergroot.

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Jaco Steyl

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Abbreviations and Nomenclature

CAM	-	Compressed air management
CFL	-	Compact fluorescent lamp
COM	-	Component object model
CSV	-	Comma delimited file
DME	-	Department of Minerals and Energy
DSM	-	Demand side management
EE	-	Energy efficiency
EH&S	-	Environmental, Health and Safety
ELI	-	Efficient lighting initiative
EMS	-	Energy management system
ESCO	-	Energy services company
GEF	-	Global Environment Facility
GPRS	-	General packet radio service
GUI	-	Graphic user interface
HVAC	-	Heating, ventilation and air-conditioning
IFC	-	International Finance Corporation
M&V	-	Measurement and verification
MD	-	Maximum demand (Electricity)
MS	-	Microsoft
NERSA	-	National Energy Regulator of South Africa
OOP	-	Object orientated programming
PC	-	Personal computer
PDF	-	Portable document format
SCADA	-	Supervisory control and data acquisition
UK	-	United Kingdom
US	-	United States (of America)
USB	-	Universal serial bus

USDOE	-	United States Department of Energy
VPN	-	Virtual private network
W	-	Watt
Wh	-	Watt hour
3G	-	Third generation (GPRS)
3CPS	-	Three chamber pipe system
k	-	Kilo (x 10^3)
M	-	Mega (x 10^6)
G	-	Giga (x 10^9)
T	-	Terra (x 10^{12})
p	-	electricity usage profile in kW
b	-	electricity baseline profile in kW
ς	-	add variable for scaling of baseline in kW
ENB	-	Energy neutral baseline in kW
ΔE	-	difference between p and ENB in kW
ec	-	cost of electricity per unit in c/kWh
α	-	Factor for scaling of ENB for Fraction method
x	-	Input variable
y	-	Output variable
#	-	Shaft (e.g. "Masimong 4#" = "Masimong 4 shaft")

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Chapter 1: Introduction

1.1 Electricity supply problems in South Africa

1.1.1 Preamble

Many South Africans experienced the discomfort of power outages from 2006 to 2008. These power disruptions occurred mostly because Eskom could not supply the full demand for electricity. In addition, Eskom has stated that this problem is expected to continue until 2012 [1]. In 2008 rolling power-cuts became a regular experience for many South Africans because the utility could not supply enough base load capacity [2]. In the third week of January 2008 only 77% of South Africa's total generating capacity was available [2]. During the winter of 2008 a nationwide electricity saving campaign was implemented and very little electricity cuts were necessary [1]. Unfortunately this programme was not sustainable and involuntary power-cuts were again implemented [1].

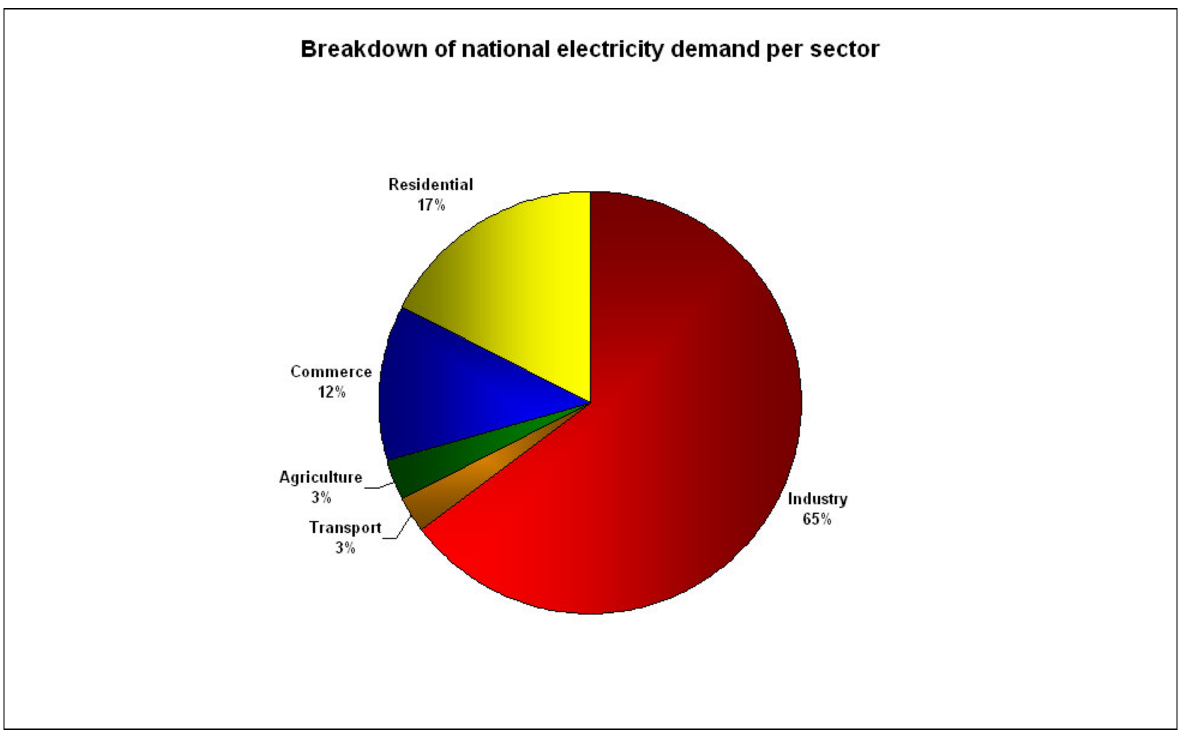

Figure 1-1: Breakdown of South African electricity demand per sector (Total load) [3]

Electrification of previously disadvantaged communities has contributed to the sharp increase in peak demand. In 2000 the South African Government announced that all residential consumers with a combined monthly income of less than R 800.00 would be entitled to 50 kWh of electricity “free of charge” on a monthly basis [4]. The aim of this rebate was to assist in poverty relief, through the provision of free basic services. Seasonal changes in temperature and adverse weather conditions also have an impact on electricity usage patterns. In South Africa a drop of one degree in the average winter temperature results in an increase in demand of 500 MW of power [4]. This in turn relates to the use of additional primary energy in the form of coal [4].

Every year the maximum demand (MD) increases as an increasing number of homes become electrified and more businesses draw energy to fuel the economy. South Africa also exports a lot of electricity. In December 2008 South Africa exported 3.7 TWh of electricity and only imported 2.4 TWh [5] . Lesotho is totally dependent on South-Africa for electricity. Electricity is again imported from Mozambique at approximately 800 MW.

1.1.2 Power stations and types of load

Eskom supplies 95.9% of South Africa’s electricity [6]. Unfortunately there are no practical means to store electrical energy on a large scale. Hydro-electric pumping systems can be used to filter out smaller peaks of electricity demand.

Due to the fact that electricity demand is not constant, different types of power stations are required to meet the fluctuating demand in the most efficient and effective manner. Two main categories of power stations can be identified: base load stations and peak load stations.

Figure 1-2: A coal-fired base load power station[1]

Base load indicates the average minimum amount of electricity consumed over an extended period of time. Base load power stations, largely coal-fired, are designed to operate continuously, since they require a minimum period of 8 hours from cold start-up to full load. In addition, starting up these power stations requires large quantities of fuel oil. Base load power stations are generally only shut down for scheduled maintenance or emergency repairs. Base load stations normally have a higher capital cost, but the fuel cost are lower [7].

[1] Camden power station, www.eskom.co.za

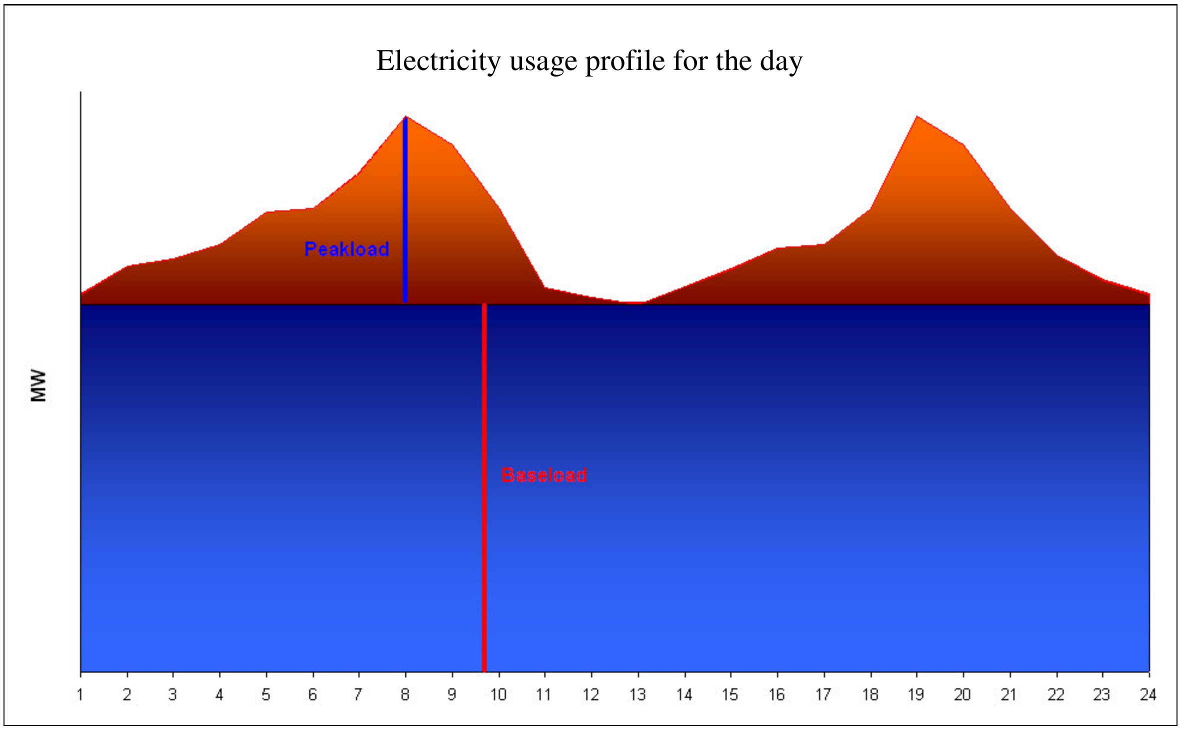

Figure 1-3: Base load and peak load times during the day

Base load power can also be supplied by nuclear power stations and, in countries with abundant water resources, hydro-electric power stations. South Africa's inconsistent rainfall and limited water resources preclude the use of hydro-electric power stations for base load needs. The country's abundant and relatively cheap low-grade coal makes coal-fired power stations an obvious base load choice.

Peak load indicates the additional demand placed on the system over and above the normal base load requirements. In South Africa, peak demand periods occur in the early mornings and early evenings. The morning peak is a combination of industrial and domestic demand, whereas the evening peak is caused mainly by domestic demand. In winter, record evening peaks have occurred as a result of the increased use of domestic heating appliances. Figure 1-1 shows the breakdown of South Africa's electricity demand [3]. Although the domestic sector uses only 17% of the base load, it is responsible for over 30% of the peak load [8]. Peak load power stations generally have a lower capital cost, but higher operating costs than base load stations [7].

Figure 1-4: A hydro-electric dam[2]

South Africa's peaking power stations are pumped storage schemes and gas turbines. Peaking power stations can react quickly to changes in demand and provide power to supplement generation capacity of base load stations.

In other parts of the world utilities have mid-merit power stations. These power stations' operating costs depends on various factors, mainly the cost of fuels. The capital costs of these plants are lower than base load plants, but still higher than peak plants. They are used to match the demand if base load power stations are not available [9][10].

Greenhouse gas emissions (GHG) are a major concern for all and will need to be addressed in the future. 60% of South Africa's CO_2 is generated by Eskom, with other GHG's, such as CH_4 (35% of national total), SO_2 (73% of national total) and NO_x (47% of national total) a huge cause

[2] Hoover dam, www.electricityforum.com/hydroelectricity.html

for concern [11]. Unfortunately, most of South Africa's power generating capacity is fuelled with fossil fuels so very little can be done in the short term to reduce GHG emissions other than reducing overall power consumption.

1.1.3 The electricity supply problem in South Africa

Figure 1-5 shows the present and projected generating capacity of Eskom's power stations and Figure 1-6 shows the growth in electricity demand over the past few years. The red line represents the peak demand. Eskom is presently unable to supply the MD of South Africa, and effective load management will have to be addressed.

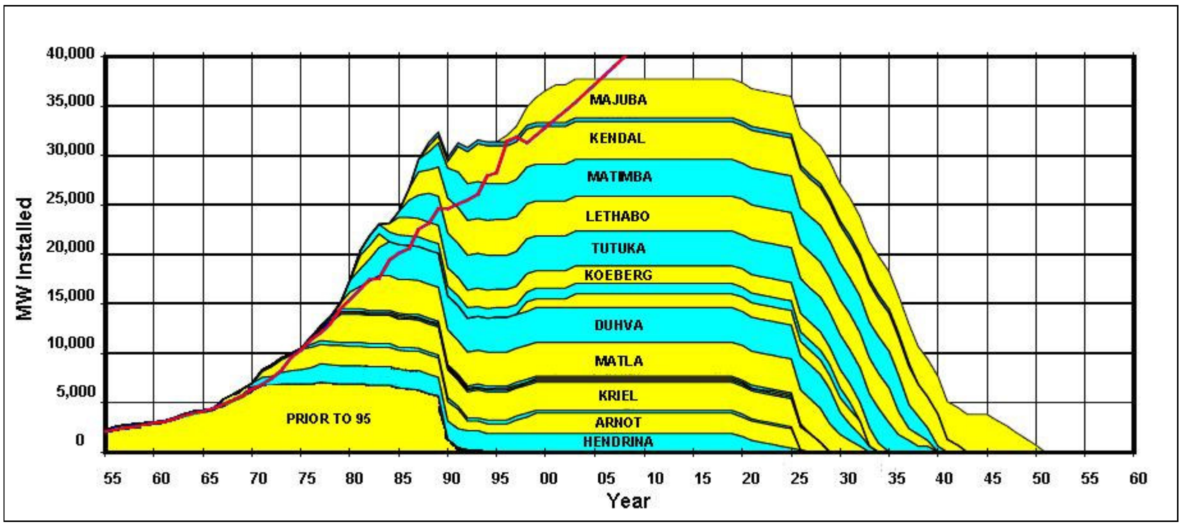

Figure 1-5: Eskom's generating capacity (historically and forecast) [13]

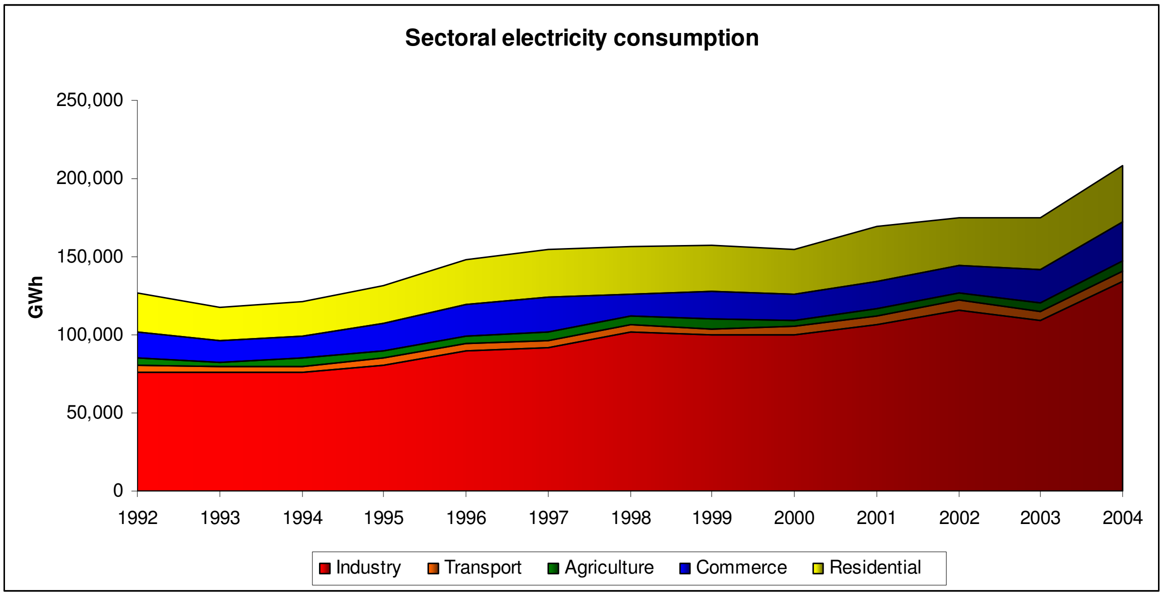

Figure 1-6: Electricity consumption growth by sector [3].

For the last few years load shedding was only required during winter periods. In 2008 consumers were also experiencing power cuts during the summer period. The reduction in reserve capacity makes it difficult to shut down generating sets for maintenance. This causes more unplanned maintenance and expenses due to excessive maintenance-related wear of equipment.

In South Africa, approximately 95% of the electricity is generated by coal-fired power stations, due to the abundance of cheap low grade coal [12]. Power stations are expensive to build and operate. For example, a modern coal-fired power station such as Lethabo, which went into commercial operation in 1990, would now cost approximately R30-billion to build [12]. Huge quantities of coal, referred to as primary energy, are consumed to produce electricity. A power station the size of Lethabo consumes an average of 50 000 tons of coal per day at a cost of approximately R2.8-million per day [12].

The electricity is transmitted from the power stations via a grid of 30 000 kilometres of high voltage overhead power lines. Voltages on this transmission grid range between 132 kV and 765 kV. The existing grid can only accommodate a specific amount of electricity. If the demand increases above this limit new transmission lines will have to be built. The construction of a 765 kV high voltage transmission line costs, on average, R1-million per kilometre [12].

Negative perceptions of nuclear power stations have resulted from disasters such as Chernobyl in Russia and Long Island in America and the possibility to produce weapons of mass destruction with material produced with nuclear reactors. France relies heavily on nuclear energy, but this is mainly because France has limited supplies of fossil fuels and the French government has historically assisted the utility in supplying technical knowledge and financed their long-term loans at very low rates [14].

Some of the short-term objectives of demand side management (DSM) are to reduce the average cost of generating capacity and improve the use of existing resources using lower risk demand side alternatives [15].

From the prior discussions it can be seen that the electricity supply problem in South Africa is threefold.

- The need for more electricity over the past few years has increased dramatically, as can be seen from Figure 1-5 and Figure 1-6.
- Eskom cannot build power stations in time to supply the increased demand because of the time it takes to develop the infrastructure.
- In 2020 some of the existing coal fire power stations will be at the end of their 50-year economically viable life cycle.

1.2 DSM projects in South Africa

1.2.1 Demand side management

The term “demand side management” was first used in the United States in the early 1980s to describe the “planning and implementation of utility activities designed to influence the time, pattern and/or amount of electricity demand in ways that would increase customer satisfaction, and at the same time produce desired changes in the utility's load-shape”[16].

Utility efforts to influence customer demand date back to the first generating power station - Thomas Edison's Pearl Street facility in New York City [17]. In the 1890s, when night-time lighting was the only load, Edison hired people to promote electric motors and other daytime uses of electricity. By encouraging round-the-clock electricity consumption, Edison was able to increase the utilization of generation capacity and reduce unit production costs. In 1882 Pearl Street had the installed capacity to power 800 light bulbs. Within 14 months this grew to 12 732 light bulbs serving 508 subscribers [18]. Today the opposite is true and the utilities attempt to reduce peak-time loads where there is a shortage of generating capacity.

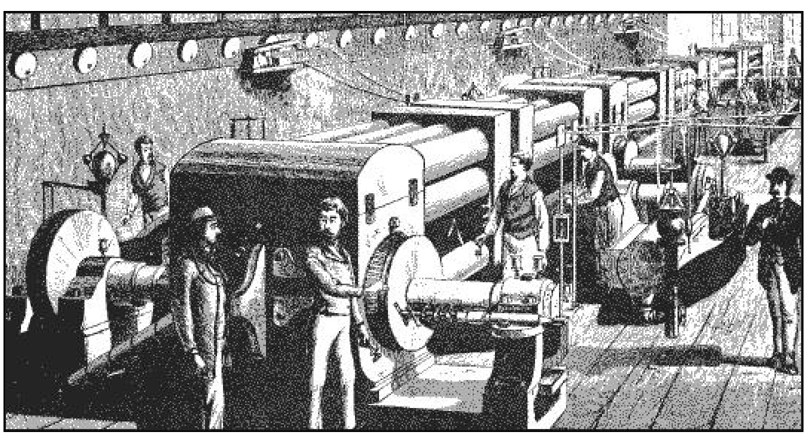

Figure 1-7: Edison's Pearls Street power station [18]

Normally an energy services company (ESCO) is employed to design and maintain the DSM projects and systems. There are numerous examples of companies that have contributed significant financial and energy savings by introducing energy efficiency (EE) programmes. In spite of these successes, it is significant that the adoption of these measures has not been universally accepted in South Africa. The reason for this can usually be found in one or more of the following [19]:

- **A company would rather focus on its core business**. Some companies are unwilling to explore other avenues to save operating costs. DSM is seen as a distraction that will waste their time and money. The acceptance of DSM in the South African Cement industry is much slower than for example the mining sector. This is because the cement industry is experiencing a huge boom in sales and its only focus is on increasing production. Relative to their sales DSM savings are small and there is a perception that DSM projects will reduce production [19].

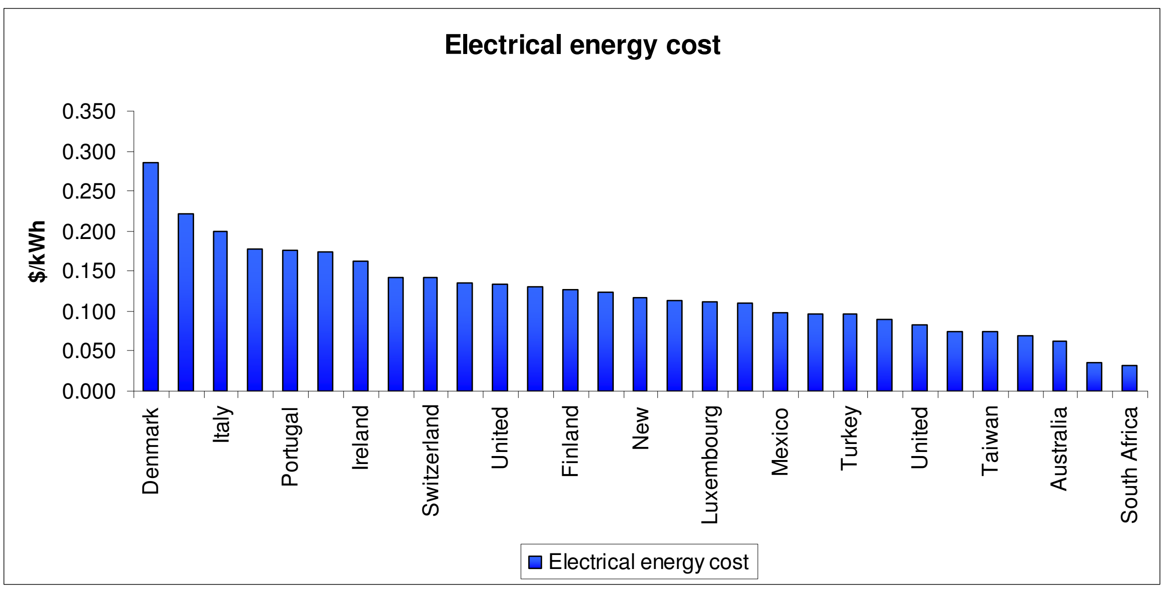

Figure 1-8: Relative electricity cost (2007) [20]

- **Electricity is cheap**. Until recently the cost of electricity in South Africa was very cheap relative to other countries as seen in Figure 1-8. For this reason there is a general perception that it is not worthwhile for small and medium electricity users to invest in energy-saving activities. Unfortunately the days of cheap electricity have come to an end, as can be seen from Figure 1-9 and Figure 1-10, and energy-saving alternatives have become more appealing [19][21][22].

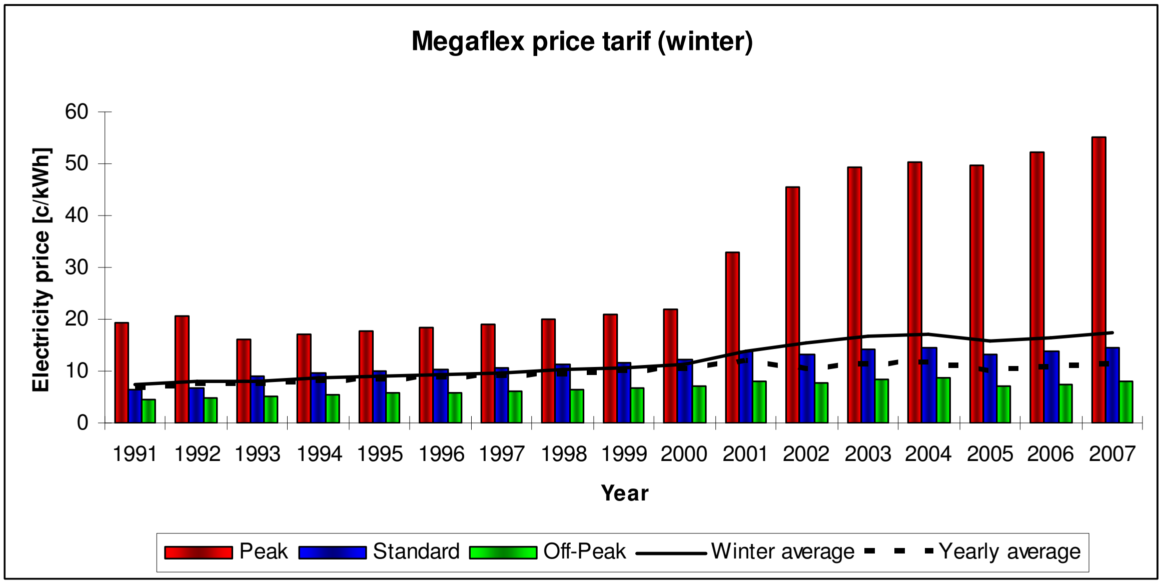

Figure 1-9: Price increases in the Megaflex pricing structure for winter months [21][22]

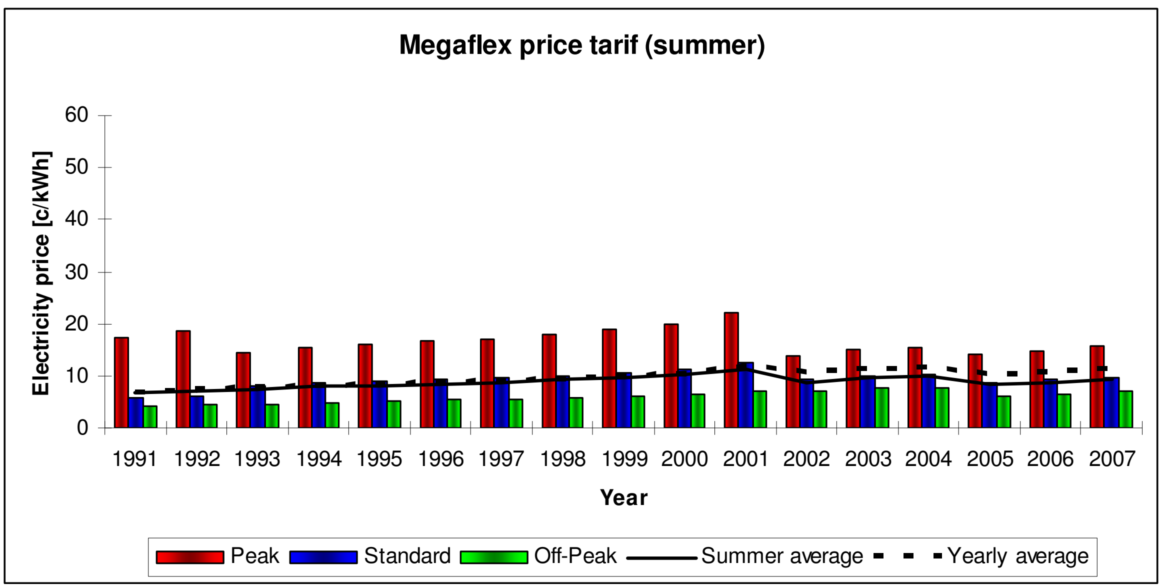

Figure 1-10: Price increases in the Megaflex pricing structure for summer months [21][22]

It can be seen that there has been a steady increase in the cost of peak electricity prices, especially in winter. Furthermore, Eskom has warned that a further tariff increase of between 20% and 25% can be expected over the next 3 years [1].

- **Resistance to change**. Some companies do not want to change their production schedules for fear of performing worse than before. The effort and risk to change outweighs the potential benefits [19].

- **Lack of capital**. Some EE measures involve the installation of expensive equipment. Users are nervous that the promises made by zealous salespersons may not be realised. Once again, education and objective information can go a long way to overcome these misgivings [19].

- **Uncertainty regarding the future**. Large electricity users are usually reluctant to commit resources to long-term projects, given the present financial instability both nationally and internationally. Payback periods need to be measured in terms of months rather than years, and this can exclude EE investment opportunities. The lack of long-term commitment has been an on-going problem in Africa, with many investors seeing better business opportunities in other regions of the world [19].

- **Lack of skills.** The skills shortage that South Africa is experiencing at the moment [23] is also a contributing factor to the poor sustainability and uptake of DSM projects. To implement a sustainable DSM project there needs to be intensive engineering design work done before, during and after implementation. If any of these phases are not fully completed, the performance and sustainability of the project will be negatively affected.

There is abundant evidence that EE programmes almost always make economic sense, whether in the industrial, transport, agricultural or residential sector [19][24]. Examples of sophisticated and well-run international companies that have made cost effective reductions in energy usage through DSM are [24]:

- **3M** has reduced energy consumption per net sales by 30% since 2000 and is seeking an overall reduction of 40% by 2008.[3]
- **Continental Tyre** has designed a plant that requires 31% less energy per tyre produced.[4]
- **Dow Chemicals** achieved a 22% improvement in energy use between 1994 and 2005 through corporate energy management systems.[5]

1.2.2 Different approaches to DSM

There are a few distinct types of DSM, of which the major ones are peak clipping, load shifting and EE.

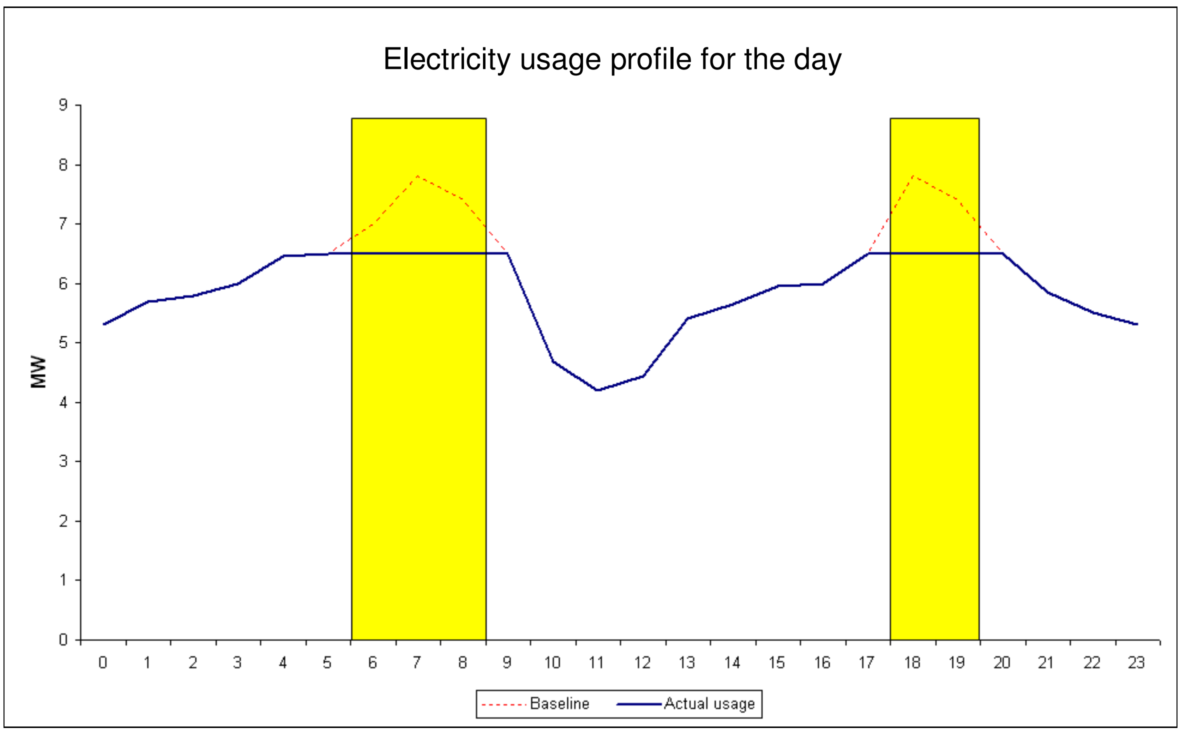

Figure 1-11: Peak clipping

[3] Presentation by Steven Schultz of 3M, Achieving superior energy performance meeting March 6, 2007 [24].
[4] US Department of Energy's Energy Matters , Summer 2006 by Christopher Russell, Energy Pathfinders Management Consulting [24].
[5] Presentation by Joseph Almaguer, Dow, Achieving superior energy performance meeting March 6, 2007 [24]

- **Peak clipping** refers to the reduction of the utility load during peak demand periods, as shown in Figure 1-11. This can delay the requirement for immediate additional generation capacity. If the demand increases beyond the maximum supply, the utility will be forced to implement load shedding. The net effect will be a reduction in both peak demand and total electrical energy consumption [25].

- **Valley filling** encourages the use of electricity during off-peak periods. This may be particularly desirable when the long-term incremental cost is less than the average price of electricity. This is often the case when there is underutilized capacity that can operate on low-cost fuels, such as waste gases from sugar-cane processing facilities. The nett effect will be an increase in total electrical energy consumption, without increasing in peak demand. The danger of valley filling is that it is very difficult to reduce the base load demand in times of an electricity shortage [25].

- **Load shifting** involves shifting load from peak to off-peak periods. The nett effect is a decrease in peak demand, without changing the total electricity consumption. A good example of load shifting is a water pumping project for a mine. During of-peak times the dams of the water pumping system are prepared for the peak hours. At peak times some of the pumps can be switched off to reduce the peak-time electricity consumption. Unfortunately, without proper planning this can increase the MD of a mine [25].

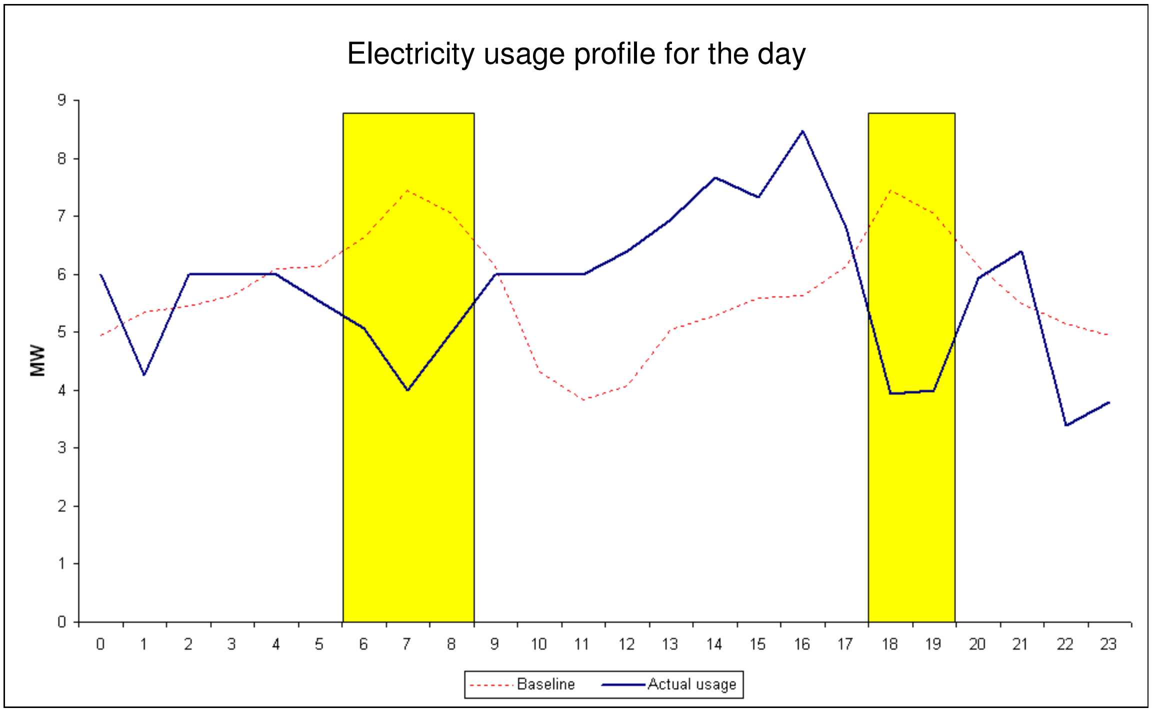

Figure 1-12: Load shift

- **EE or strategic conservation** refers to the reduction in end-user consumption. Nett reductions in both the peak demand and the total electricity consumption are achieved [25]. Green buildings that require less heating and cooling or lighting are a good example of this.

- **Flexible load shape** refers to variations in reliability or quality of service. Instead of influencing load shape on a permanent basis, the supplier has the option to interrupt electrical supply when necessary. In this case there will be a nett reduction in peak demand and little if any change in total electricity consumption, because the electricity service is required later in the day. A good example of this is the ripple controllers installed on geyser systems in residential homes. If the geysers are switched of during peak times it will need to heat up the water at a later stage excluding some of the heat losses [25].

1.2.3 A brief history of South African DSM

In the 1970s the largest electricity users in the residential sector were refrigerators. By improving the efficiency of the refrigerators, their electricity consumption was reduced by 30% [26]. Lighting in South Africa is also a large electricity consumer. The Efficient Lighting Initiative (ELI) programme in South Africa was implemented by the International Finance Corporation (IFC) and funded by Eskom and the Global Environment Facility (GEF). The purpose of the programme was to accelerate the penetration of energy-efficient lighting technologies. Consumers were encouraged to use modern, high-quality, efficient lighting technologies such as the compact fluorescent lamp (CFL) [4].

This ultimately led to the sale of 1,658,949 CFLs during this campaign. Annual electricity savings were estimated to be 134 000 MWh and a peak demand reduction of 61 MW with a corresponding 75% reduction in price of the CFL [27].

Eskom’s demand side management programme aims to provide lower cost alternatives to generation system expansion by concentrating on the efficient use of electricity. Consumers are encouraged to use electricity more efficiently and outside Eskom’s peak periods. This is a joint initiative between the Department of Minerals and Energy (DME), the National energy regulator of South Africa NERSA and Eskom, which aims to save 4 255MW over a 25 year period: the equivalent of one large coal-fired power station [1]. The annual DSM target was set at 153 MW. This includes EE and DSM projects.

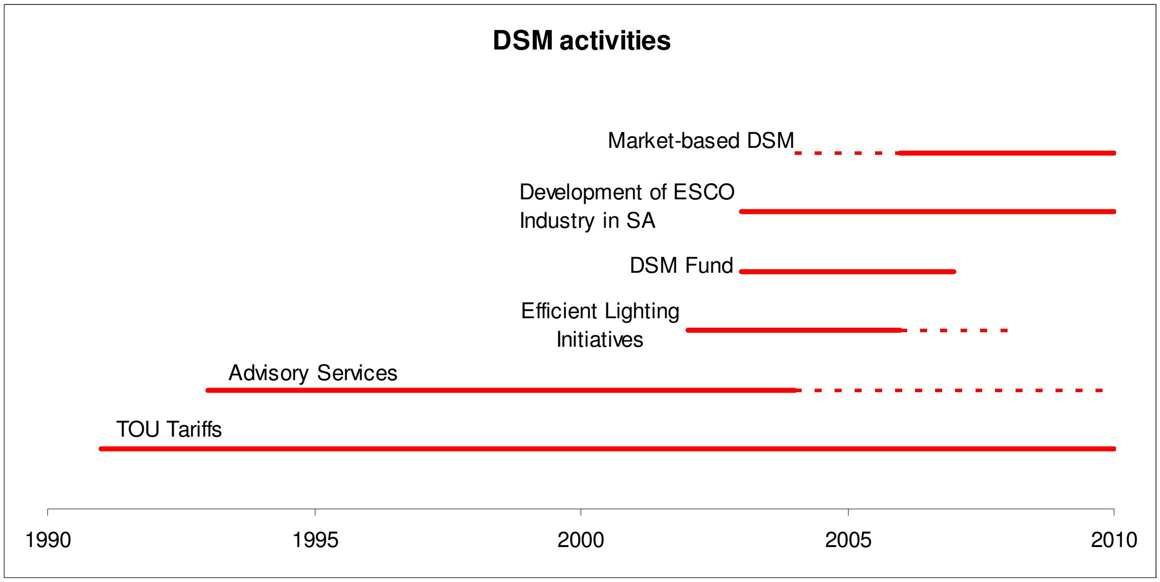

Figure 1-13: DSM activity and progress[6]

After the electricity crisis in the Western Cape during the summer months of 2006/2007, Eskom initiated an accelerated DSM programme that aims to save 3 000 MW by 2012 and 8 000 MW by 2025 [1], Table 1-1 shows the targets that were set for the accelerated DSM program. Furthermore, Eskom called on all users to reduce their electricity usage by 10% in January 2008 [2]. When the target was not met, Eskom was forced to implement a nationwide load shedding programme. This is a steep target to reach as there was only a reduction of 6.7% (weather adjusted) in California with the electricity crisis they experienced during 2001 [28].

Table 1-1: Targets of accelerated DSM program [1]

Programme	Target MW
Efficient lighting	155
Extended operation of back-up diesel generators	50
Industrial, municipal and commercial efficiency measures	40
Subsidies of efficient appliances	25
Extensive conservation drive	110
Gas cooking and heating	50
Water heating load management	7

[6] Image from ESKOM. http://www.eskom.co.za/live/content.php?Item_ID=2787&Revision=en/0

The main sectors where DSM is presently implemented in South Africa are residential, commercial and industrial/mining. Savings achieved is shown in Figure 1-14. Note that the accelerated DSM program had a very positive impact in 2008 [1].

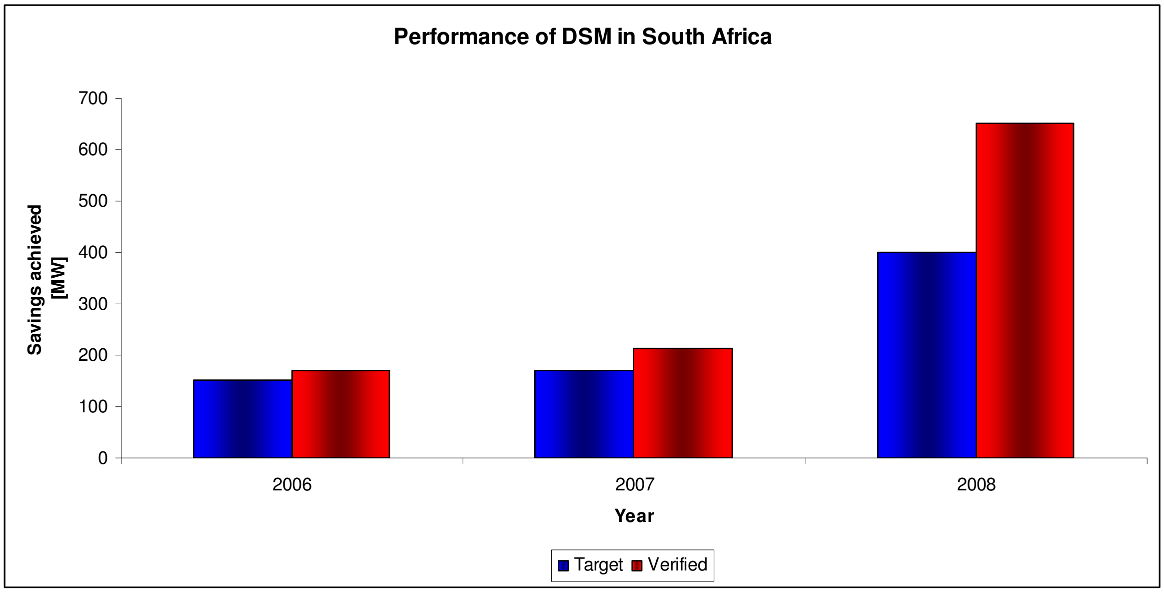

Figure 1-14: The performance of implemented DSM projects for 2006 – 2008 [1]

1.2.4 Realisation of DSM savings for the client

On the industrial side the cost savings for the customer is driven by variable time of day rates for electricity during the day for large electricity consumers. The price of electricity is cheaper in off-peak times and expensive in peak times, as shown in Table 1-2 and Figure 1-15. These tariffs are for the Mega Flex rates in c/kWh and only applicable to users with a demand of more than 1 MW (2007/2008).

Table 1-2: Price of electricity [29]

Season	Off-peak	Standard	Peak
Winter	7.95	14.62	55.30
Summer	6.90	9.74	15.69

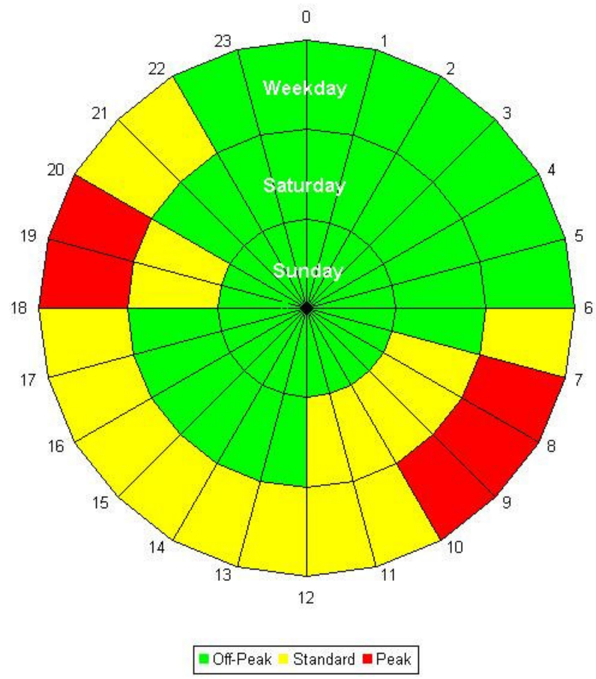

Figure 1-15: Megaflex time periods [29]

An ESCO is contracted to make use of the cheaper electricity during off-peak periods to build up reserve margins for peak times. This reserve margin can then be utilised during peak periods. This can be done in various ways. The method used in this thesis will be the energy management system (EMS) to control the pumping equipment on a mine.

Savings are calculated in comparison to a historical baseline which is an indication of electricity usage prior to the implementation of a DSM project. Normally this is based on a three-month average.

Figure 1-16 shows the actual electricity usage profile and an energy neutral baseline (ENB) for a typical production day and project. An ENB is a baseline that is scaled (for load shifting projects) to have the same electricity usage as the normal electricity usage profile of a specific day. For example, the two profiles of Figure 1-16 should be scaled in such a way that the areas under the two profiles are equal.

ENBs are calculated daily to ensure that the savings reflect an accurate performance for that day and will be discussed in greater detail in section 2.2.3.

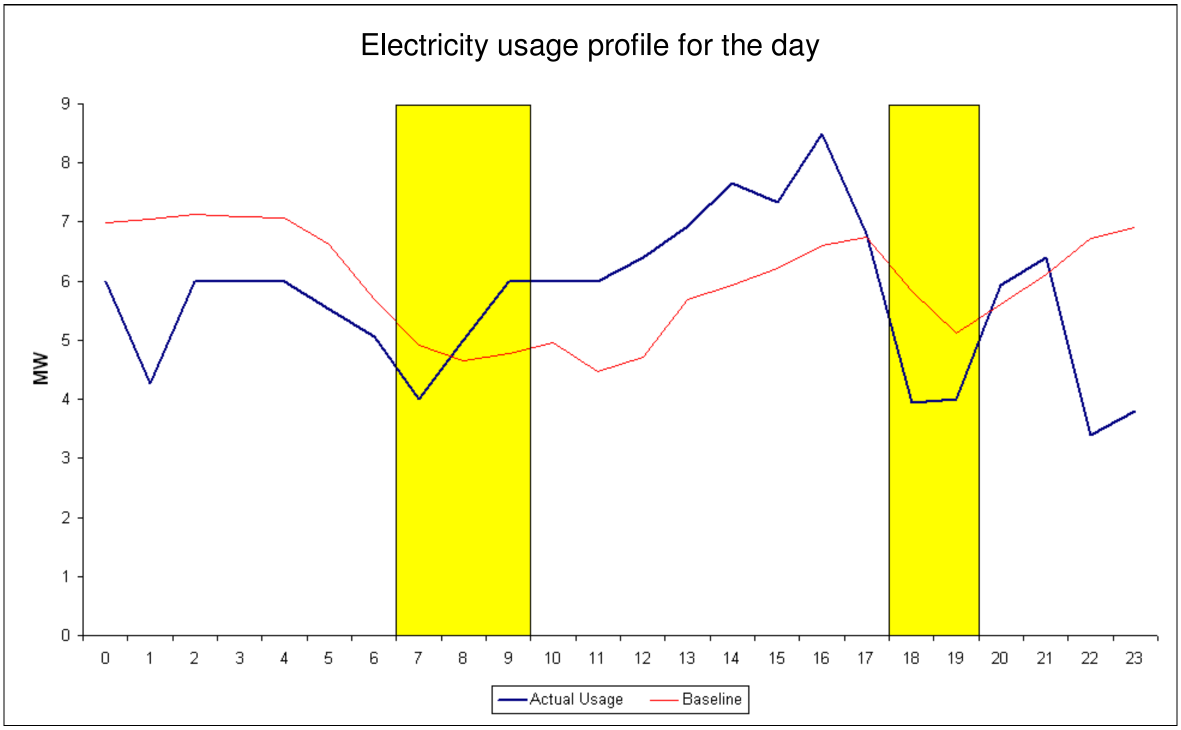

Figure 1-16: Actual profile and baseline for a typical production day

1.2.5 Missed opportunities

It may sometimes happen that on a given day the DSM project performed sufficiently well to shift the contractual load. However, there may still have been some unrealised potential for this day. On these days there is thus a missed opportunity for cost savings and load shifting. Figure 1-17 shows the historical baseline and the actual electricity usage, which is used to calculate the realised savings and load shift for the day. The optimum or proposed profile is shown to indicate what the electricity usage profile for the day could have been if the EMS was allowed to operate to its optimum potential.

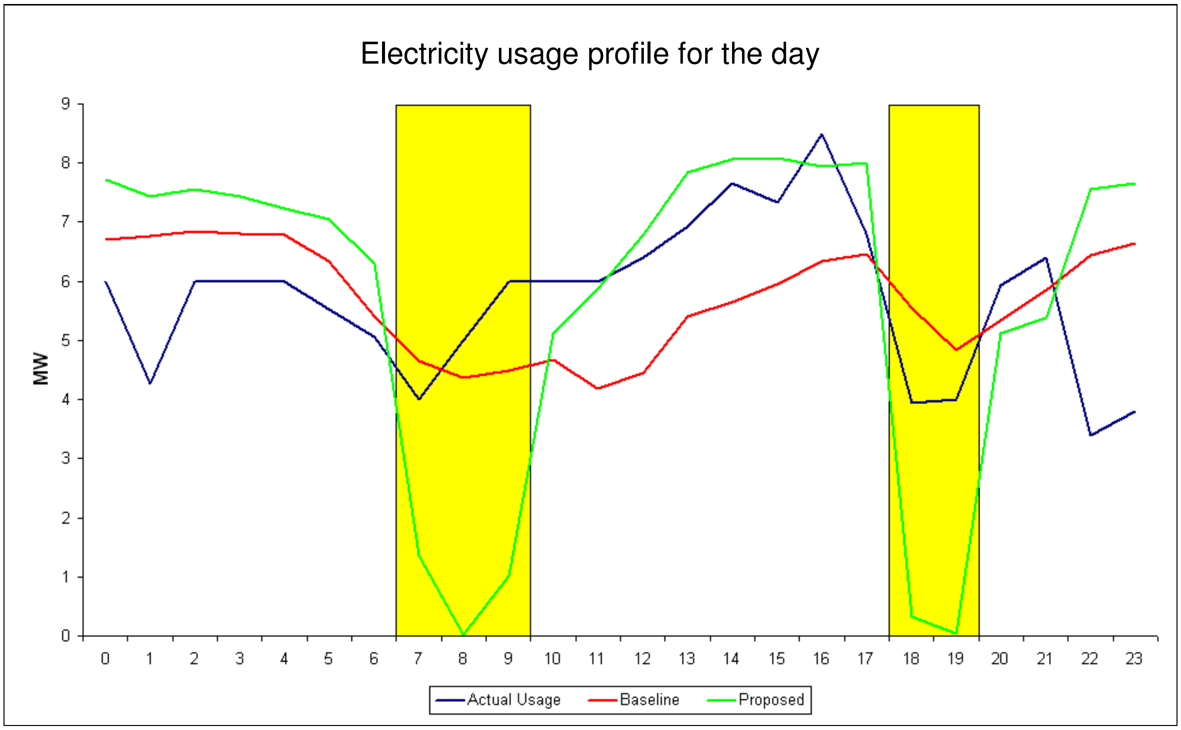

Figure 1-17: Realised savings and missed opportunities

1.3 Sustainability of DSM projects

1.3.1 Problems experienced globally with DSM

Experience in countries such as the United States (US) and the United Kingdom (UK) has shown that neither a restructuring of the utility nor the market can guarantee EE [28][30]. Although some programmes, like the Best Practise project of the US Department of Energy (USDOE), have been successful, 98% of US industrial facilities still lack full-time energy managers [24]. This is due to the concern of many industrial firms that DSM savings are not sustainable [31].

Historically, DSM projects have not been sustainable over the long term. Initially the DSM projects implemented in California fell short by 30% to 70% on expected savings, mostly in the residential sector [32][35]. In the Western Cape, DSM programs implemented in 2006/2007 showed that the electricity savings decreased by 64% in one year in the evening peak hours [36].

The results for the DSM projects in the Western Cape during the winter of 2007 are shown in Table 1-3. Figure 1-18 graphically illustrates this trend.

Table 1-3: Performance of DSM projects in the Western Cape [36]

Month	Morning off-peak	Morning standard	Morning peak	Midday standard	Evening peak	Evening standard	Evening off-peak
May 2007	62.04	198.38	281.07	221.50	370.14	189.04	108.17
June 2007	160.15	293.99	399.66	38.58	**649.85**	462.63	221.57
July 2007	62.82	229.94	367.55	260.94	522.92	308.38	59.23
August 2007	151.30	187.45	260.59	153.83	353.75	276.45	149.97
September 2007	122.51	155.37	158.32	108.42	**236.66**	141.58	91.82

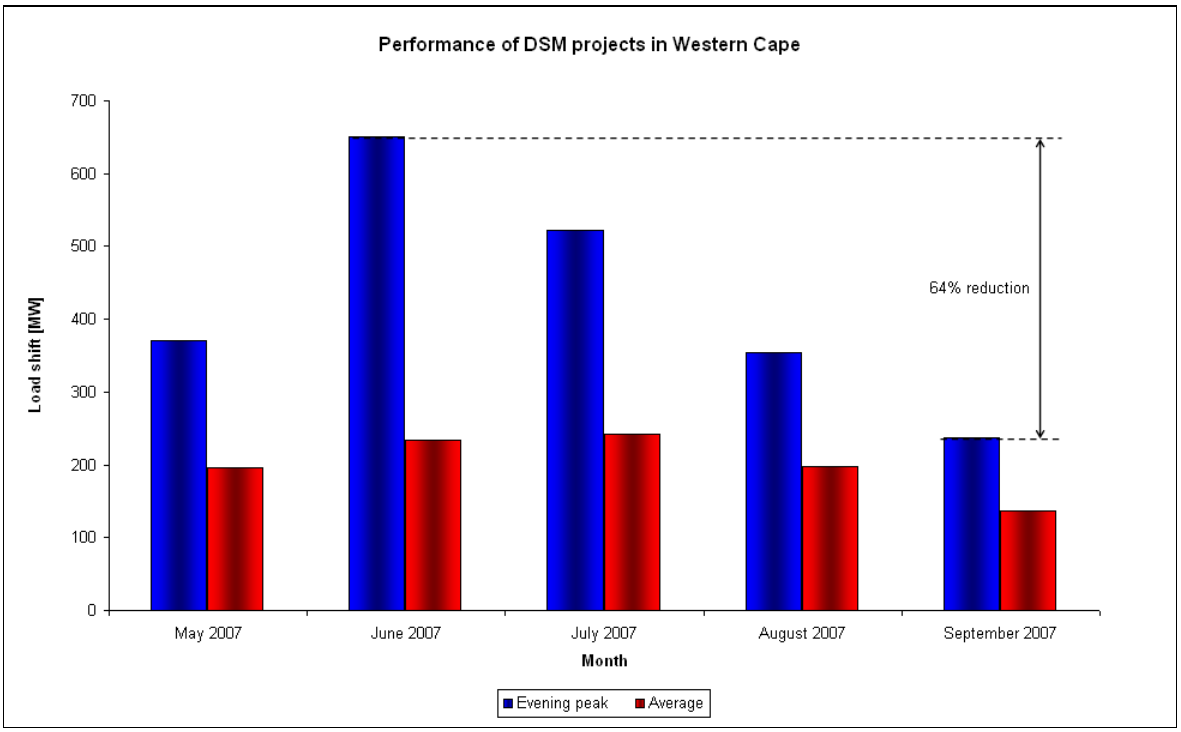

Figure 1-18: Performance of DSM over time [36]

At the commencement of a DSM project all the sub-systems are still working and a lot of effort is put into the project. With the progress of the project there is a reduction in performance due to various reasons (as discussed in 1.3.2), until the performance of the project falls to that particular project's sustainable capacity.

To reverse this trend will require a great effort from the ESCO and client. Most of the lost savings can be attributed to "condonable" reasons that release the ESCO and/or the client against penalties from the utility. There is still the loss of monetary savings for the client. "Condonables" are instances where a project could not realise the proposed load reduction due to technical reasons. For example, a pump failure during the day might not permit the system to prepare for the evening peak.

Unfortunately, it is very difficult to obtain DSM performance figures that include the "condonable" data. Detailed DSM performance figures could not be obtained from either Eskom or the NERSA for purposes of this study. Reports from the Measurement and Verification (M&V) teams to Eskom are classified.

1.3.2 Causes for the poor sustainability of DSM projects

This reduction in DSM performance must be addressed. In the Californian DSM projects it was found that the inflexibility of regulators and utilities could be a cause for the poor sustainability of DSM projects [37]. This is because inflexibility discourages innovation from ESCOs [37][31]. More involvement of the regulatory bodies is also needed [38][31].

To solve the problem of the decline in DSM performance the root causes must first be determined. Some of the significant reasons for the lack of sustainability for a DSM project are:

Low priority. If a DSM project is not supported from management level it is bound to experience serious difficulties. Another reason is that some companies, especially mines, would rather focus on environmental, health and safety (EH&S) issues than on DSM programmes.

Some clients are also apprehensive about the impact of a DSM programme on the EH&S programmes of the mine. This is typically because, for a pumping system, the project must operate on the limit of safety margins during peak times to facilitate the maximum performance of the DSM programme.

A loss of interest by the client. Due to human nature, a person will lose interest in a monotonous activity over time. This is also true for the monitoring of DSM projects. If a project is not continuously monitored, the performance can deteriorate. If the client is promptly informed of this deteriorating DSM performance, immediate action can be taken to rectify the situation. Unfortunately, this is not always possible. The time delay from the day that the incident occurred to the time that the ESCO becomes aware of the change in performance can sometimes take up to a week. This is clearly unacceptable.

Another problem is a casual attitude of technical staff, which is not aware of the resulting savings realised by a DSM project. They therefore don't realise the importance of their role, yet they are responsible for maintaining the system. If the production engineer could be made aware of the missed opportunity to save money, pressure could be placed on the technical staff to maintain the system and to schedule maintenance in the off-peak times where possible.

Changes in production schedule. If the demand for a product or service for a specific industry grows, the demand for electricity will also increase. If the business has an established and successful DSM project, it will mean spare capacity is available during the off-peak times. This spare capacity can rather be utilised before a capital expenditure is done to increase the installed capacity. This will not allow the DSM project to deliver the promised load shift. The financial gain of more production will mostly outweigh the DSM cost savings.

Staff turnover. When a skilled control room operator or an engineer resigns, retires or is dismissed, the DSM project results will be affected due to a loss in continuity and experience. The new operator's training will have to include a clear understanding of the potential of the EMS and its ability to safely control the plant.

Another problem with the sustainability of DSM in South Africa is that there is very little motivation for the ESCOs to maintain the project. Elsewhere in the world the implementation costs of the DSM infrastructure must be carried by the ESCO and this capital must be recovered from the savings [39]. In South Africa the capital is put up by Eskom and the ESCOs' remuneration is based on the first three months' performance. If more DSM projects incorporated a contractual maintenance programme, it would improve the long-term performance of the project.

1.4 The need for a DSM feedback solution

1.4.1 Preamble

A study published by the USDOE on commercial systems showed that faulty heating, ventilation and air-conditioning (HVAC) equipment accounts for 2 to 11% of the electricity consumption of a building [40]. Performance would improve by an advanced diagnostic and control system that can report on performance and identify problems as they occur [39].

1.4.2 Existing feedback solutions

The quality and quantity of information on industrial electricity usage patterns should be improved and implemented projects should be monitored more closely [31]. Existing reporting packages, such as Crystal Report or Factory Suite, are excellent packages for indicating actual DSM performance. However, these packages cannot give intelligent interpretations and indications of DSM performance. These packages also need to run client-side, i.e. on the physical server, which controls the system. This complicates the setup process and the reporting chain. Some of the commercially available systems are:

- **Crystal report[7]:** An automated reporting solution used in the banking sector, amongst others, to generate bank statements for clients. This package requires the data to be in a specific structure before it can be used, i.e. the data must be pre-processed by hand or another program. The package is mostly integrated with an Oracle-based database.

- **Factory suite[8]:** An integrated reporting program for the supervisory control and data acquisition (SCADA) system FS Gateway. It can perform a limited amount of calculations and can only work in conjunction with Factory Suite SCADA systems.

- **TasOnline[9]:** A maintenance-reporting solution. Theoretically it could be adapted to generate savings reports as well, but this will need substantial further development of the existing software. The reporting solution has had stability problems with some SCADA configurations in the past (see Beatrix 4# in 4.7.1).

None of these packages can report on missed opportunities as described in 1.2.5. This is a very significant prospect to motivate clients to help improve the sustainability of their projects.

[7] www.businessobjects.com
[8] www.wonderware.com
[9] www.tasonline.co.za

1.4.3 Problems with automated reporting

- **Quantity of data.** Collecting and processing of data present enormous problems due to the large volume and its complexity. Without automated calculation methods using spreadsheet-type software this would almost be an impossible task. With the aid of spreadsheets, data processing becomes easier, but it is still a very tedious process.

- **Technical difficulty.** A suitably qualified person needs to be employed by the ESCO to ensure the technical accuracy of these calculations and the interpretations of the results. Some of the calculations involved are very complex and many of the parameters need to be evaluated. Without an in-depth analysis of past and present performance, system capacity and changes in production schedules, it will not be possible to gauge the extent of the missed opportunities.

- **Time delays.** Calculations are done manually and during office hours. If a problem occurs in the morning, the data will only be processed the following morning. The problem will only be rectified in the afternoon shift, which means that two days' performance will suffer. If a problem is encountered on a Friday morning, it will probably not be rectified before the Monday, with the result that four days' performance will be affected.

1.4.4 An example of the effectiveness of reporting

Figure 1-19 shows the average evening load shift for the pumping system at Kopanang Gold mine. The dotted blue line shows the least squares fitting through the data points. The black line indicates the contractual evening load shift for the project. It can be seen that the project performed well over its contractual requirements for the first year and a half of operations. This is in part due to the fact that the project was very closely monitored by all parties involved and the project engineers from the ESCO sent daily reports to the mine's shaft engineer.

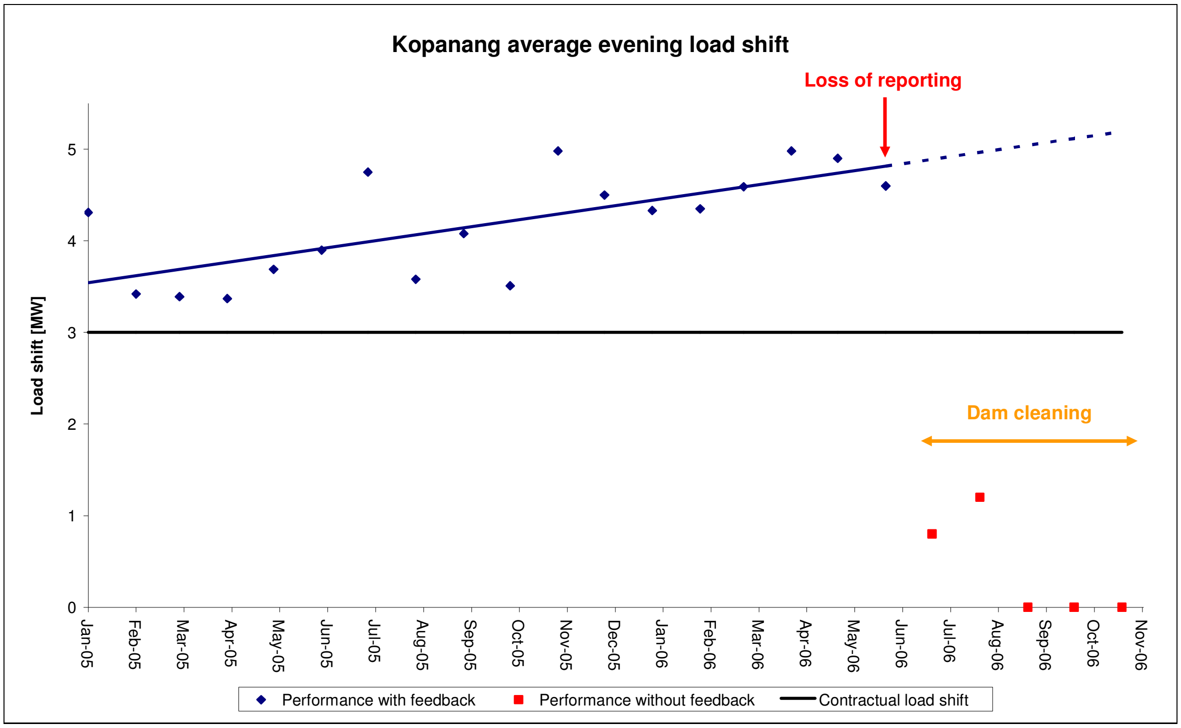

Figure 1-19: Average monthly evening load shift for Kopanang Gold mine

These reports were generated by hand every morning. The data was downloaded manually with a dial-up connection which is very slow. This data was then copied to a spreadsheet where the electricity usage profile was calculated. The baseline was compared against the ENB and the morning and evening load shift was then determined. A short report was then compiled, including a graph giving the electricity usage profile and the ENB. This report was then e-mailed to the shaft engineer.

In July 2006 technical communication problems occurred between the ESCO's head office and the project site. The data downloading system became very slow and unstable. Several attempts were made to download the data from the servers. On most days the data could not be successfully downloaded, with the result that the daily reports were not delivered. This coincided with maintenance of underground dams from August 2006. The dam cleaning process reduced the potential for load shift dramatically, because less dam capacity was available to store water.

The performance of the DSM project suffered severely. Figure 1-19 shows how the average load shift exceeded the contractual target of 3 MW prior to the loss of performance reporting. In July 2006 the actual load shifted was reduced to below 1 MW. This discussion will be continued in Chapter 4.3.1.

1.5 Problem statement – A unique need

The reason for the reduced load shift of Kopanang showed that there is a definite requirement for an automated feedback solution for DSM projects. The following core tasks were identified:

- Automated data transfer from the project's locations to the ESCO's head office with redundancy kept in mind.
- Automated data calculations.
- Automated reporting with little or no user input.
- Varying reporting periods, including daily, weekly and monthly reports.
- Adaptability of the system to incorporate more projects.

1.6 Outline of this document

The outline of this document will take the following form:

Chapter 2: - A new automated feedback solution (page 32)

In this chapter all the requirements of the feedback solution will be explored and the process of the development explained.

Chapter 3: - Implementation (page 58)

In this chapter the implementation of the feedback solution will be discussed. Issues that will be covered:

- Head office implementation
- Project site implementation
- Problems experienced during implementation of the reporting solution

Chapter 4: - Verification (page 67)

In this chapter the verification of the feedback solution is discussed. The issues that will be covered:

- Reduction in man-hours spent collecting and processing data and generating reports.
- Accuracy and reliability of the feedback solution
- Impact on DSM results

Chapter 5: - Conclusion (page 95)

This chapter will conclude the study and suggest issues for further development.

Chapter 2: A new automated feedback solution

A new feedback solution, developed specifically for South African DSM projects, will help to prevent the deterioration of DSM results.

2.1 Prelude

The previous chapter showed that there is a definite requirement for an automated feedback solution specifically tailored for the South African DSM environment. This chapter will discuss the details of how the manual reporting system originally worked, its strong and weak points, and how it can be improved by a single, automated feedback solution.

Figure 2-1 shows the control and data flow for a typical DSM project. The ESCO's EMS controls the client equipment to enable load shift. The performance data is logged in the project performance database. This data is then usually downloaded by the ESCO via an internet dial-up connection. Other means are available such as travelling to the site and manually transferring the data to a portable storage device.

The performance data is then manually processed with the help of a spreadsheet program. Reports are generated and sent to all the relevant parties, among others the site monitoring personnel. The processed data is also used to optimise the EMS.

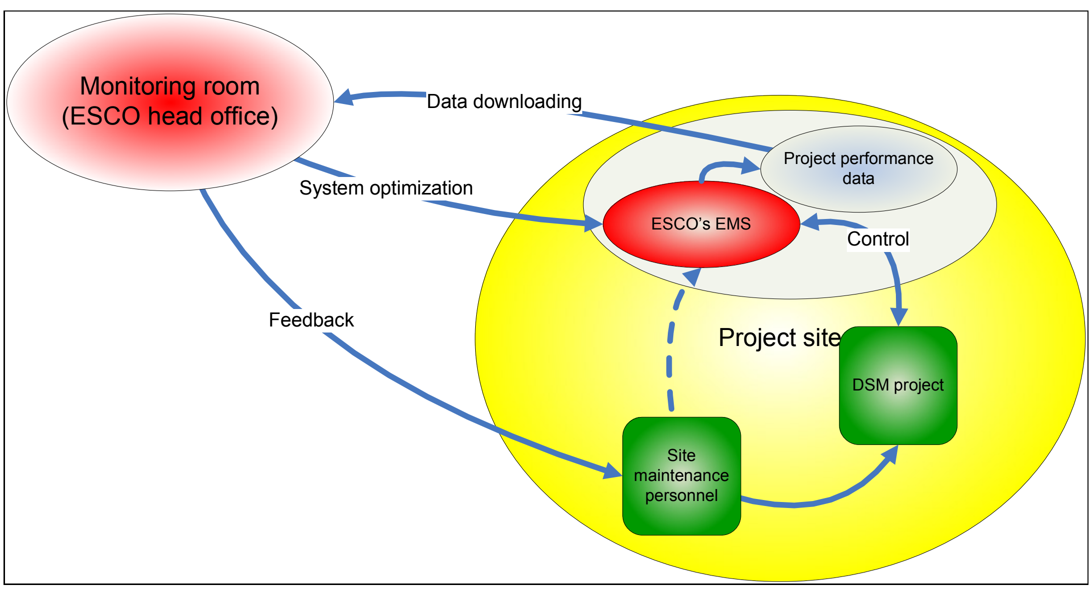

Figure 2-1: Control and data flow diagram

2.2 Foundation of savings calculation

2.2.1 Manual data processing

With manual reporting the data is downloaded via a dial-up connection from each project site on a daily basis, as shown in Figure 2-2. This is a tedious process and because of poor telecommunications infrastructure at some sites, not always successful. For example, the lines are prone to interruptions during communication or the data transfer is so slow that it isn't functional.

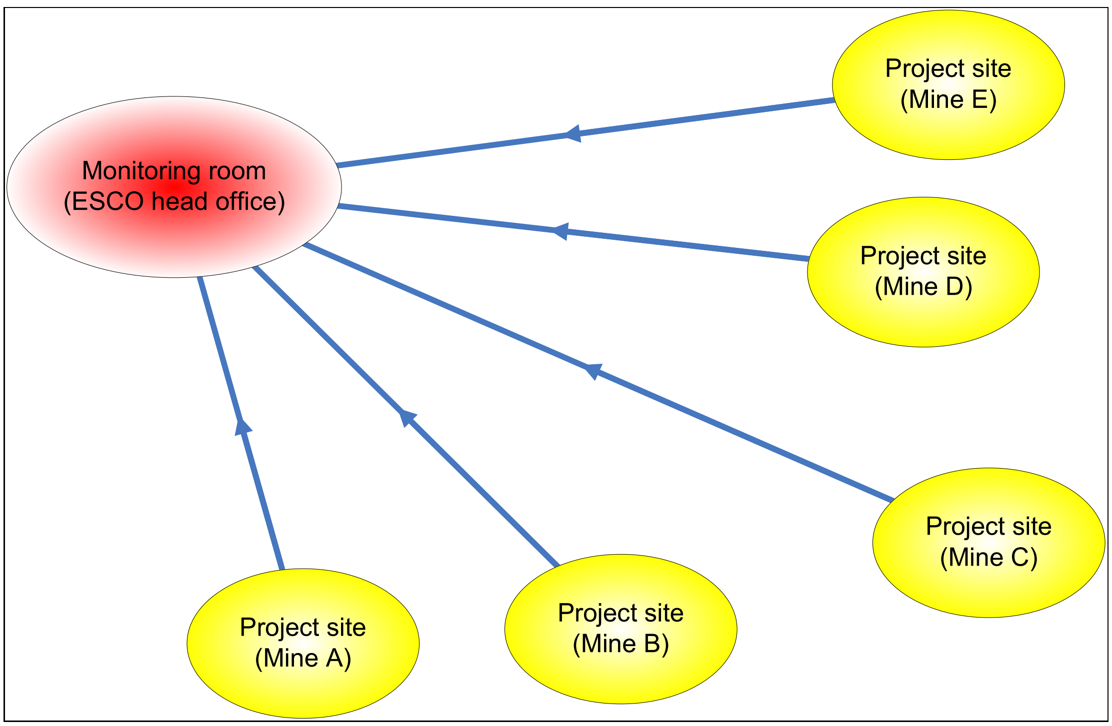

Figure 2-2: Downloading of a single day's data

While the data is being downloaded, the project engineer responsible for a given project will normally start processing the data with the aid of a spreadsheet-type calculator. Deliverables from this process are, among others, graphs of electricity usage for the specific day, total load shift in MW and cost saving in Rand.

A summary of each day's data is stored in a central location. From here it is referenced to create a daily report that could be sent out to the clients. This is, however, not always done because of the amount of time required to compile the reports.

At the end of each month, a monthly report is generated and despatched to the clients. In addition a summary of the projects' performance is sent to the M&V team. This procedure is sometimes delayed for various reasons. The major source of delay is the breakdown of telecommunication to the project site.

The process described above has many flaws that must be addressed. Most of the processes could be automated. Redundancy of the data acquisition especially, is a problem. If a delay in one of the systems is encountered, the entire process will come to a halt due to the highly sequential nature of the reporting chain.

2.2.2 Shortcomings of the manual procedure

The present method of manual reporting is not sustainable due to the following reasons:

- It takes the project engineer an excessive amount of time. See Figure 2-3.
- It is a tedious process.
- There are too many weak points in the reporting chain, especially the communication between the project site and the head office of the ESCO.

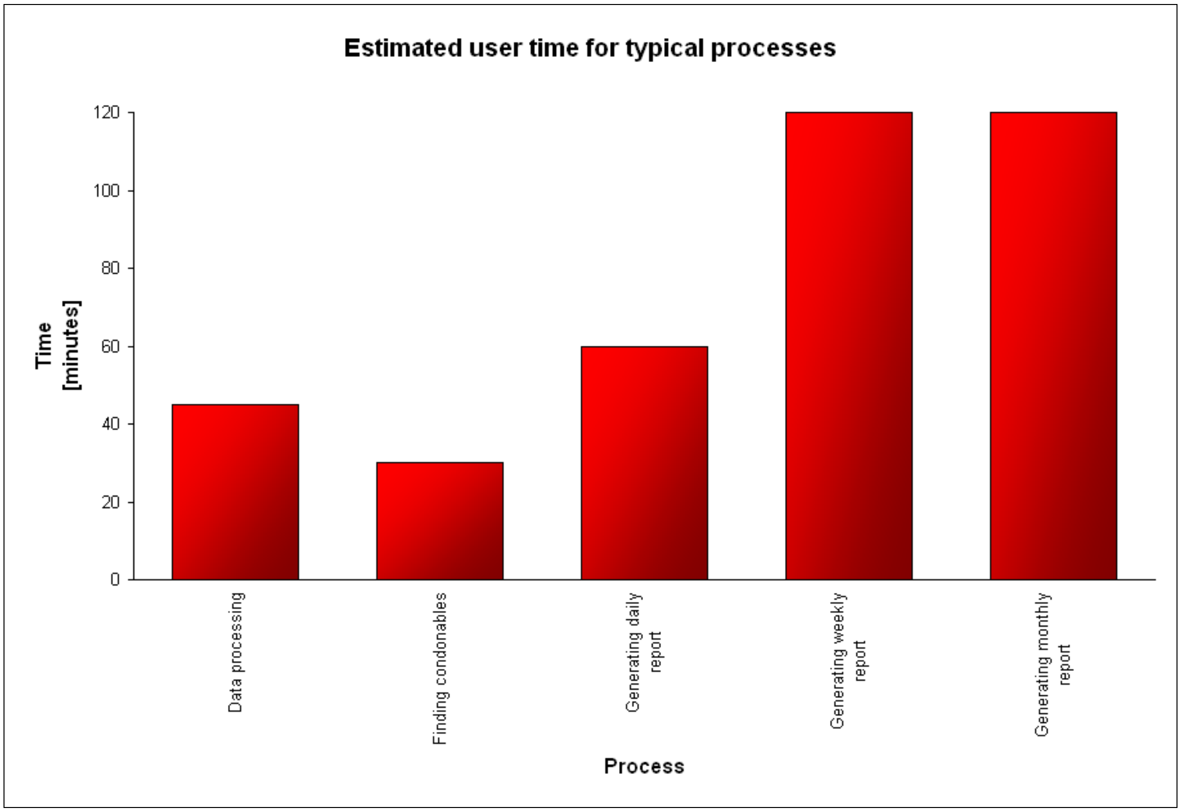

Figure 2-3: The time it takes for one engineer to do typical tasks without any automation

In addition, a detailed breakdown of the daily data would require even more time. The availability of more detailed information would enable the project to be managed more efficiently.

2.2.3 Calculation methods

To calculate the savings for a project, certain procedures are required. Firstly an electricity usage profile for the day must be determined. This profile is then compared to a baseline in order to calculate the savings. The baseline is normally scaled to reflect more accurately what savings are realised compared to pre-implementation of DSM on the system. This is a requirement because the electricity usage of the project is not constant over time.

Figure 2-4 shows the actual electricity usage profile, the historical baseline and the morning and evening peak hours.

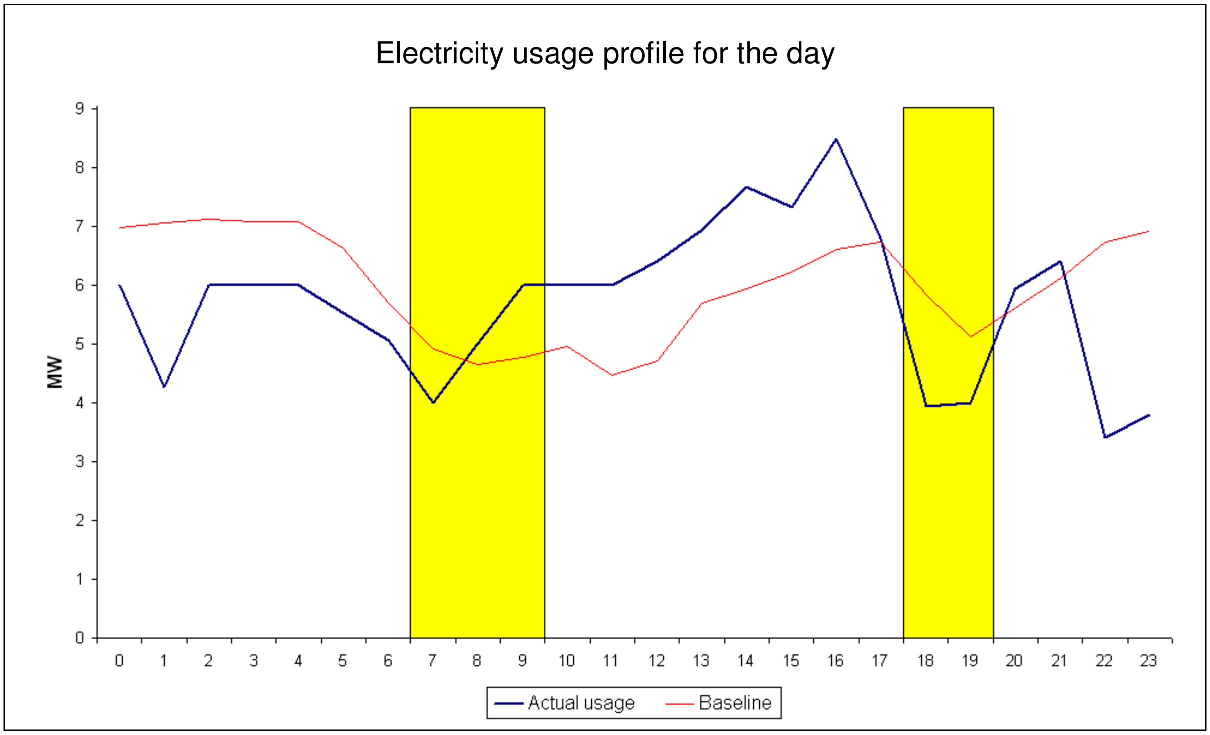

Figure 2-4: Electricity usage profile for a day with baseline

Scaling of the baseline must take into account whether any EE is involved. If EE is not involved, an energy neutral, or equal energy usage, baseline must be calculated.

Methods of scaling the baseline

Scaling of the baseline in a partial or non-EE project is necessary. This is because the total electricity usage will not always be the same as the total electricity usage of the baseline profile. There are two distinct schools of thought of how to scale an ENB, namely the add method and factor scaling.

Add method

With this method the difference between the actual electricity usage profile and the baseline is divided into the 24 hours of the baseline profile, as shown in Figure 2-5.

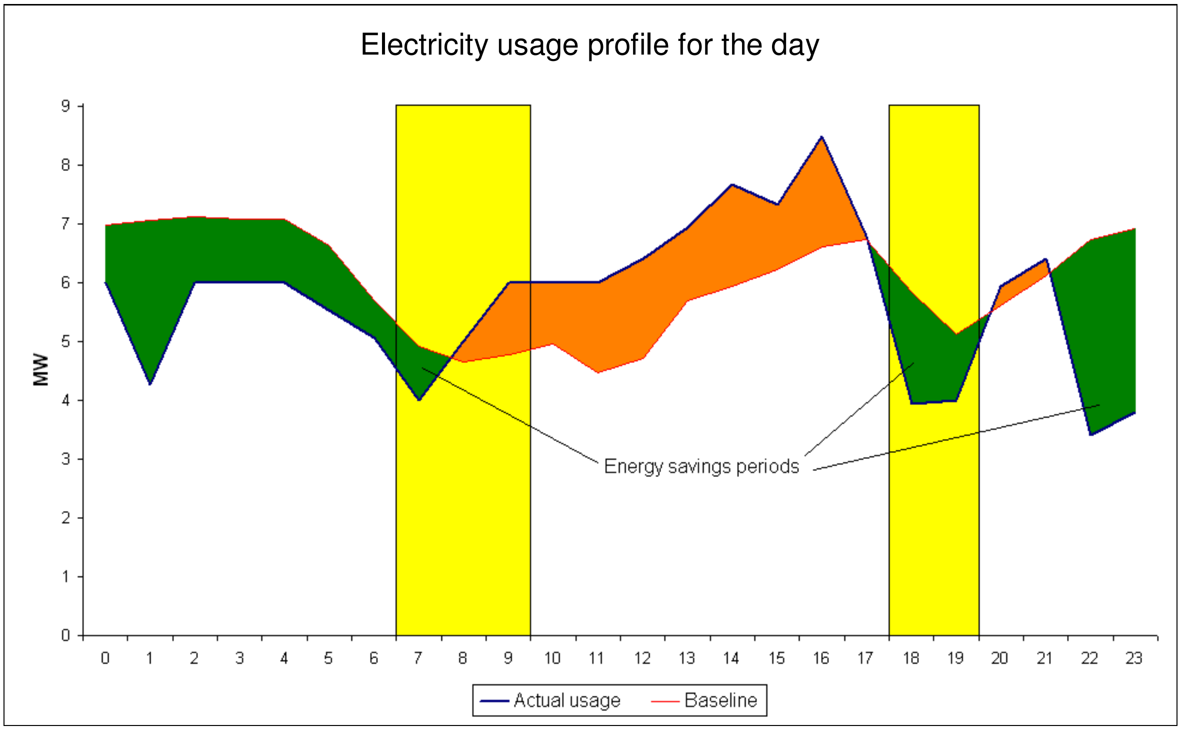

Figure 2-5: Electricity usage profile and baseline showing the difference

In equation form this can be written as

$$\sum_{i=0}^{23} enb_i - \sum_{i=0}^{23} p_i = 0 \qquad (1)$$

with p the actual electricity usage profile. To obtain enb a variable ς (sigma) is added to the historical baseline b, where

$$\varsigma = \frac{\sum_{i=0}^{23} p_i - \sum_{i=0}^{23} b_i}{24} \qquad (2)$$

and

$$enb_i = b_i + \varsigma \quad for \quad i = 0,1,...,23 \qquad (3)$$

Figure 2-6 shows the ENB with the electricity usage profile for a day.

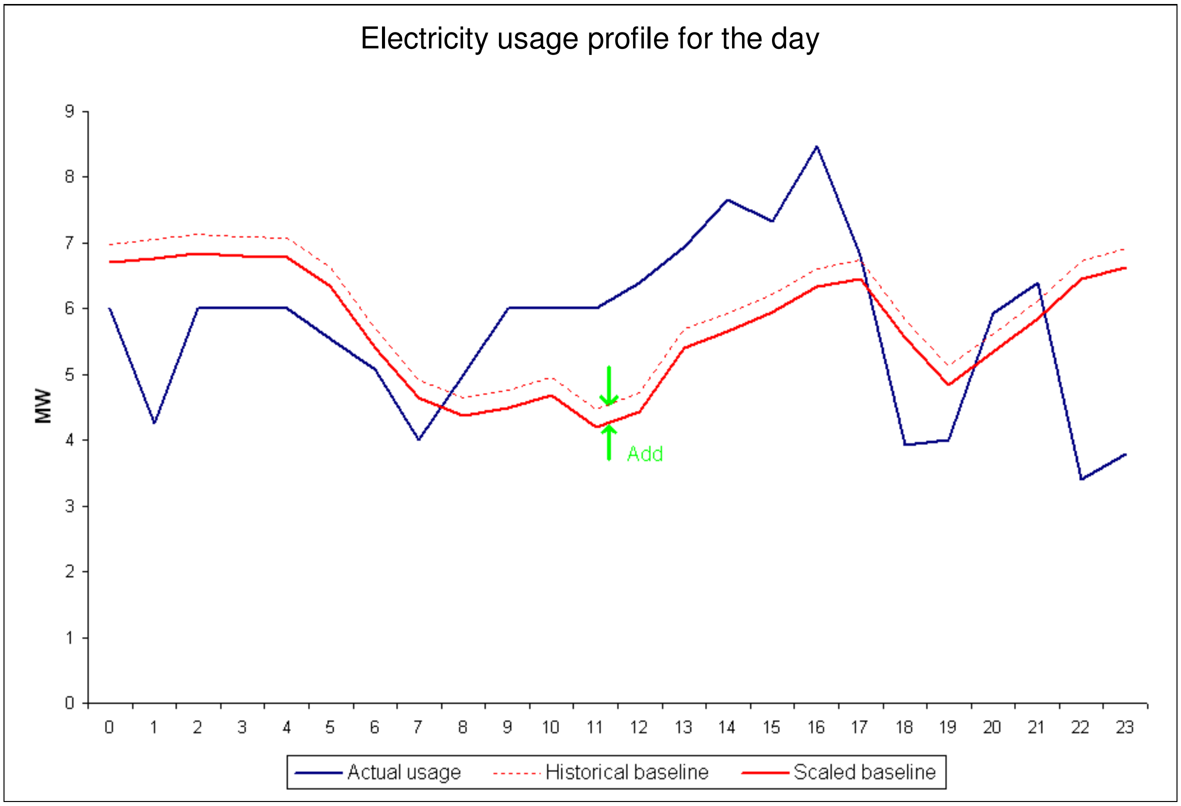

Figure 2-6: Electricity usage profile, baseline and ENB

The difference between the ENB and the electricity usage profile can now be computed to obtain ΔE_i, which is used to compute the savings. The equations are:

$$\Delta E_i = p_i - enb_i \,, \tag{4}$$

$$LoadShift_{morning} = \frac{\Delta E_7 + \Delta E_8 + \Delta E_9}{3} \tag{5}$$

$$LoadShift_{evening} = \frac{\Delta E_{18} + \Delta E_{19}}{2} \tag{6}$$

and

$$CostSaving = \sum_{i=0}^{23} \Delta E_i \times ec_i \tag{7}$$

with ec_i the cost of the electricity in c/kWh.

Factor scaling method

In this method the historical baseline is multiplied by a scaling factor, *α*. This factor is obtained by dividing the total electricity used during the day by the total electricity used in the historical baseline, i.e.

$$\alpha = \frac{\sum_{i=0}^{23} p_i}{\sum_{i=0}^{23} b_i} \tag{8}$$

The original equation (3) can then be rewritten in the form

$$enb_i = \alpha . b_i \quad for \quad i = 0,1,...,23 \tag{9}$$

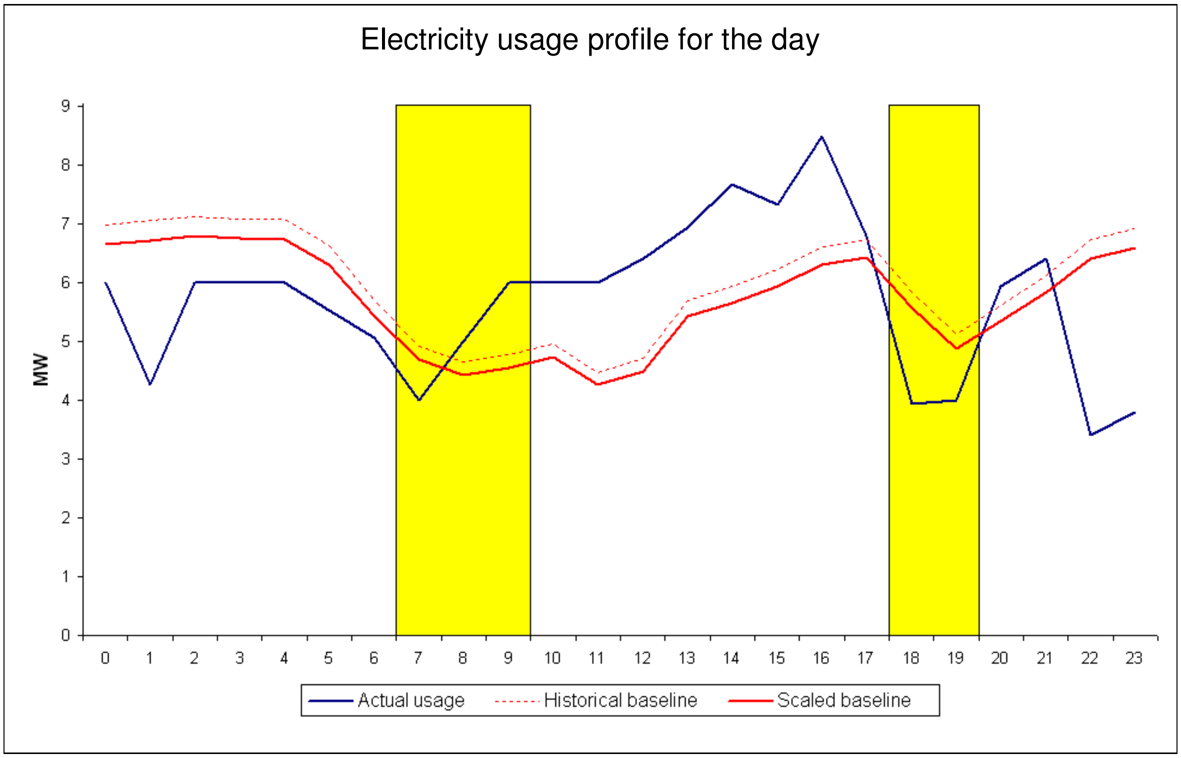

Figure 2-7: Factor scaling method

The factor scaling method is more widely accepted, as it is more accurate on days with low electricity usage. When the actual total electricity consumption is much less than the historical baseline it may happen that the ENB may fall below the zero line as seen in Figure 2-8. Although the area underneath both methods' ENB is equal, the add method would be flawed, because this indicates that baseline had a negative electricity usage.

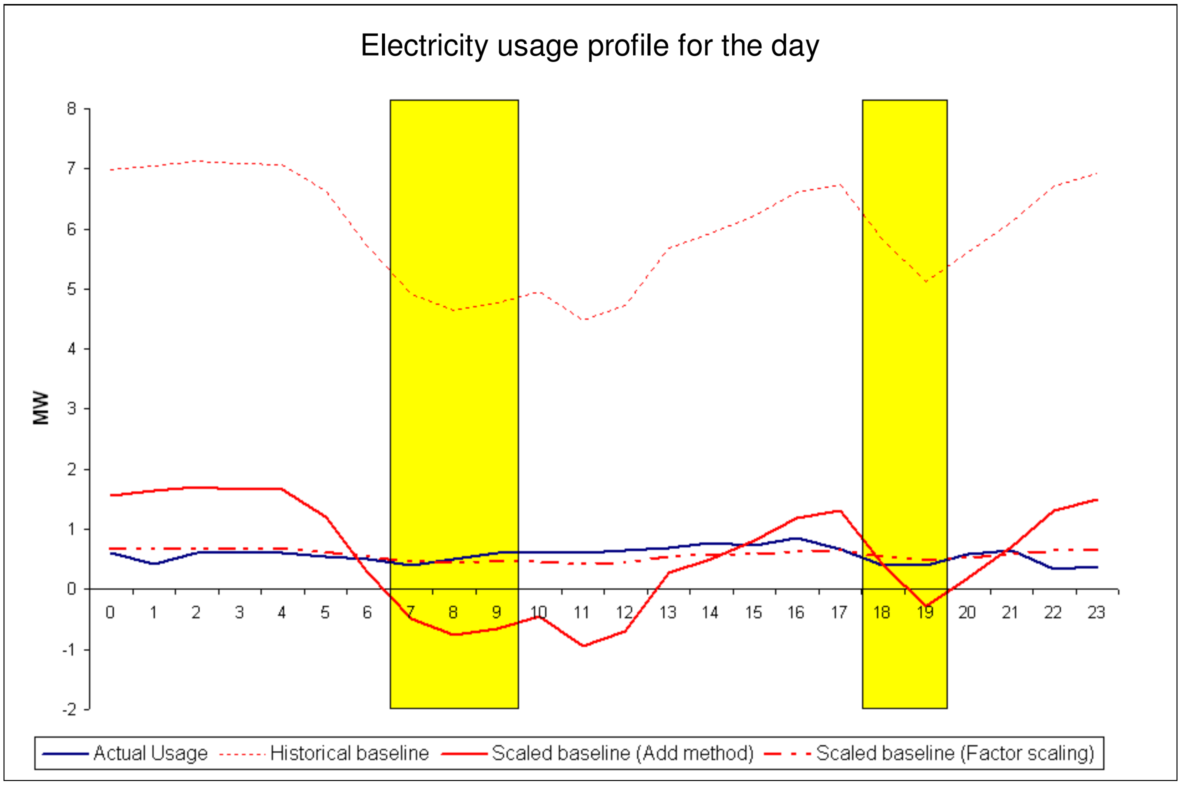

Figure 2-8: Profiles with low electricity usage (Add method as opposed to factor scaling method)

Other methods of baseline scaling

Some projects cannot be scaled by the previous two methods when EE is involved, even if it is only a partial EE project. These projects include the Three Chamber Pipe System (3CPS) or systems where more efficient pumps are installed. Compressed-air management (CAM) and fridge plant projects also include EE. These projects have to be scaled differently because with EE the system will use less electricity to do the same amount of useable work.

At Tshepong gold mine in the Free State a 3CPS was installed during the initial project installation. This enabled the mine to use the gravitational-potential energy of the cold water entering the shaft, to pump hot water to surface. Figure 2-9 shows a schematic layout of this pumping system.

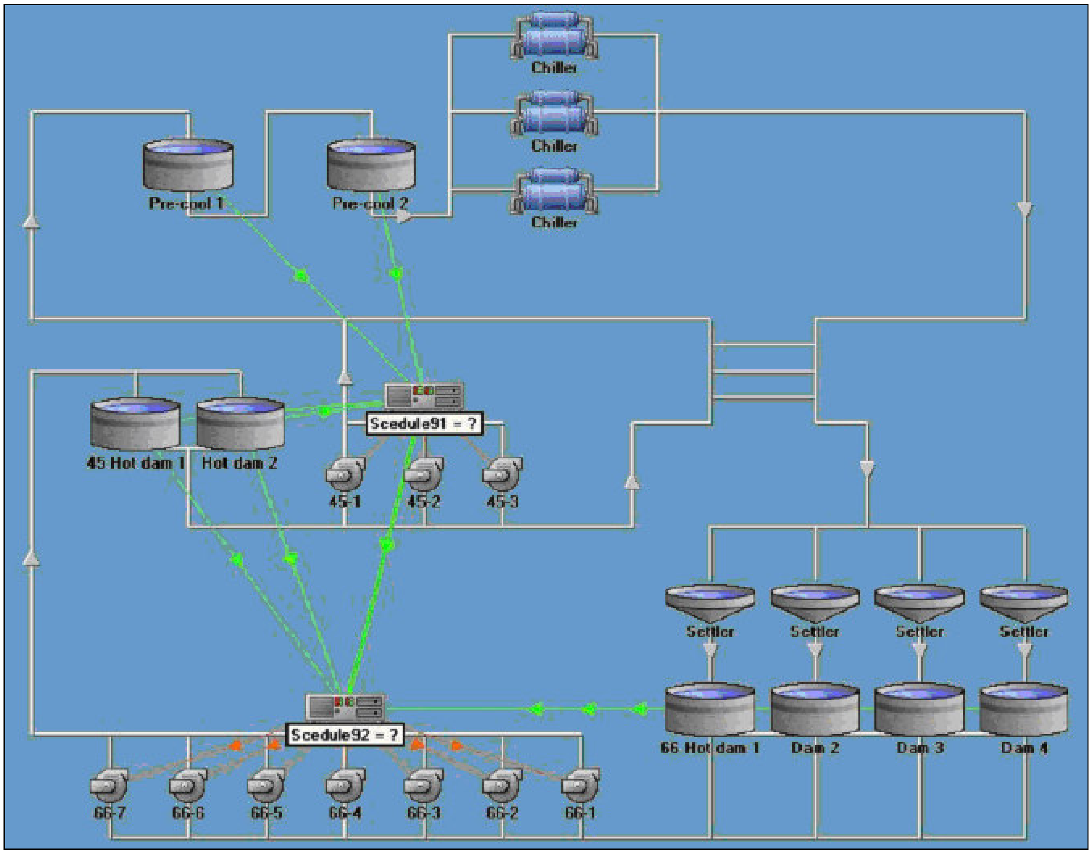

Figure 2-9: Layout of the pumping system at Tshepong gold mine [41]

Unfortunately not all the potential energy in the system can be used due to losses in the system and break downs. If there is a break down of the 3CPS, none of the potential energy can be recovered. The 3CPS is only able to pump the water from 45-level to the surface [42]. To enable water scaling at Tshepong mine, a three month assessment was conducted to determine the amount of electricity used to pump water out of the system.

2.2.4 Missed opportunities

Missed opportunities form an important part of the reports. This allows the client to see how much electricity and money could have been saved if the DSM project was functioning effectively. It will also motivate the client not to impede the operation of the EMS, and thus achieve better load shift results for the utility, ESCO and the client.

To calculate the missed opportunities, an optimum profile must be determined. This profile will indicate how the system could have performed if all the sub-systems were functioning correctly and with no interference from the operators. The optimum profile is obtained by conducting simulations on a computer system, which will simulate most of the external influences, based on historical data.

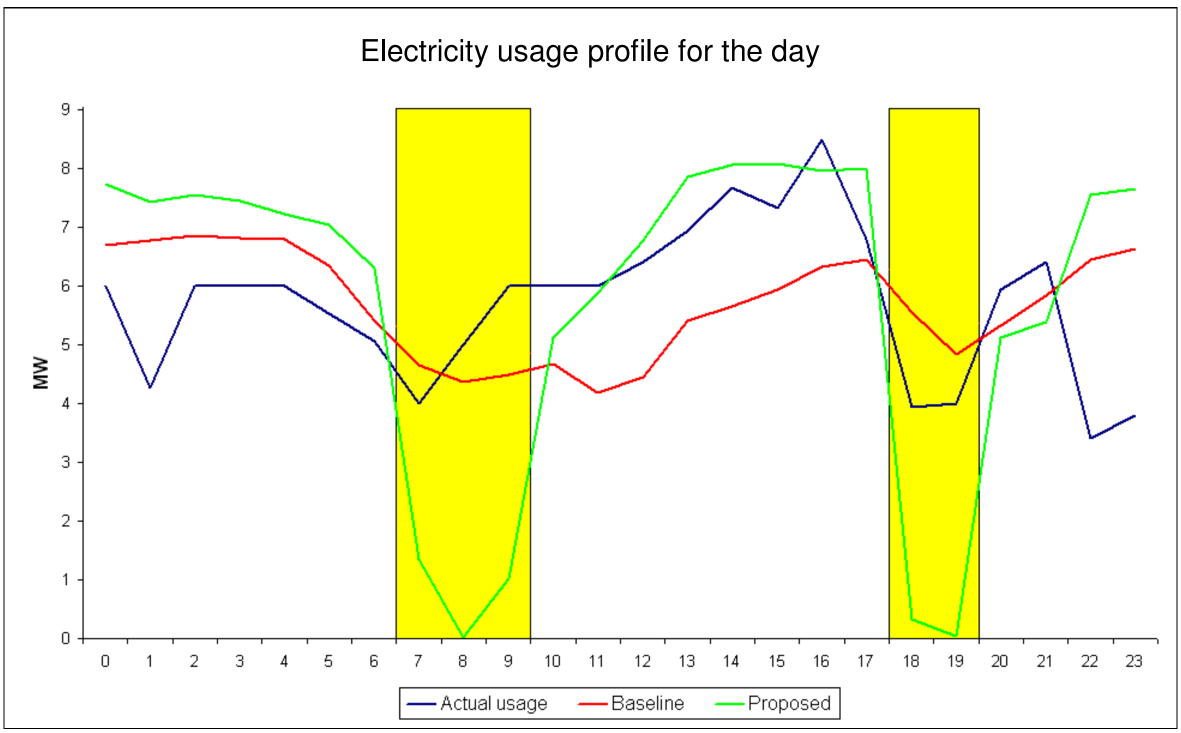

Figure 2-10: Electricity usage profile, baseline and proposed profile

Figure 2-10 shows the baseline and the proposed profile, scaled to the actual electricity usage profile, for a typical day. Missed opportunities occurred when the difference between the energy neutral scaled proposed profile and the actual electricity usage profile is large. The green line indicates the proposed or optimum profile. The optimum profile must be calculated for each day.

2.3 Requirements for the new solution

2.3.1 Automation

The feedback solution must be able to collect data automatically from the projects. The transfer of the data should also be done in a standard transfer protocol that is robust and compatible with the existing infrastructure. It must be able to automatically calculate project performance. Furthermore, it must be able to generate reports in a standard editable format such as Microsoft (MS) Word.

2.3.2 Reliability

The feedback solution must be able to repeat a process if it fails at the first attempt. It must also be able to notify an operator when an error occurs during the processing of data. Data redundancy must be ensured by making backups of all the original data. Memory usage of the program must be managed to ensure stable performance of the feedback solution.

2.3.3 Accuracy

The data processing capabilities of the feedback solution must be verified for accuracy during the commissioning phase. Tests must be carried out on every data set to ensure data accuracy. Processed data must also be checked to ensure integrity. The data integrity tests consist of a process of checking for unlikely data structures. An example of this is a dam level that stays constant for a prolonged period of time, as found in 4.7.1.

2.3.4 Integration into existing infrastructure

The feedback solution must make use of the existing data structures of the control software because this cannot be changed. Existing data carriage infrastructure should be used as far as reasonably possible. It must be able to run on a normal office personal computer (PC). A large server installation with high performance processors should not be required. This will allow project engineers to process data off-site in the commissioning phase of a new DSM project.

2.3.5 Reporting frequencies

The feedback solution must be able to compile reports in various forms, including daily, weekly and monthly reports. This will be discussed in more detail in 2.4.3.

2.4 Development specification

2.4.1 Data acquisition

The data acquisition from the various sites must be fully automated. Initially this was not possible for all the sites. A decision was made for an e-mail-based system to be used because some mining companies prohibit all access of outside data lines for security purposes. At these sites an outgoing e-mail is allowed, but all incoming data must pass through the firewall. Remote viewing of these sites is also possible by utilising an encrypted portal.

A program was developed to send daily e-mails of the performance logs for the previous day. These files were encrypted and compressed to enhance security and save bandwidth. The e-mails from the various sites were standardized to a single protocol.

If data acquisition fails repeatedly, a warning must be given. The operator must then ensure that the problem is solved by a maintenance team. It must also be possible to supply data manually to the feedback solution when the communication infrastructure breaks down.

2.4.2 Processing

Processing is done in an external file that can be easily edited by a spreadsheet-type program. This procedure will ensure easy customisation for every project. The project engineers do not require any programming knowledge to be able to edit these files. A standard protocol for the interface of the file was followed throughout the development phase and for future developments.

2.4.3 Reports

The reports that must be generated are daily-, weekly-, monthly-, Eskom feedback- and group reports. Sometimes, for example, three monthly custom reports must be generated to study a system phenomenon over time.

Daily reports (See Appendix B.1 for sample report)

The purpose of a daily report is to inform the client of a previous day's performance. This feedback enables the rectification of any problems that may have been encountered.

The report consists of the following:

- A table summary of the day's performance giving the following parameters:
    - Load shift for the morning and evening peak periods.
    - Average load shift for the month.
    - Contractual load shift.
    - Cost saving for the specific day.
    - Cost saving for the specific month.
    - Electricity consumption for the day.
    - Percentage of the day that the EMS was manually overridden by the control room operators.
- A graphic comparison between the electricity usage profile and the baseline, as shown in Figure 2-11. The blue line is the actual electricity usage profile for the day, the green line

is the ENB and yellow bands indicate the peak periods. Red bands indicate data loss and a grey band indicates manual override of the EMS.

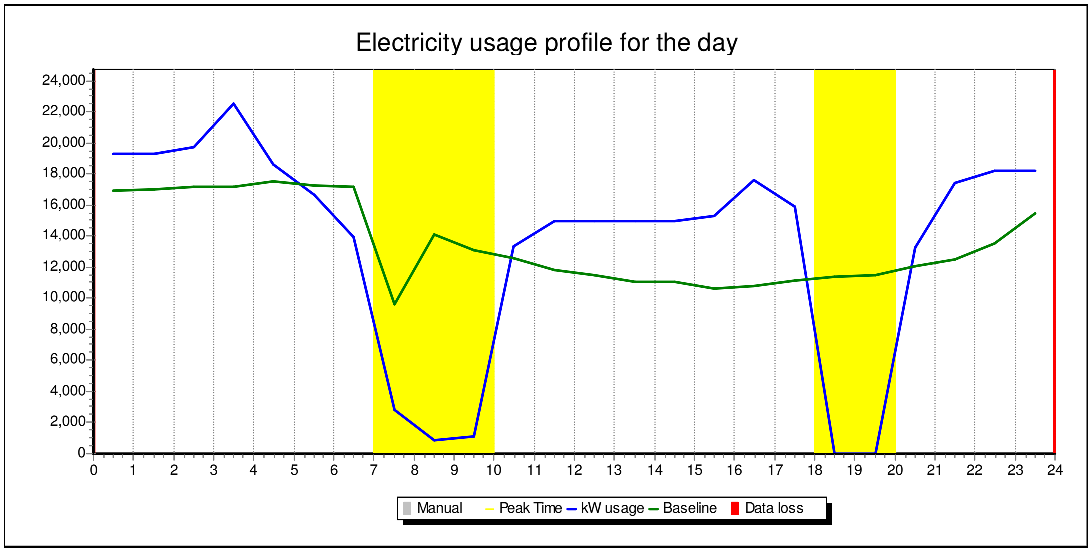

Figure 2-11: Electricity consumption profile for a typical day

- Graphs for every mining level, showing dam levels and schedules on the level (Figure 2-12). The red and blue lines indicate up- and downstream dam levels. The pink line indicates the schedule dictated by the EMS and the green line the actual pumps running.

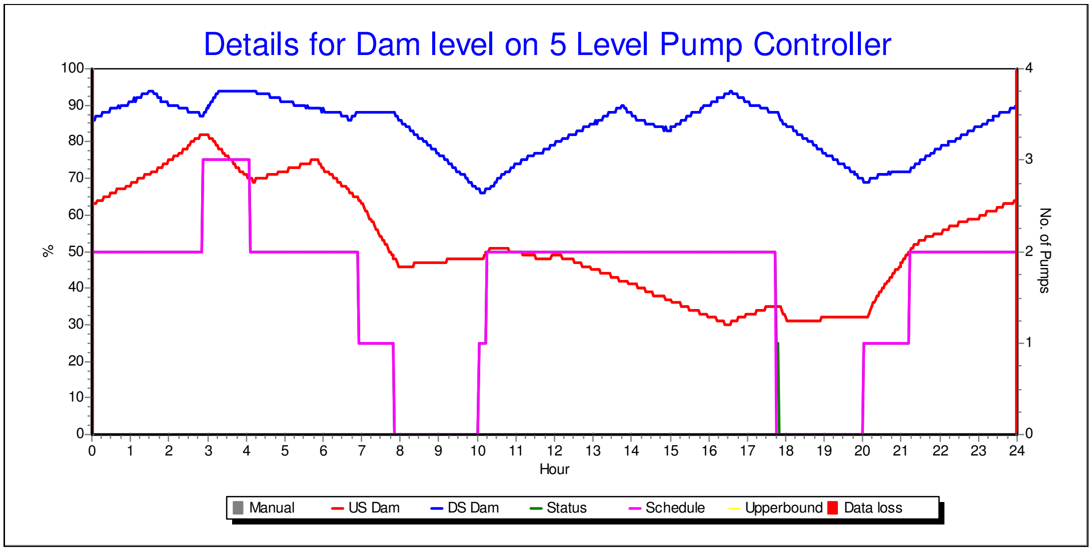

Figure 2-12: Dam levels and pump schedules for a typical day

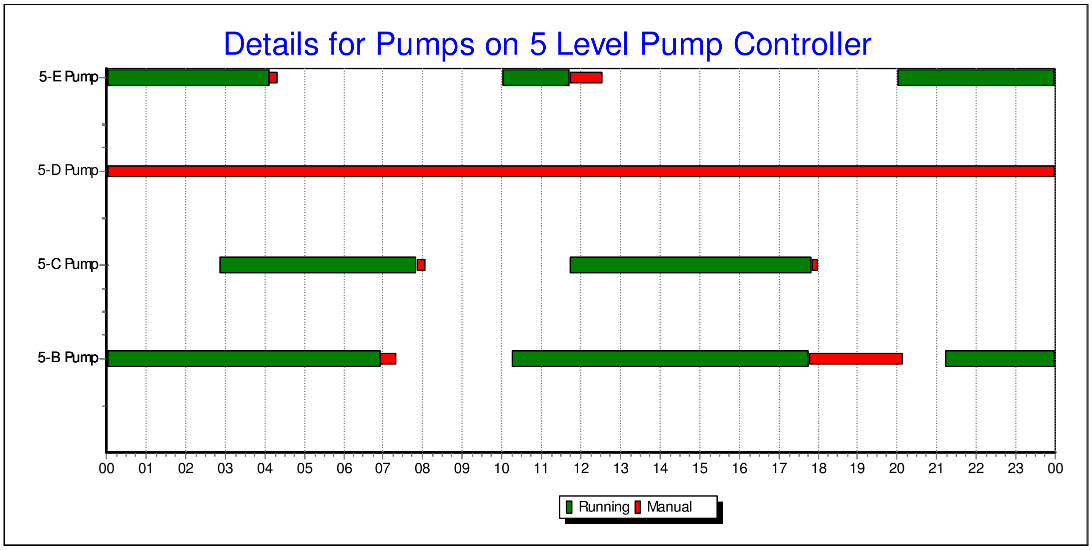

Figure 2-13: Pump running times for a typical day.

- A graph for every mining level indicating the availability and running times for equipment i.e. pumps (Figure 2-13). The red and green bars in Figure 2-13 indicate the running times for a given pump. A red bar indicates that the REMS system did not have control of that pump. This single pump override could be the result of a SCADA failure or as a result of manual override. Figure 2-12 and Figure 2-13 will enable the reader to distinguish between operator interference and EMS malfunctions.

Weekly and monthly reports (See Appendix B.2 and B.3 for sample reports)

The purpose of the monthly report is to give feedback at managerial level, i.e. the shaft engineers, which would enable them to evaluate the present performance of the system.

The report consists of the following:

- A table summarising the past performance of the project, containing:
    - Proposed savings.
    - Savings achieved.
    - Unrealised potential or over performance.

- Accumulated totals.

- Proposed savings for a project is normally determined while the project is still being investigated. This figure is the theoretical potential for the project. It is calculated by using the same electricity usage of the historical baseline, spread into a conservative optimum profile to maximise the savings. This profile is not easily realised, but it is still possible to exceed the proposed savings, especially in high production times.

- A graph showing the past performance of the project (Figure 2-14). The red and blue bars show the proposed and actual savings for the previous year(s). The yellow and green bars show the proposed and actual monthly savings accumulated for the year to date. The deficit, as a result of the manually operated project, is clearly seen here.

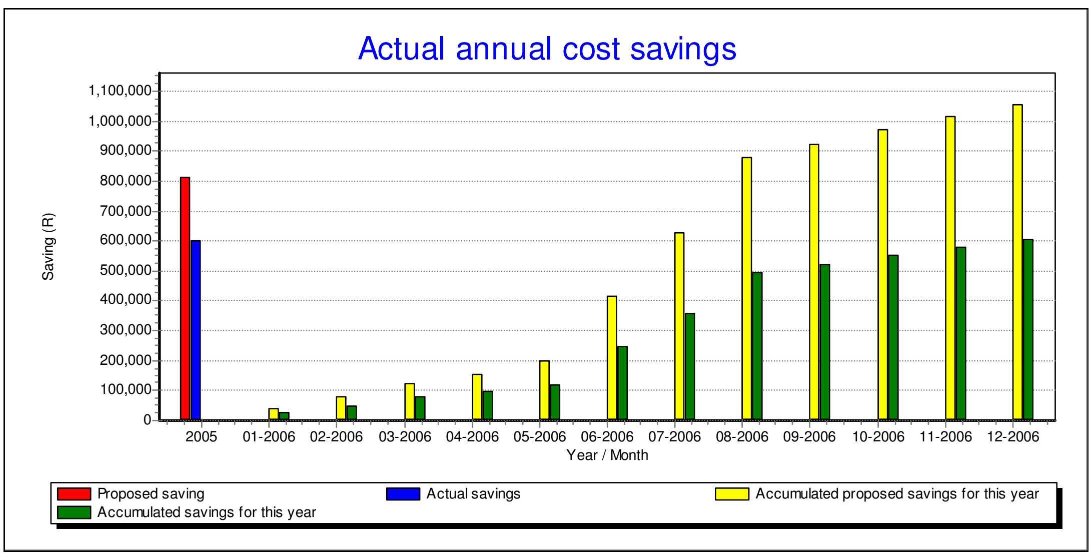

Figure 2-14: Graph of past performance of a project

- A graph showing the performance of the project for the year (Figure 2-15). The graph is similar to Figure 2-14, but the totals are not accumulative. The savings during the three winter months are much larger than the rest of the year due to the Megaflex pricing structure.

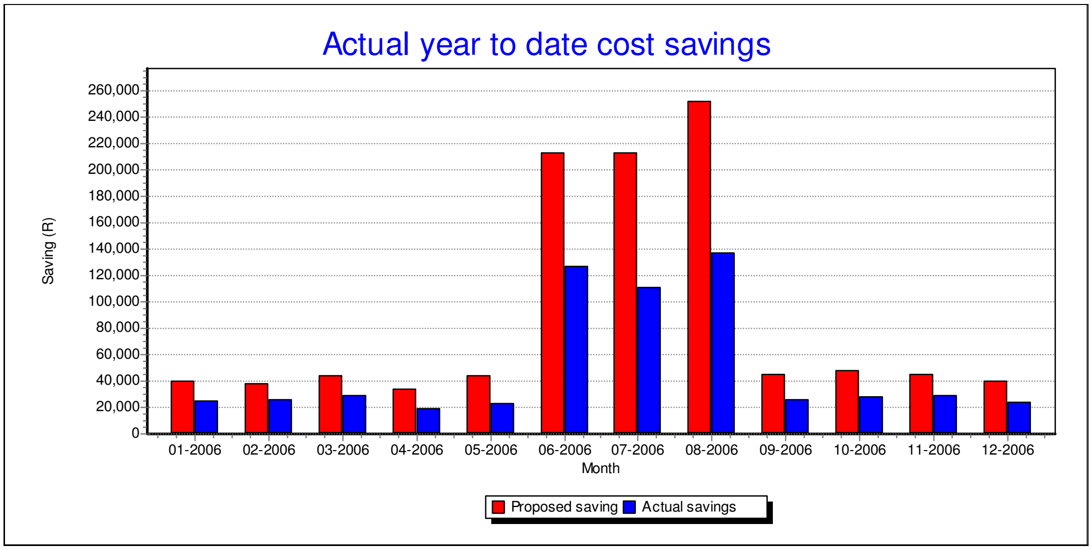

Figure 2-15: Graph of project performance for the year running

- A graph showing the cost savings for the period (Figure 2-16)

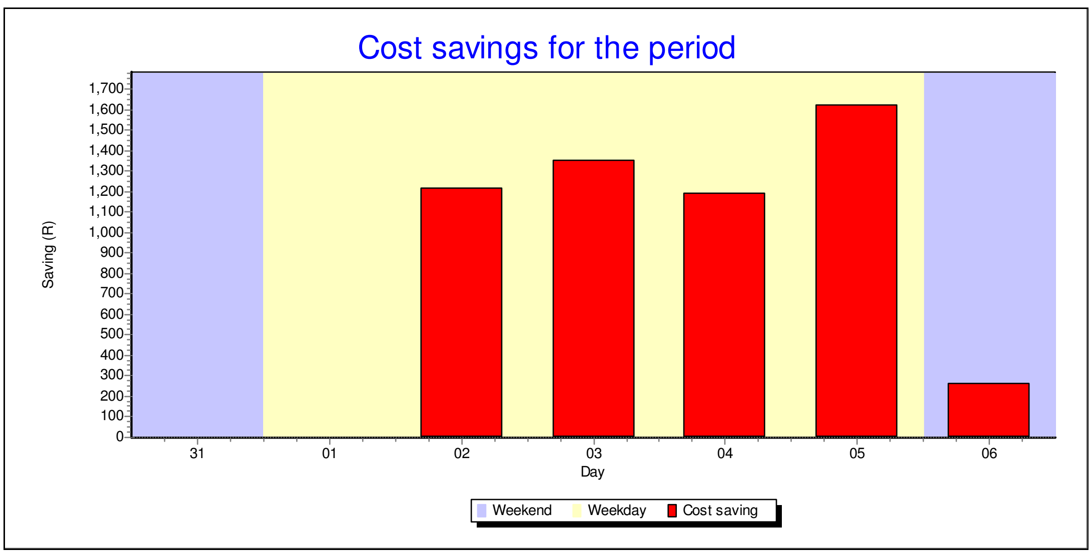

Figure 2-16: Cost savings for the period

- A graph showing the average electricity usage profile for the period with the baseline (Figure 2-17).

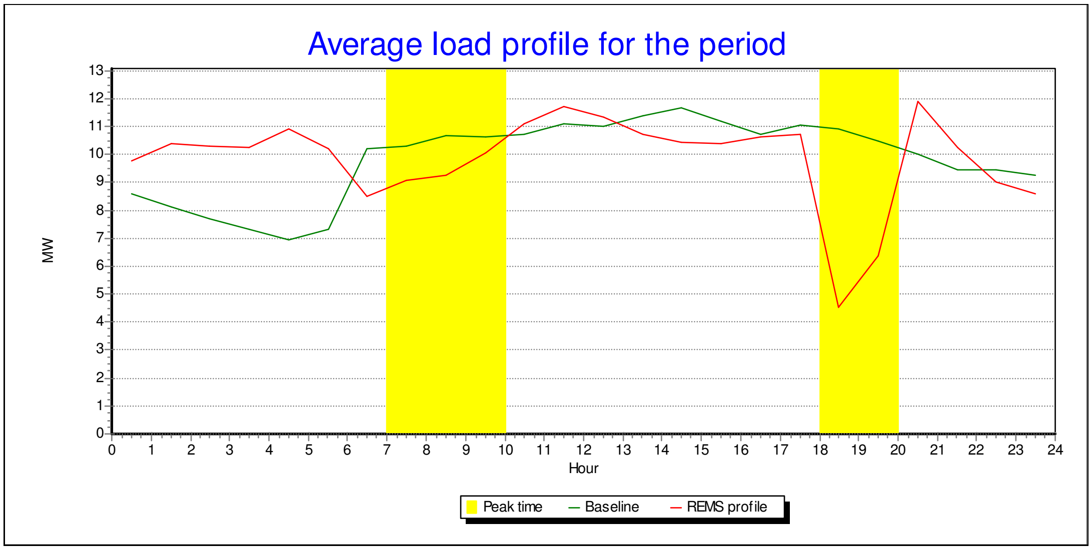

Figure 2-17: Average electricity usage profile

- A graph showing the morning and evening load shift results for the period (Figure 2-18).

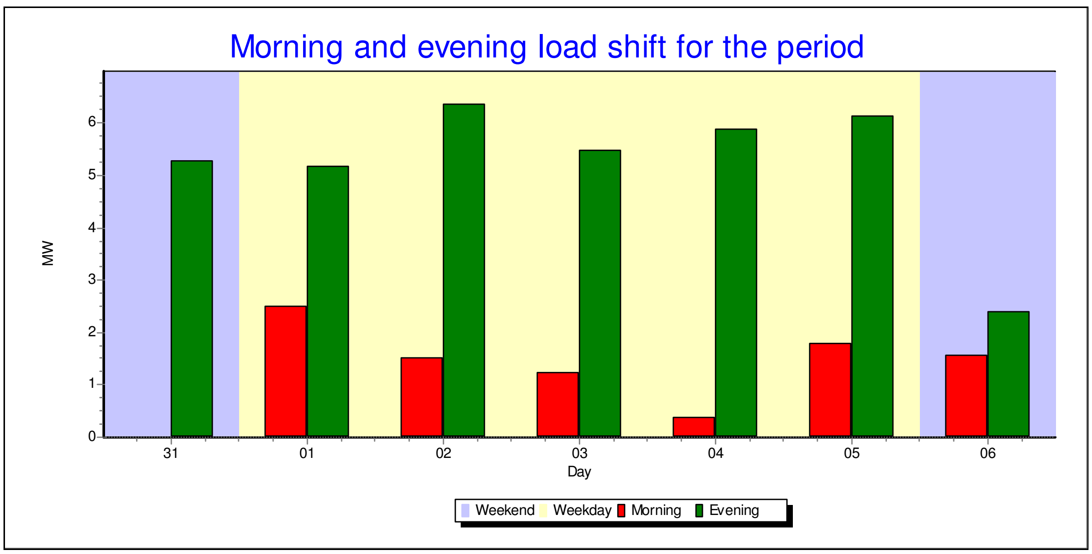

Figure 2-18: Load shift results for the period

- A table giving the daily performance for the week or month. This includes:
    - Actual saving
    - Missed opportunities
    - Reason for missed opportunity

- Manual intervention (% of day)
- Electricity consumption

Group reports

The group report documents the results of various DSM projects on different sites. It is typically used by head office engineers of a mine group such as Harmony, Gold Fields or AngloGold Ashanti to determine whether the capital expenditure is justified for DSM projects. Most mining houses have EE targets self-imposed or as a requirement from the Government due to the electricity crisis at the beginning of 2008.

The report consists of:

- A table comparing the various projects:
    - Project proposed monthly saving
    - Monthly saving achieved
    - Unrealised potential or over-performance
- Date of project proposals submitted
- Overviews of existing projects with relevant data concerning the Eskom project
- Average electricity usage graphs for every project, similar to Figure 2-17
- A graph comparing the performance of the projects (Figure 2-19). The blue bars show the cost savings that the ESCO realised for the client. The red and green bar shows the morning and evening peak load shift respectively.

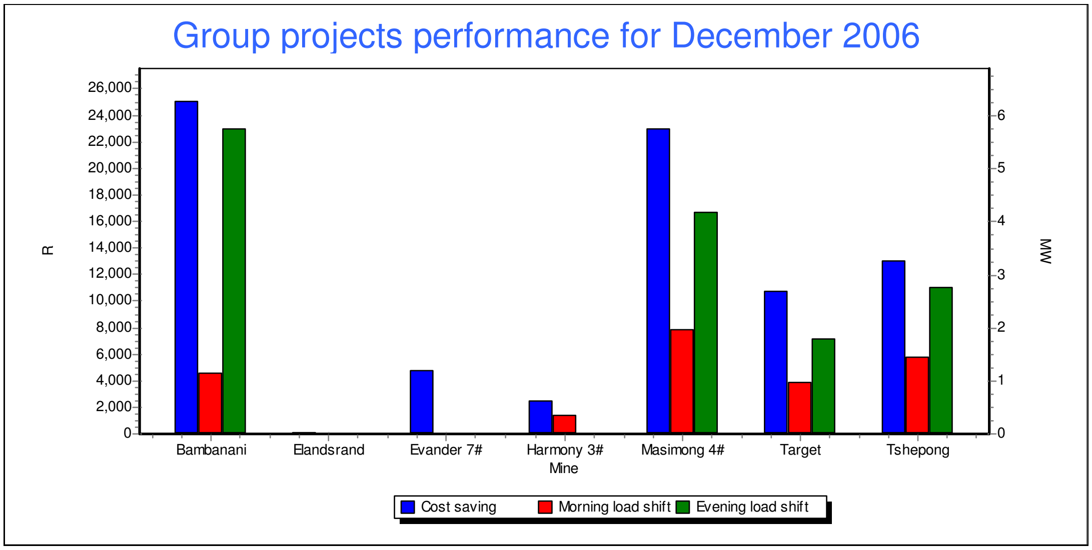

Figure 2-19: Projects performance

2.5 Developing the solution

2.5.1 Coding

From the outset, this project was designed to be easily expandable. This made the programming more complicated, but also more flexible. Meticulous research and careful planning were required from the beginning of the project. Although this was done there was some scope creep due to the fact that more and more possibilities were discovered during the development and implementation phases of the project.

There are numerous programming methodologies of which the dominant ones are procedure-driven and the more widely accepted object orientated approach. Object orientated programming (OOP) is preferred because it is more expandable than a procedure-driven program. OOP is also more powerful due to its flexibility.

Borland Delphi was chosen as the programming language. Delphi makes it possible to concentrate more on the actual technical programming. This is largely because it eliminates most of the IT-related aspects of the programming. Delphi also makes it easier to write user interfaces so that more time can be spent on the actual programming. It is more powerful than most other graphic user interface (GUI) languages, such as Visual Basic.

The program was developed in a very structured way. As each piece of code was developed it was used by project engineers to check for errors and performance issues. As a result program development took longer than expected and required an extension to the development phase of the project by twelve months.

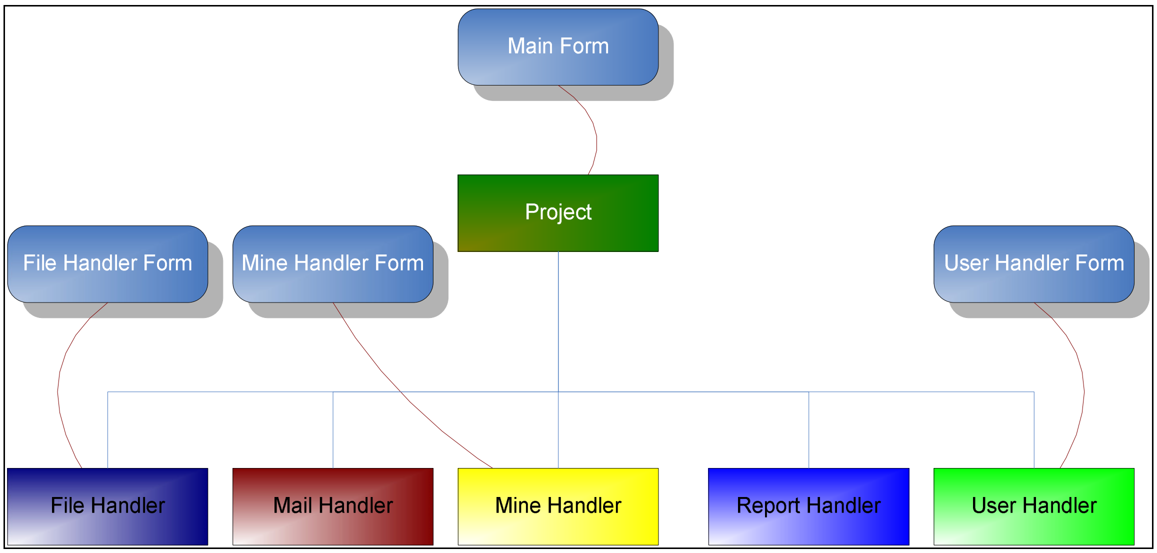

Figure 2-20: Main layout of the code

The main modules in the development stages of the program were:

Data calculations. At this module of the project all the outputs were text-based files. Data input is in a comma-delimited format. The status of all the parameters of the project is given every two minutes. The output of the program is also text-based files. Debugging information in the files allows problems to be identified and can be used to verify the program against the manual methods of calculations.

Database compilation. In this module the data was compiled into spreadsheet-type files to allow for easier access by the project engineers. This data can then be used to compile reports.

Optimisation of calculations. In this module the program could now be optimised for improved performance and less system utilisation. It is very difficult to develop a program with maximum efficiency from the beginning. If efficiency is kept in mind during the initial programming it is easier to optimise the program later on. With better programming methods and optimisation of source code the processing times could be reduced by up to 90%. A considerable amount of data must be processed. The data log file captured from a single day would fill more than 100 pages. The total computational time using the data captured over a period of a one month was reduced to 16 seconds on a normal desktop computer using a 2.4GHz Intel processor.

User interface development. For the main user interface, extensive use was made of colour to enable the user to assess the day's performance for a project at a glance. Blue was used where a project performed well, orange for borderline performance and red for poor performance. Figure 2-21 shows the main user interface.

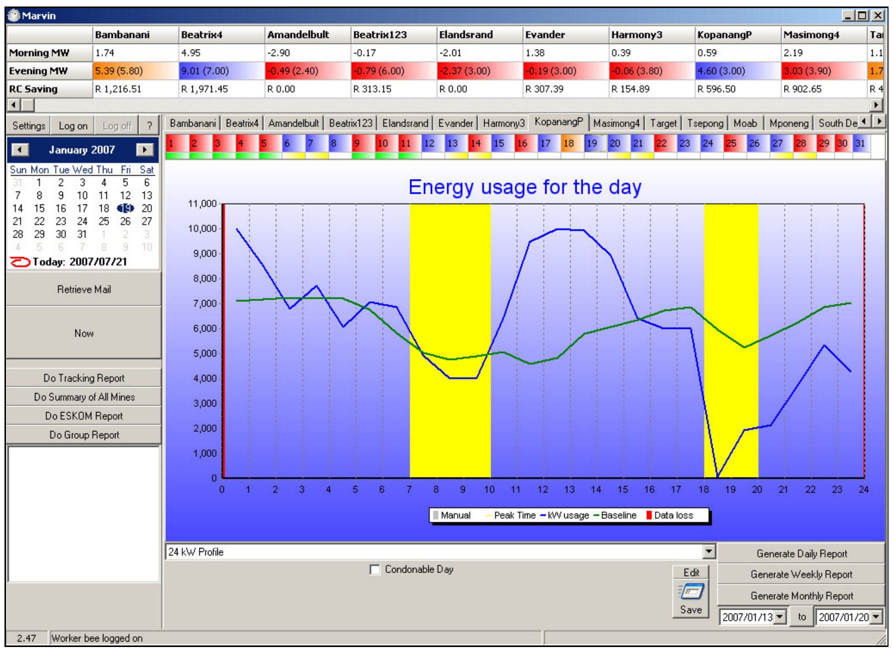

Figure 2-21: Main user interface of the program

Reporting. During this module the reporting procedure of the program was developed. It was decided to compile the reports in Microsoft Word format. This made it easier for project engineers to work with the reports and then pass this information on to the clients. Communication with MS Word was through Component Object Models (COM-objects) which is very slow and makes it difficult for fault-finding. Other options were explored but the cost implications made them less attractive.

Automation. Lastly, the automation of the program was developed. An e-mail system was developed that would send the data from the location of the project to the head office. The program could retrieve the data, calculate the daily performance and compile the report.

2.5.2 Testing

The program was thoroughly tested during each development module. Formal testing of the integrated program was done at completion. All the data of the project, taken over a period of one month, was compared to the data acquired from previous methods of calculations. A few discrepancies were noted during testing. Manual calculations of the affected data causing the discrepancies were done and found that the data calculation by the previous method was incorrect!

A further discussion of the verification of the system is given in Chapter 4. A more detailed discussion of the program code cannot be given here as it is the intellectual property of the ESCO.

2.6 Operation of the feedback solution

The feedback solution operates on an automatic basis. Users interact with the feedback solution through a GUI that gives a broad and highly visual interpretation of the performance of the project.

Daily reports are generated as the data is collected from the various locations. These reports are then automatically e-mailed to the relevant project engineers. The project engineer must then examine the report and submit comments, which are then sent on to the client.

2.7 Conclusion

Prior to this study there was no single solution that could address all the needs of the ESCO. By careful planning a single feedback solution was developed to fully automate the feedback of DSM results.

This feedback solution has the potential to significantly reduce number of man-hours normally spent by the ESCO on processing data and generating reports, as seen in Figure 5-4. The reporting solution can also provide the client with maintenance reports and quantify monetary savings realised by a fully functional EMS.

Chapter 3: Implementation

Implementation of the feedback solution is tested on
10 projects to verify if it can improve DSM results.

3.1 Prelude

The hardware and software systems must be installed and tested before the feedback solution can be implemented successfully. Responsibility for communication between the projects is contracted out to telecommunication service providers.

3.2 Requirements for implementation

3.2.1 Software

The following software is required for the feedback solution server:

- MS Windows is required because the feedback solution is specifically developed for the Windows environment and can be adapted for other operating systems. More development tools are available for Windows than for example Linux. Project engineers are also more comfortable with the operating environment of Windows.

- MS Excel: All communication with the calculators is in native programming. This means that COM-objects are not used for communication, and therefore Excel needs not be installed on the server. However, operators need to have access to the “summary of all mines” file and must be able to edit calculations if required (see 3.3.2). For this purpose Excel would have to be installed on the feedback server.

- MS Word: It is essential to install Word because the reporting solution uses COM-objects of Word to compile the reports. There are no native objects to create Word files, as for Excel.

- PDF writer: Although PDF is not essential it does allow the project engineers to send out reports in Portable Document Format (PDF) more easily.

The EMS servers:

- The software required to transmit the data archives to the feedback solution must be installed on each of the EMS servers. This software, called Sentinel, was developed in conjunction with the feedback solution. Another software program, Hermes, was developed to manage the communication infrastructure.

3.2.2 Hardware

- Server: The feedback solution was designed to operate on a normal desktop or notebook computer requiring no special processing capabilities. This ensures that project engineers can use the feedback solution for on-site implementation to determine the system performance during implementation and optimisation of simulations.

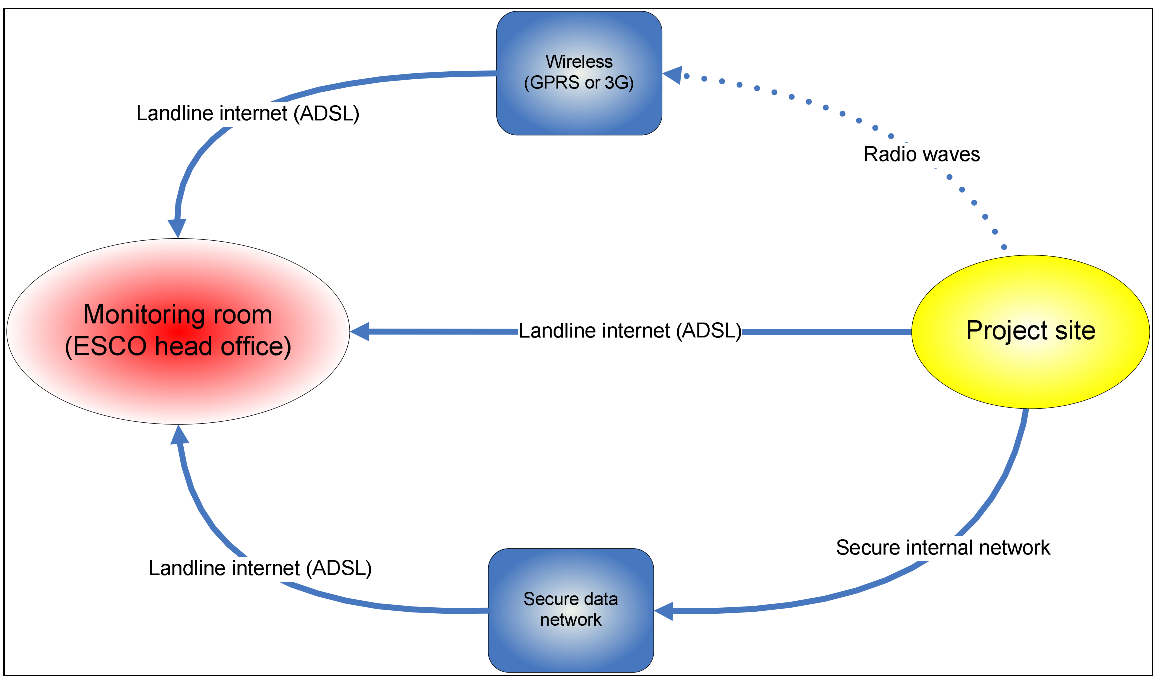

Figure 3-1: E-mail channels

- Off-site modems: three different types of modems are used for the feedback solution. These are landline, general packet radio service (GPRS) and third generation GPRS (3G). Some mines are unable to use a standard landline modem, for example Harmony 3#, because of the poor quality of the landline infrastructure. On other mines, for example

Beatrix 4#, it is not possible to install wireless modems because of interference from large electrical equipment nearby. For the Anglo-Gold mines no modems are allowed due to security risks. Anglo-Gold supplies its own e-mail infrastructure.

3.2.3 Contracts

It is essential for the ESCO to have remote viewing capabilities so that problems that may arise can be rectified without actually travelling to the site. Various software packages such as Symantec PC Anywhere can be used to connect directly to the computer at the site. Control of the DSM operation is then possible from the office of the ESCO. This presents a security risk and is also very slow due to the fact that normal telephone lines are used.

An improved method for remote viewing capability is to use an internet connection with a mobile service provider. To reduce the security risks a virtual private network (VPN) must be used. Only computers that are on the same VPN are able to communicate with each other. No other outside connection is possible. A VPN uses the same telecommunications infrastructure as the normal mobile network and no extra capital costs are involved (Figure 3-2).

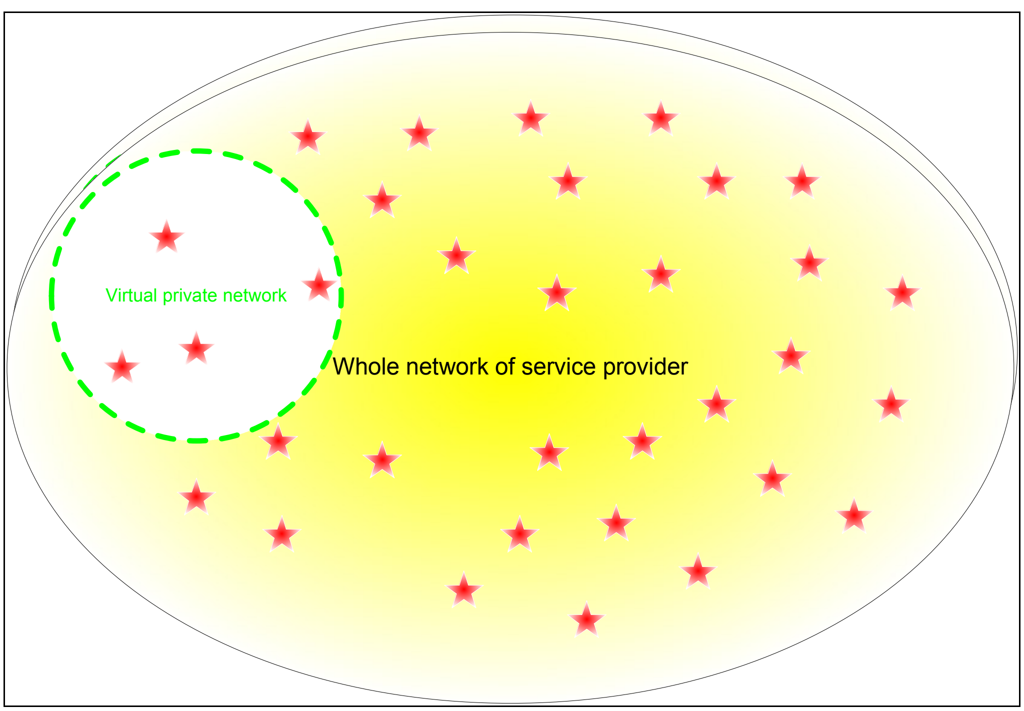

Figure 3-2: A virtual private network

A contractual agreement between the service provider and the ESCO is required to be able to make use of a VPN. A SIM-card is acquired on a monthly contract, and subscribed to a data account. Table 3-1 and Table 3-2 show the total calculated data traffic that will be used for each month.

Table 3-1: E-mail volume for one month

E-Mail	50	kB
Views per month	30	
Total E-Mail	1.46	MB

Table 3-2: Remote viewing volume for one month

Platform View	50	kB/min
View Per Day	30	min
Total views per month	20	
Total View	29.30	MB

At the start of this program mobile data costs were still relatively expensive and it was very important to minimise the costs. The Data Messenger contract from one of South Africa's leading mobile service providers was chosen. On this contract additional data bundles could be purchased beforehand to reduce the total cost over the five-year period of the project.

Table 3-3: Cost calculations for different data packages, in 2007[10]

Package	DataMessenger	DataMessenger	DataMessenger
Bundle		MyMeg 20	MyMeg 75
Once-off	R 97.00	R 97.00	R 97.00
Subscription	R 9.00	R 37.00	R 97.00
Per SMS	R 0.22	R 0.22	R 0.22
Free SMS	0	0	0
Per Mb	R 2.00	R 4.00	R 4.00
Free Mb	5	25	80
Subscription	R 9.00	R 37.00	R 97.00
SMS	R 6.60	R 6.60	R 6.60
Data	R 51.52	R 23.05	R 0.00
Monthly total	R 67.12	R 66.65	R 103.60
Period Total	R 4,027.41	R 3,998.81	R 6,216.00

[10] Prices and packages from Vodacom as of 2007. www,vodacom.co.za

Table 3-3 shows the total cost for each of the three packages considered. It can be seen that the Data Messenger with a 20 MB bundle would be the most cost-effective package. Because the cost difference between the two packages was reasonably small, the standard package was chosen as it would lower the risks due to contractual obligations to the ESCO.

3.3 On-site implementation – Head office

3.3.1 Adding a new project

To add a new project to the feedback solution, or to edit an existing project, the following screen prompt of Figure 3-3 is used, together with the parameters of Table 3-4.

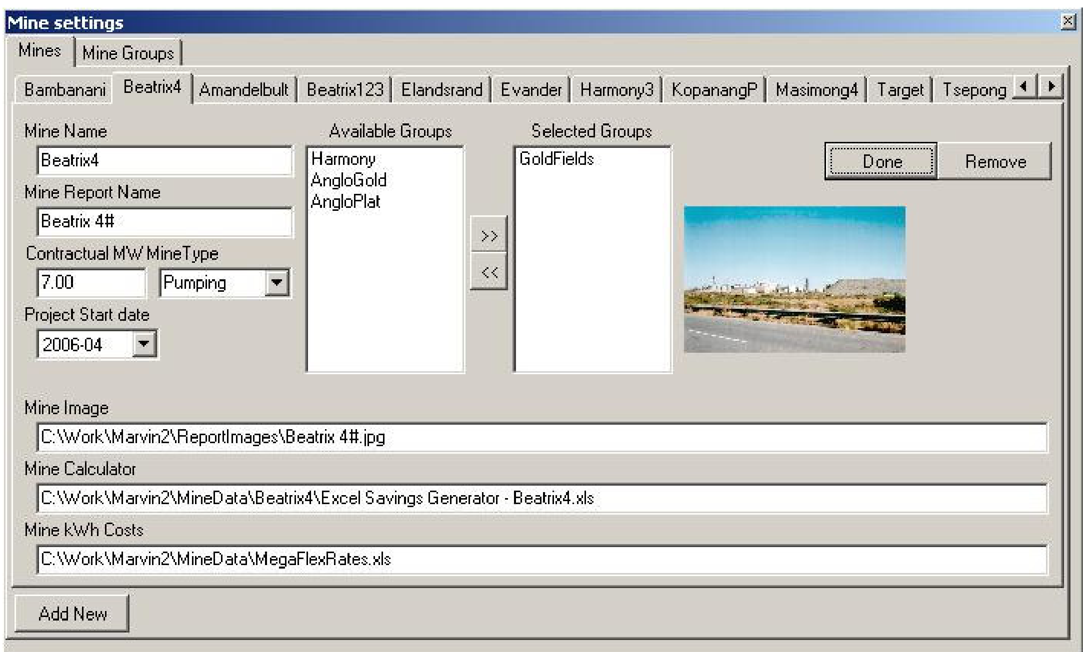

Figure 3-3: Adding a new project

Table 3-4: Parameters required adding a new project

Parameter	Description
Mine name	The ESCO's name for a project
Contractual MW	Contractual evening load shift, in MW
Project start date	The implementation date of the project
Mine group	The mine group the project belongs to
Mine’s calculator	Filename for the mine’s calculator spreadsheet
Mine kWh Costs	Filename for the mine’s electricity costs

3.3.2 Spreadsheet calculator setup

To complete the setup of a project the calculator spreadsheet of the mine must be customised. Figure 3-4 shows the page of the calculator that must be edited.

MINE DATA WORKSHEET

Mine data 1 - Baselines (in kWh)

	M&V Baseline			Proposed Baseline		
Hour	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday
0	17956.72	17956.72	17956.72	17315.94	17315.94	17315.94
1	18000.90	18000.90	18000.90	17046.29	17046.29	17046.29
2	18222.79	18222.79	18222.79	16920.59	16920.59	16920.59
3	18241.96	18241.96	18241.96	16798.24	16798.24	16798.24
4	18538.02	18538.02	18538.02	16144.71	16144.71	16144.71
5	18308.42	18308.42	18308.42	15384.88	15384.88	15384.88
6	18187.76	18187.76	18187.76	14476.59	14476.59	14476.59
7	10611.77	10611.77	10611.77	6639.65	6639.65	6639.65
8	15128.50	15128.50	15128.50	7405.41	7405.41	7405.41
9	14128.29	14128.29	14128.29	9124.94	9124.94	9124.94
10	13640.66	13640.66	13640.66	12375.82	12375.82	12375.82
11	12854.30	12854.30	12854.30	13440.59	13440.59	13440.59
12	12467.17	12467.17	12467.17	14353.71	14353.71	14353.71
13	12043.01	12043.01	12043.01	15655.47	15655.47	15655.47
14	12069.82	12069.82	12069.82	15949.76	15949.76	15949.76
15	11654.67	11654.67	11654.67	16342.18	16342.18	16342.18
16	11835.62	11835.62	11835.62	16195.12	16195.12	16195.12
17	12203.18	12203.18	12203.18	13291.18	13291.18	13291.18
18	12458.26	12458.26	12458.26	0.00	0.00	0.00
19	12496.45	12496.45	12496.45	0.00	0.00	0.00
20	13085.92	13085.92	13085.92	13110.35	13110.35	13110.35
21	13554.83	13554.83	13554.83	16475.41	16475.41	16475.41
22	14509.19	14509.19	14509.19	17180.41	17180.41	17180.41
23	16523.34	16523.34	16523.34	17098.82	17098.82	17098.82

Mine data 2 - Contractual Evening Loadshift (in MW)

7.00	0.00	0.00

Mine Data 3 - Pumpgroups

The PumpGroups names must be the same as the ones that are found in the Pumpgroupslog. The maximum allowed levels is n = 14.

n = 3

	Group Names	Pumps in Group	Pump Names				
1	21 Level Pump Controller	5	21-A Pump	21-B Pump	21-C Pump	21-D Pump	21-E Pump
			3200	3200	3200	3200	3200
2	25 Level Pump Controller	5	25-A Pump	25-B Pump	25-C Pump	25-D Pump	25-E Pump
			1100	1100	1100	1100	1100
3	5 Level Pump Controller	4	5-B Pump	5-C Pump	5-D Pump	5-E Pump	
			3200	3200	3200	3200	

Mine Data 4 - Levels

n = 1

Figure 3-4: Project specific data

Table 3-5: Mine specific data for the calculator spreadsheet

Parameter	Description
M&V Baselines	The historical baselines for weekdays, Saturdays and Sundays, in kWh
Proposed baselines	The optimum profile, used to calculate missed opportunities, in kWh
Contractual load shift	The contractual load shift for each day-type, in MW
Pump group data	Data for grouping of different pumps for reporting purposes
Pump size	The installed capacity of a pump, in kW

3.4 Off-site implementations

3.4.1 Communication infrastructure

Software: The program Hermes is capable of managing the infrastructure on sites where wireless is the only reliable means of communication. This program opens and closes connections and monitors whether the communication line is active. If communication is lost, Hermes will automatically attempt to re-establish the connection.

Wireless modems: Various types of wireless modems were tested. Router type modems were used initially but proved to be unsatisfactory. Redundancy was also a very big problem. Universal Serial Bus (USB) modems were also tested but these modems gave problems after prolonged use. Industrial RS 232 modems, with high gain external antennas were found to give the best results. The failure rate of these modems was far less than the conventional modems.

Landline modems: A few landline modems were also tested together with various hardware configurations. USB modems proved sufficiently reliable for landline communication.

3.4.2 Data logging and archiving

Logging of performance data is done by the EMS. This data is kept in a comma delimited text file format (CSV). Text files are large in comparison to the amount of data they contain, but can easily be compressed to save bandwidth when being e-mailed. The software program, Sentinel, was used to collect and compress the daily data files and e-mail them to the central processing server.

3.5 Checklist for off-site implementations

Table 3-6: Checklist for installation

Item	Detail
A - Landline modem installation	
1. Check line	Is there a dial tone on the line present? Is the line's connection quality good?
2. Install drivers	Install the modem's drivers and reboot server
3. Install surge protection	Install an in-line lightning protector on the phone line
4. Physically connect modem to server	Connect the modem to the server
5. Preliminary line integrity test	Manually do a dial-up to internet server
6. Setup Dial-up connection	Configure the Windows Dial-up handler
7. Test Dial-up connection	Test if the Windows Dial-up handler functions correctly
8. Simulate "connection lost"	Disconnect phone line and reconnect after connection is lost to see if the Hermes program automatically resets the connection
B - Wireless modem installation	
1. Find best signal strength	Search for a location with the best reception
2. Install antenna	Install correct gain antenna
3. Install drivers	Install the modem's drivers and reboot server
4. Physically connect modem to server	Connect the modem to the server
5. Setup Dial-up connection	Configure the Windows Dial-up handler
6. Test Dial-up connection	Test if the Windows Dial-up handler functions correctly
7. Connection Duration test	Check if the connection is stable over a set time
8. Simulate "connection lost"	
C - Software installation	
1. Install Sentinel	Install and configure Sentinel
2. Install Hermes	Install and configure Hermes
3. Setup E-mail	Configure e-mail settings
4. Send test e-mail	Send test e-mail and confirm delivery with recipient
5. Test alarms	Simulate alarms
6. Schedule data archiving	Set times for data archiving
7. Schedule e-mails	Set times to send e-mails

3.6 Conclusion

The on-site and off-site implementation of the feedback solution was discussed in this chapter. Only a few simple steps are required to add a new project to the existing number of projects. In Chapter 4 the verification of the feedback solution and the impact it has on DSM results will be discussed.

Chapter 4: Verification

4.1 Prelude

Case studies on various clear-water DSM pumping projects were used for verification purposes. These projects varied from state-of-the-art to poorly maintained mines as well as some mines that have ceased production.

The sites that were selected for implementation are given in Table 4-1.

Table 4-1 : Implementation sites for case studies

Project	Owner	Location	Description
Bambanani	Harmony	Free State	Large, old mine with medium infrastructure.
Beatrix 4#	Goldfields	Free State	Old Oryx mine. Large mine with medium infrastructure.
Beatrix 1,2&3#	Goldfields	Free State	Three smaller shafts combined into one DSM project.
Elandsrand	Harmony	North West	Old mine.
Evander 7#	Harmony	Mpumalanga	Old mine with regular technical problems.
Harmony 3#	Harmony	Free State	Old mine.
Kopanang	AngloGold	Free State	Large mine with good infrastructure.
Masimong 4#	Harmony	Free State	A non-production mine pumping water only.
Mponeng	AngloGold	North West	Flagship of the South African mining industry.
Tshepong	Harmony	Free State	A large mine utilising a three-pipe system.

4.2 Methods for verification

4.2.1 Identifying objectives

The goals that have to be addressed in the verification of the feedback solution are the following:

- Does the feedback solution reduce man-hours spent?
- Is the feedback solution reliable and accurate?
- What was the effect on DSM results?

4.2.2 Explanation of success measurement graphs

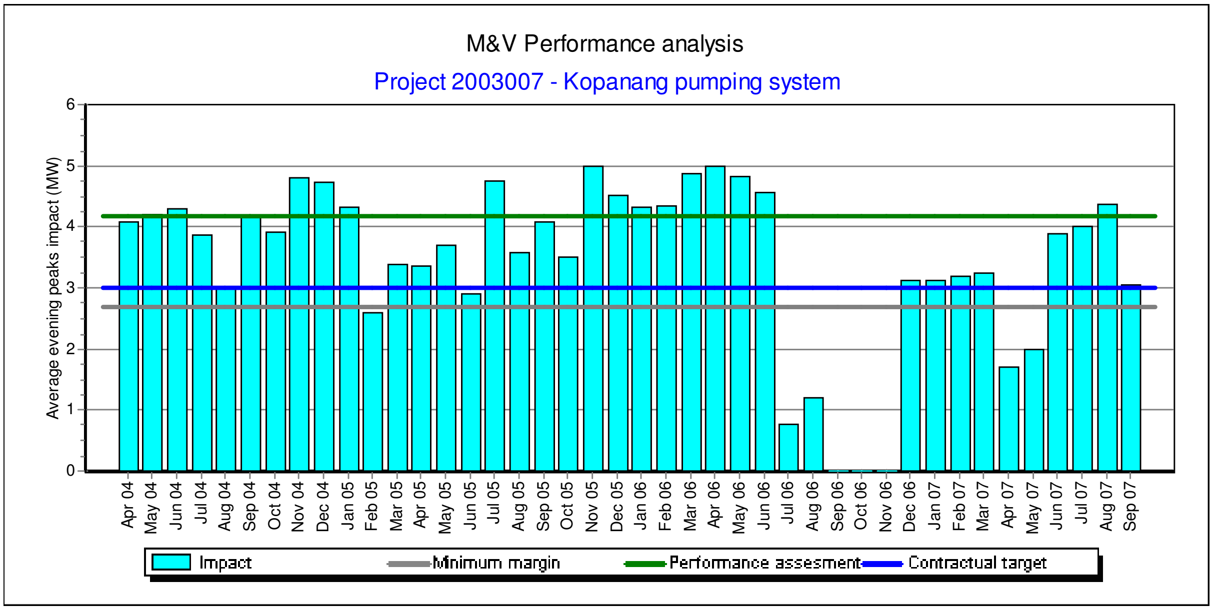

Figure 4-1: Performance analysis graph

The performance analysis graph shown in Figure 4-1 gives a visual representation of the performance of a DSM project over time.

- The turquoise bars indicate the average evening load shift for each month after project implementation.
- The dark blue line indicates the contractual evening load shift of a project. This quantity is the contractual load shift agreed upon between Eskom and the ESCO in the proposal phase of a project. It is calculated with the aid of the simulations developed by the ESCO. A conservative safety margin may be built into the simulation model by the ESCO.
- The green line indicates the performance assessment load shift of the project. This is the average evening load shift during the first three months of a DSM project.
- The grey line shows the minimum acceptable margin based on 90% of the contractual target. The Utility may penalise a client if the DSM project performs below this margin.

This figure can be used to evaluate the short-term performance of the project.

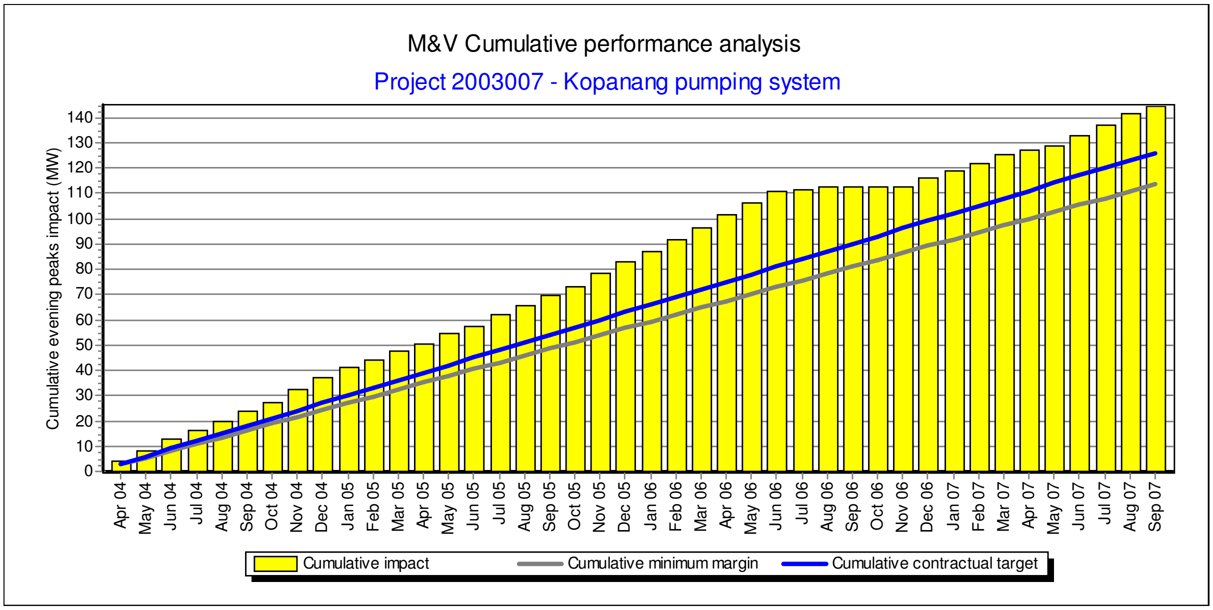

Figure 4-2: Cumulative performance analysis graph

The cumulative performance analysis graph, Figure 4-2, illustrates the long-term DSM impact of a project.

- The yellow bars show the measured load shift of the project accumulated on an average monthly basis.
- The blue line shows the contractual load shift of the project.
- The grey line is the 90% minimum margin below which the client is liable for penalties.

From this graph the long-term viability of a DSM project can be evaluated. For example, Figure 4-2 shows that there was a loss of performance from June 2006 to November 2006. However the overall cumulative performance never deteriorated below the cumulative contractual performance. The utility will not penalise the client in this instance.

4.3 Automation – Facilitating daily reporting and reducing man-hours

4.3.1 Kopanang gold mine

Figure 4-3: Kopanang gold mine (AngloGold Ashanti)

Table 4-2: Project details for Kopanang

DSM Project name	Kopanang pumping system
Contract starting date	January 2004
Project completed	March 2004
Contractual load shift	3.00 MW
Performance assessment load shift	4.18 MW

Kopanang gold mine is situated near Orkney in the Free State. The DSM project was the first project implemented by the ESCO and has continuously performed better than contractual obligations.

The mine requires daily reports on the system performance. This results in a greater work load on the ESCO's employees responsible for the project. After implementation of the feedback solution the engineer now has to only scan through the report to identify obvious malfunctions. This report, with comments, is then forwarded to the responsible person at the mine. These reports are more detailed than previous reports and give feedback on pump running and cycling times, a major concern for any large pumping project.

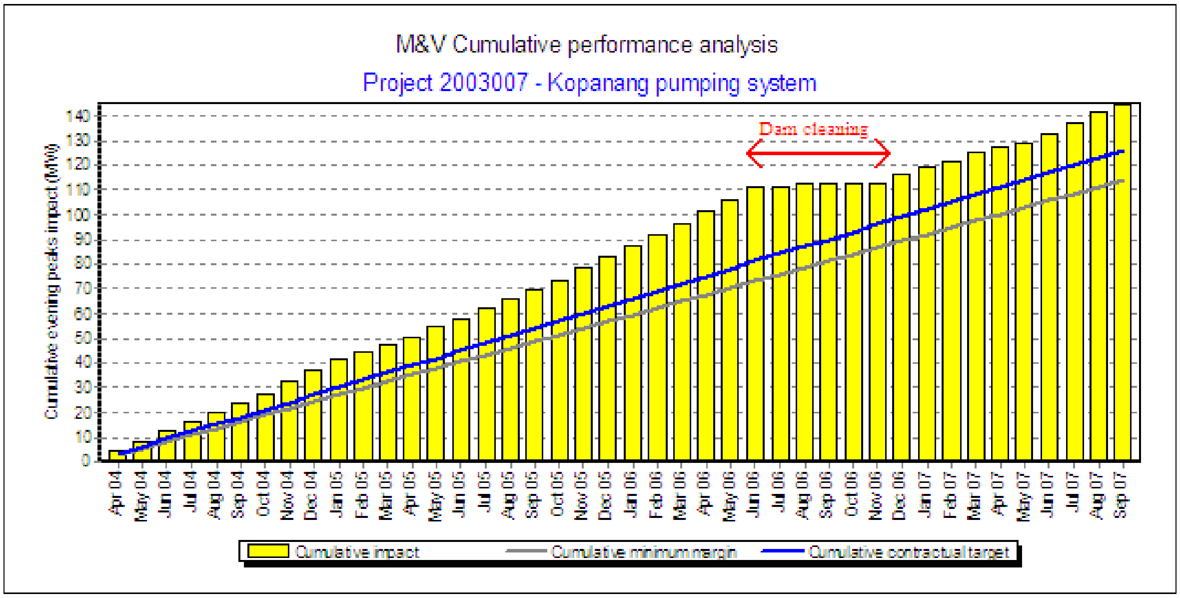

Figure 4-4: Historic cumulative performance analysis for Kopanang pumping system

During the winter of 2006 the mine carried out extensive maintenance on its pumping infrastructure and, in particular, the underground dams. The dams accumulate mud over time and this mud could damage the pumps. Mud also reduces the capacity of the dam and therefore the electricity saving potential of the level. Dam cleaning protects the pumps and could generate a large income if the sludge is processed for gold and other precious metals.

The maintenance of the dams coincided with a breakdown in communication with the mine, as discussed in Chapter 1.4.4, which resulted in very poor performance over this period. A projected loss of savings in excess of R700 000 was experienced. After completion of the maintenance period, during which DSM reporting was automated, the DSM project was again restored to perform better than the contractual obligation.

4.4 Accuracy and reliability

4.4.1 Tshepong gold mine

Figure 4-5: Tshepong gold mine (Harmony)

Table 4-3: Project details for Tshepong

DSM Project name	Tshepong pumping system
Contract starting date	June 2005
Project completed	September 2005
Contractual load shift	3.10 MW
Performance assessment load shift	4.19 MW

At Tshepong gold mine, the control room operators receive performance incentives in line with the DSM performance of the project. This helps the EMS meet its design performance and is reflected in the actual performance results of the DSM project.

The instrumentation engineer receives a daily report on the project performance of the previous day. This report will indicate whether manual intervention has taken place. Figure 4-6 shows the number of pumps required to run by the EMS (pink line) and the actual number of pumps running (green line).

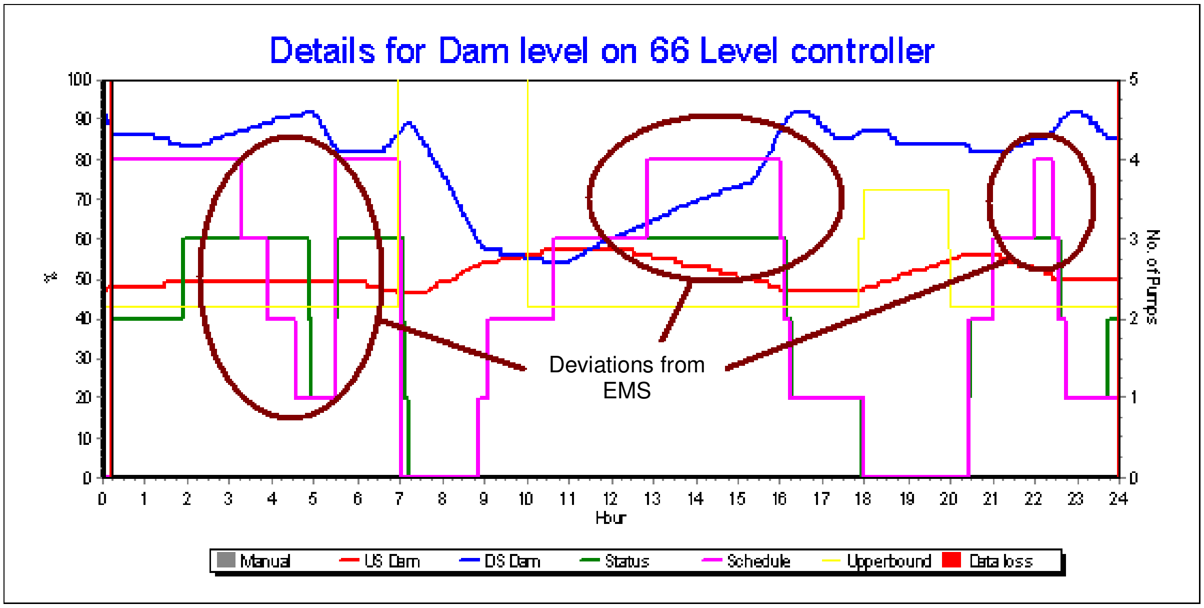

Figure 4-6: Pumps requested and available

As can be seen in this figure, three different periods of non-scheduled pump operation occurred. Figure 4-7 shows the running times for all the pumps on this level. The red lines indicate when a pump was unavailable for use. By comparing Figure 4-6 and Figure 4-7, it can be seen that the system could not prepare for peak time because insufficient pumps were available. The instrumentation engineer is then advised of this schedule variation so that it can be discussed with the operators.

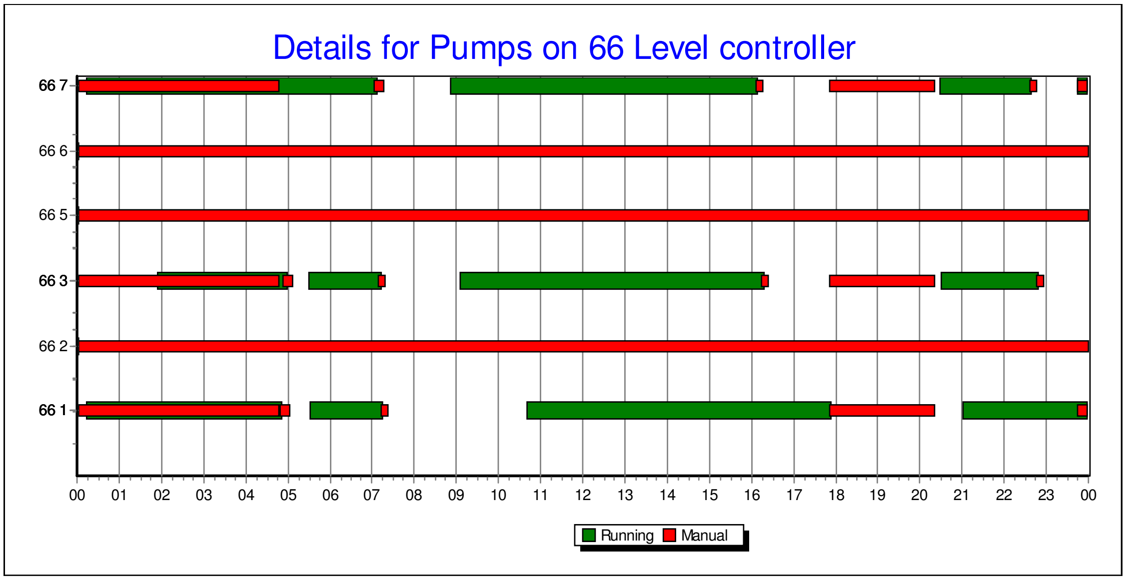

Figure 4-7: Running times of pumps and availability

The pumping project at Tshepong Gold mine has historically always performed better than the contractual evening load shift of 3.1MW. As shown in Figure 4-8, there are some months where the project only performs marginally above the contractual load shift.

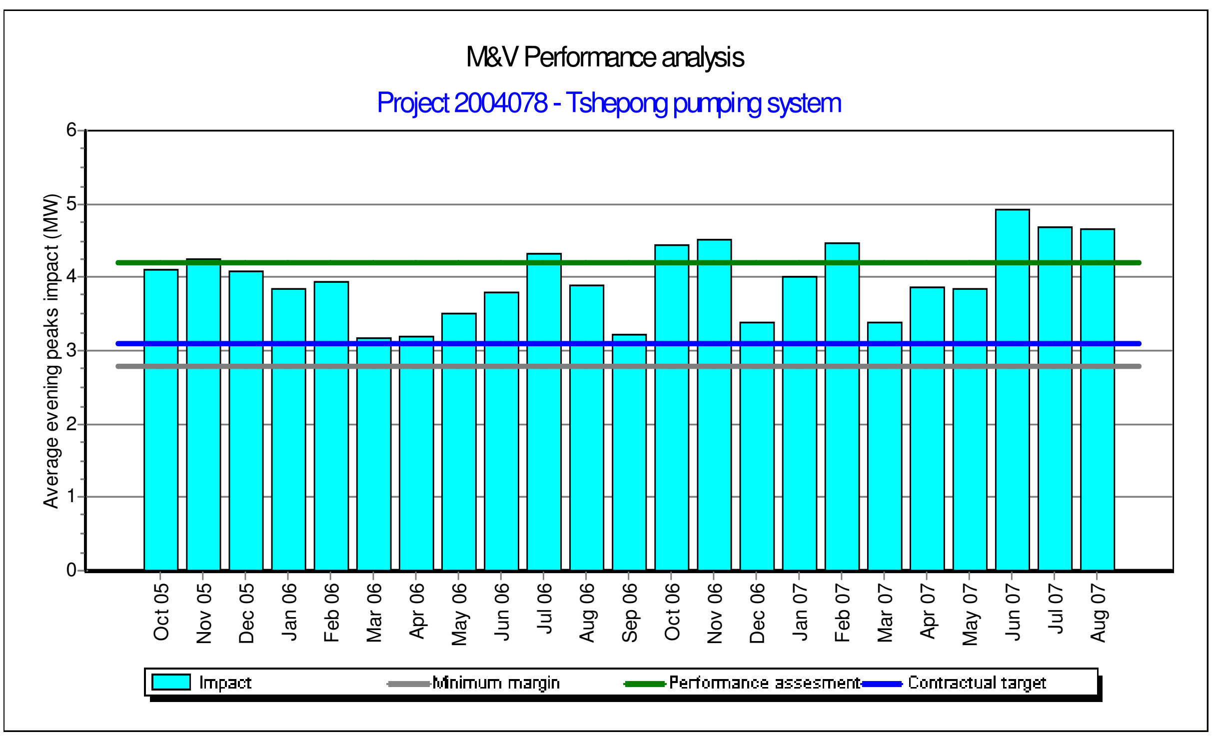

Figure 4-8: Historic performance analysis for Tshepong pumping system

4.5 Improving DSM results

4.5.1 Beatrix 1, 2&3# gold mine

Figure 4-9: Beatrix 3# gold mine (GoldFields)

Table 4-4: Project details for Beatrix 1, 2&3#

DSM Project name	Beatrix 1,2,3# pumping system
Contract starting date	June 2005
Project completed	June 2006
Contractual load shift	6.00 MW
Performance assessment load shift	6.20 MW

Beatrix 1, 2 & 3# consists of three separate shafts located in close proximity to each other. The water management of the three shafts forms part of a single system. Two of the shafts have been automated and controlled by the ESCO's EMS. The third shaft is still manually controlled. During the initial project assessment stage the performance showed an improvement, but it was not sustained, as shown in Figure 4-10.

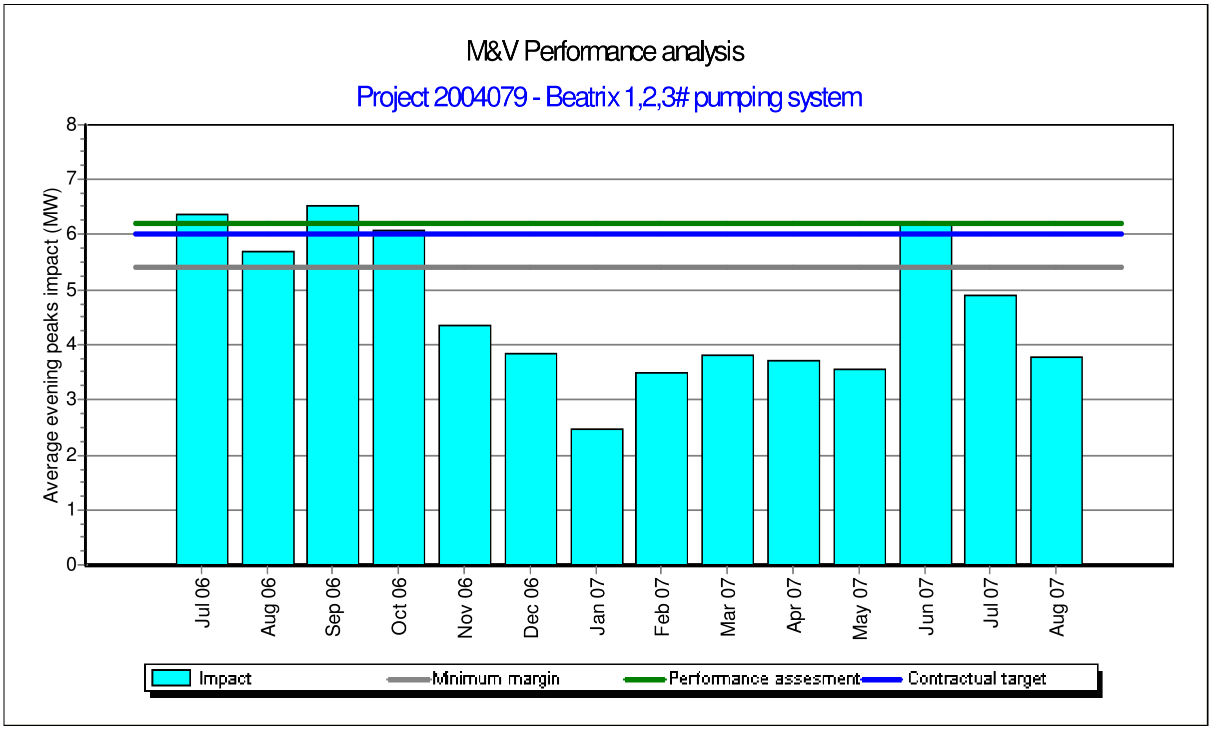

Figure 4-10: Historic performance analysis for Beatrix 1, 2&3# pumping system

In May 2007 the ESCO consulted with the engineering manager of the mine on the possible reasons for the poor performance of the DSM project. The discussion proved fruitful and resulted in a temporary improvement in DSM performance. However, the performance of the project again deteriorated.

A fully automated EMS must be implemented on the third shaft to improve the sustainable DSM performance.

4.5.2 Elandsrand gold mine

Figure 4-11: Elandsrand gold mine (Harmony)

Table 4-5: Project details for Elandsrand

DSM Project name	Elandsrand pumping system
Contract starting date	January 2004
Project completed	May 2004
Contractual load shift	3.00 MW
Performance assessment load shift	4.80 MW

At Elandsrand gold mine poor maintenance and a sharp drop in production caused a significant decline in the performance of the DSM project.

The reporting solution would help to reduce the missed opportunities and justify capital expenditure for maintenance. This capital could be paid back with the savings that the ESCO's EMS could realise.

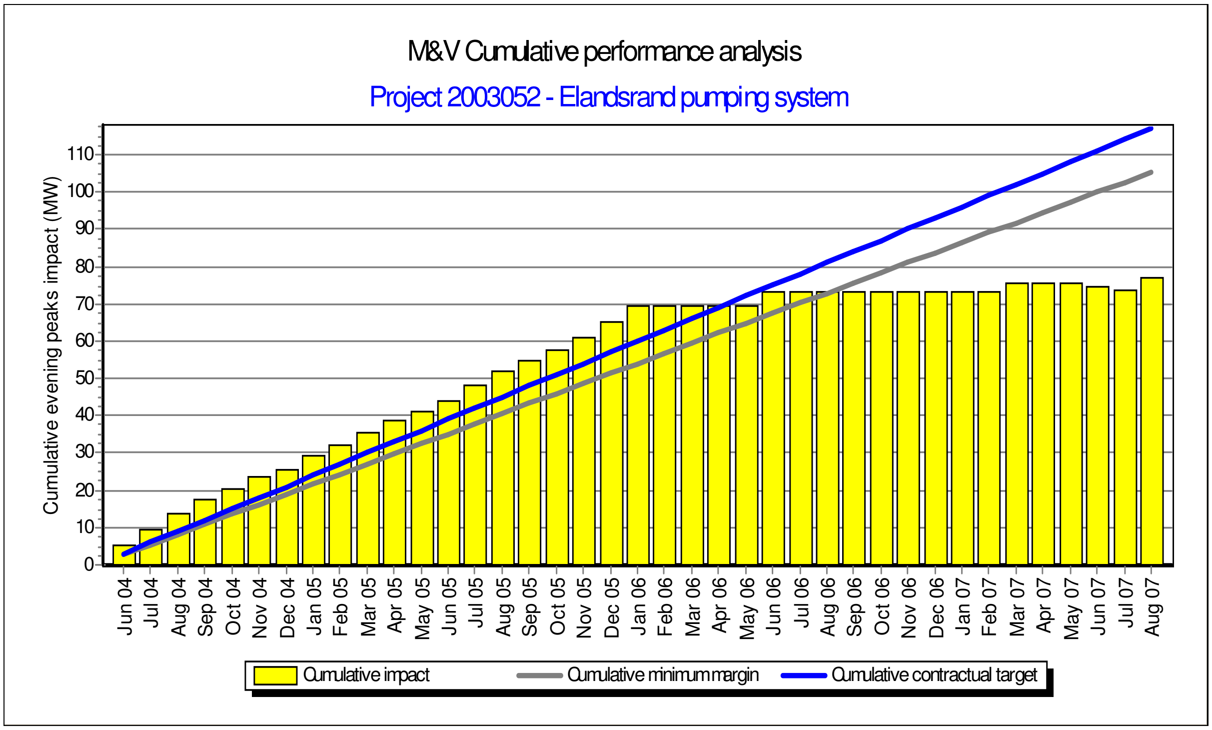

Figure 4-12: Historic cumulative performance analysis for Elandsrand pumping system

In January 2006 the mine commenced an extensive maintenance program on the pumps and underground settler dams. The buffer capacity of the dams was reduced during this period. Optimal use of the EMS for load shifting was not possible due to the lower dam capacity resulting in under-performance of the DSM project. Subsequent to this, a series of technical difficulties continued to plague the DSM project. In August 2007 the mine experienced a shaft emergency where 3200 workers were trapped underground for 48 hours. Production continued after the incident, but was continually halted because of other problems, such as pump breakdowns and SCADA failures.

4.5.3 Harmony 3# gold mine

Figure 4-13: Harmony 3# gold mine (Harmony)

Table 4-6: Project details for Harmony 3#

DSM Project name	Harmony 3# pumping system
Contract starting date	July 2004
Project completed	June 2005
Contractual load shift	3.80 MW
Performance assessment load shift	4.21 MW

Harmony 3# is a very old mine situated near Virginia in the Free State. The poor state of the infrastructure on the mine caused problems for all parties involved. Communication for data retrieval and monitoring purposes was also a problem due to old and unreliable telephone lines. At times it can take up to a month for the ESCO to obtain the logged data from the mine in order to assess its performance. Full automation of the project also presented its share of problems as discussed in 3.2.2.

Despite these problems the DSM project at Harmony 3# has historically performed better than the contractual target without giving exceptional results. This was largely due to daily reports sent to the mine on DSM performance. Unfortunately, the project suffered severe losses in performance between December 2006 and April 2007 due to communication breakdowns. By implementing the feedback solution, the ESCO was able to return the project to its original performance with the assistance of the mine engineer. Key issues resolved were:

- Establishment of reliable communication channels with the mine, with dual redundancy in the form of wireless and land line
- Timely delivery of daily, weekly and monthly reports
- Re-establishment of the positive participation of the client

These steps led to improved performance, as can be seen in Figure 4-14.

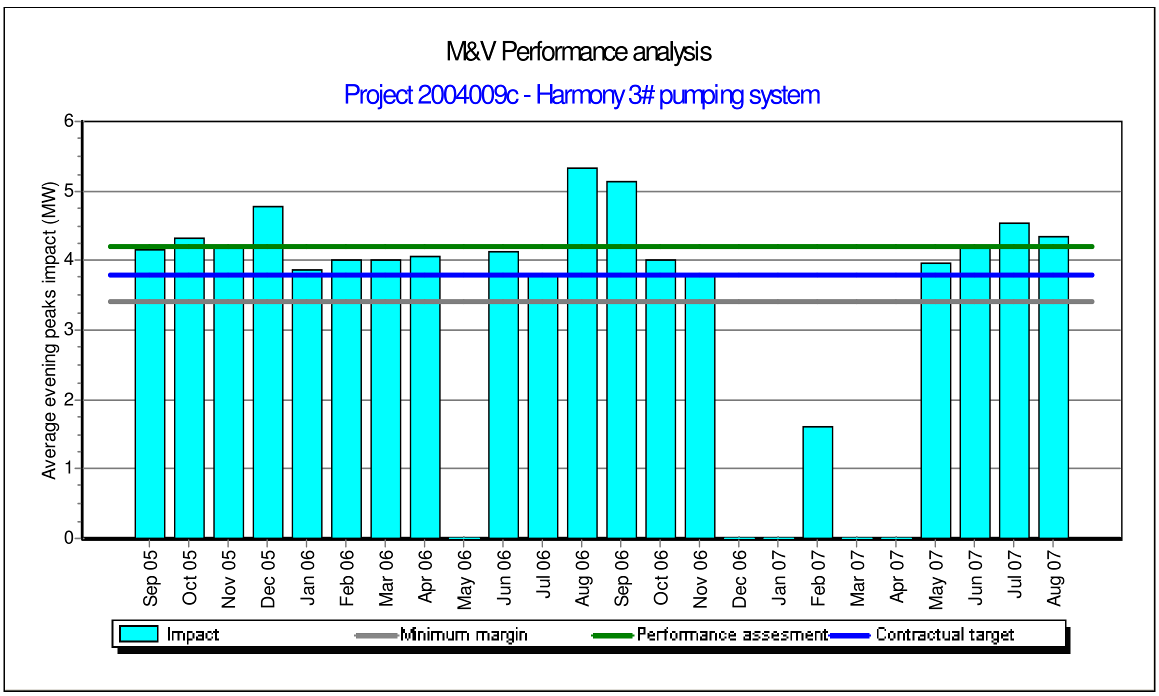

Figure 4-14: Historic performance analysis for Harmony 3# pumping system

4.6 Sustainable performance

4.6.1 Masimong 4# gold mine

Figure 4-15: Masimong 4# gold mine (Harmony)

Table 4-7: Project details for Masimong 4#

DSM Project name	Masimong 4# pumping system
Contract starting date	July 2004
Project completed	June 2005
Contractual load shift	3.90 MW
Performance assessment load shift	4.44 MW

Masimong 4# is located in the Free State gold fields. This mine ceased production for some time. However, water must still be pumped from the underground tunnels to prevent flooding of other shafts. The DSM performance at this mine frequently exceeds the contractual load shift. A cost saving in excess of R 600 000 has been realised by the implementation of DSM. Performance tracking reports have ensured that the DSM project is maintained at its present high level of performance (Figure 4-16). These savings are particularly important to this mine as it has very little income and is therefore only a drain of money on the Harmony group. Maintenance of the shaft pumps is justified by the DSM savings and this facilitates better performance due to the fact that there are fewer breakdowns (missed opportunities). The result of this DSM project is proof that good maintenance practises result in good savings.

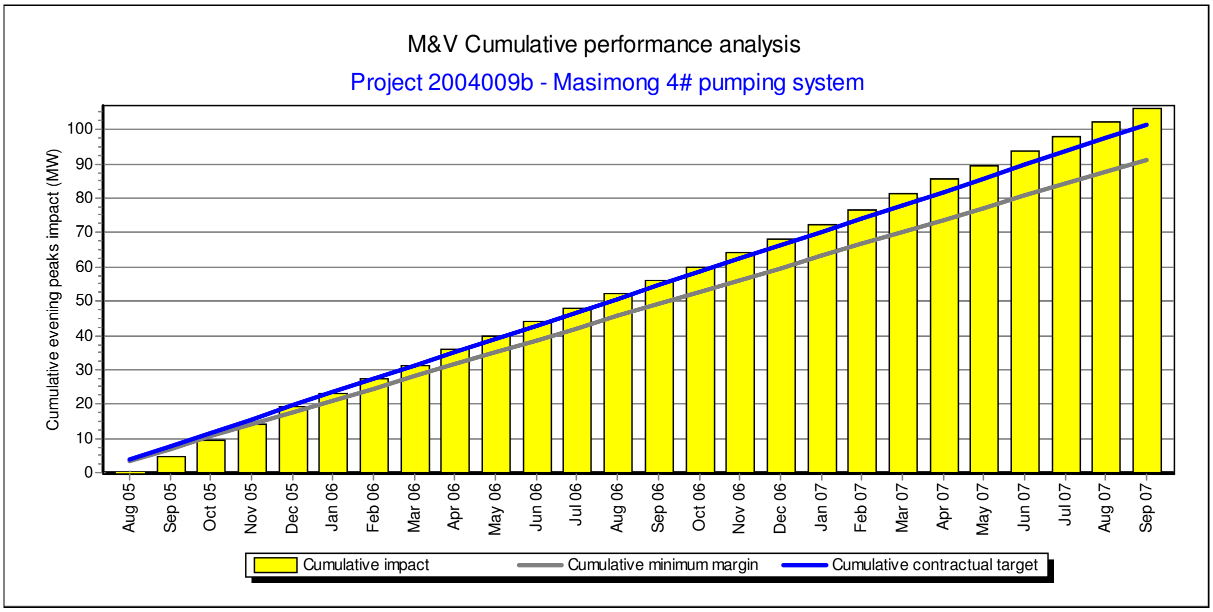

Figure 4-16: Historic cumulative performance analysis for Masimong 4# pumping system

4.6.2 Mponeng gold mine

Figure 4-17: Mponeng gold mine (AngloGold Ashanti)

Table 4-8: Project details for Mponeng

DSM Project name	Mponeng pumping system
Contract starting date	February 2005
Project completed	November 2005
Contractual load shift	6.20 MW
Performance assessment load shift	11.72 MW

Mponeng gold mine is situated on the border between the North-West and Gauteng provinces. The DSM project has always performed better than the contractual evening load shift. Regular maintenance of the infrastructure at this mine has resulted in optimal performance of the EMS. With the implementation of the feedback solution a sustainable DSM project is ensured. The Ems continually shifts more than 12 MW out of the evening peak, realising financial savings in excess of R 2.8 million for the mine.

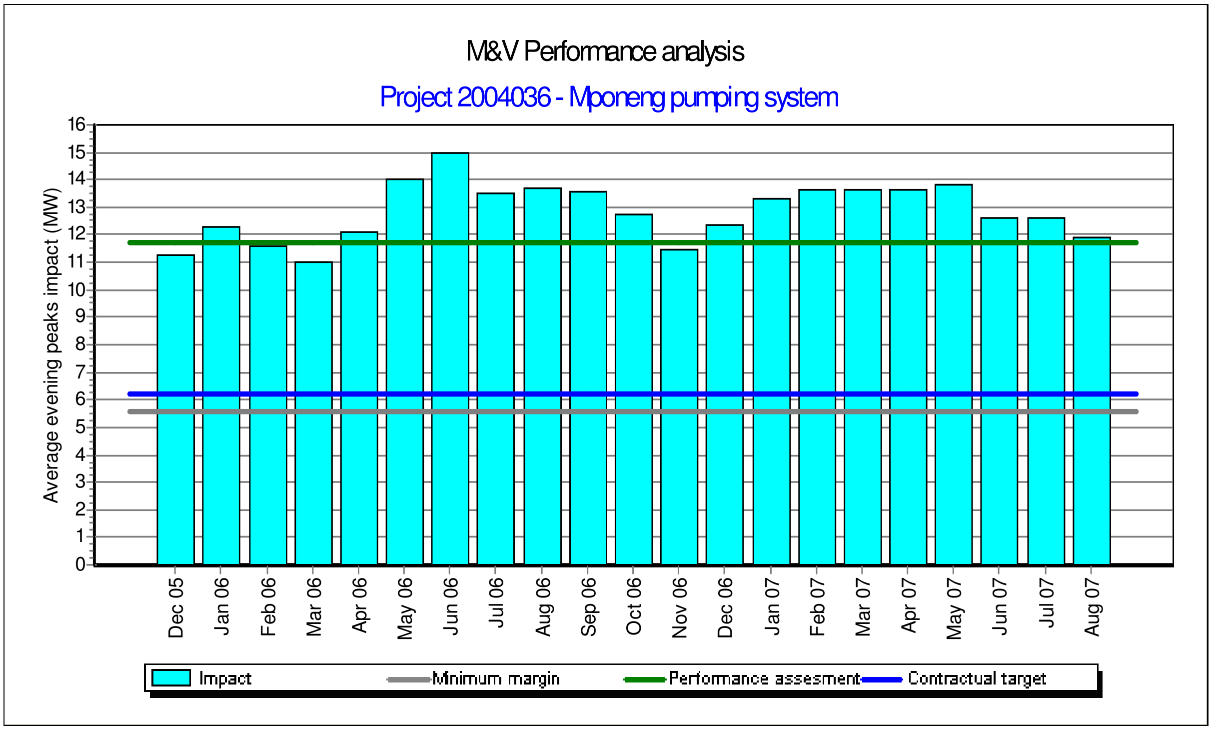

Figure 4-18: Historic performance analysis for Mponeng pumping system

4.7 Additional benefits

4.7.1 Beatrix 4# gold mine

Figure 4-19: Beatrix 4# gold mine (Goldfields)

Table 4-9: Project details for Beatrix 4#

DSM Project name	Oryx pumping system
Contract starting date	January 2005
Project completed	March 2006
Contractual load shift	7.00 MW
Performance assessment load shift	11.86 MW

The Beatrix 4# clear water-pumping project historically exceeded the contractual load shift up to December 2006. A new company was contracted by the mine to implement a program to monitor and report on parameters, such as pump running times and bearing temperatures for maintenance purposes. This system used the SCADA of the ESCO to obtain data. The software implemented by the maintenance company had component incompatibilities that caused the SCADA system to fail. Unfortunately, the users were initially unaware of this problem.

A serious safety hazard resulted because the SCADA showed that the dam levels were within acceptable limits while in actual fact, the dams were flooding. Furthermore, the ESCO's EMS could not function and was unable to shift any load. The graphs generated by the feedback solution provided sufficient proof that these problems were caused by the newly appointed maintenance company. Figure 4-20 shows clearly that the dam levels, shown by the red and blue lines, remained constant from just before 12h00. This is virtually impossible because the mining area is below the water table, which results in a constant influx of water into the system. The dark green line represents the number of pumps running prior to SCADA failure. The pink line indicates the actual number of pumps required to run by the EMS.

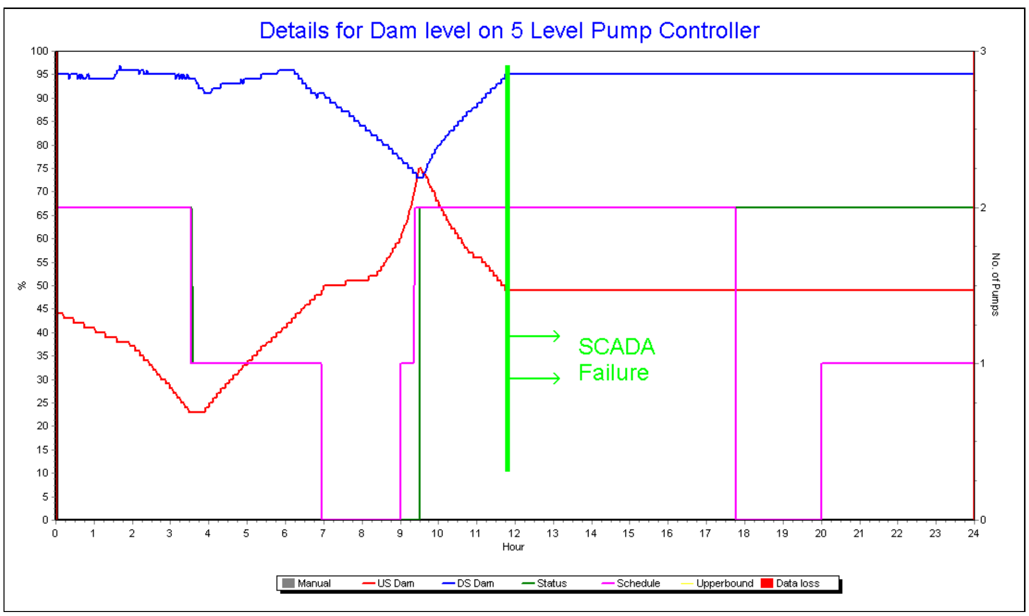

Figure 4-20: Dam level graph

It can also be seen in Figure 4-20 that the upstream dam level (red line) was falling rapidly before the SCADA failure. If the dam level falls too low, the pumps may start to cavitate because of loss in suction pressure and damage the impellers of the pumps. If the dam level falls further, mud can enter the pumps and do even more serious damage.

After establishing that incompatibility between the systems caused the SCADA failure, the maintenance company's system was removed and the EMS again operated normally.

4.7.2 Bambanani gold mine

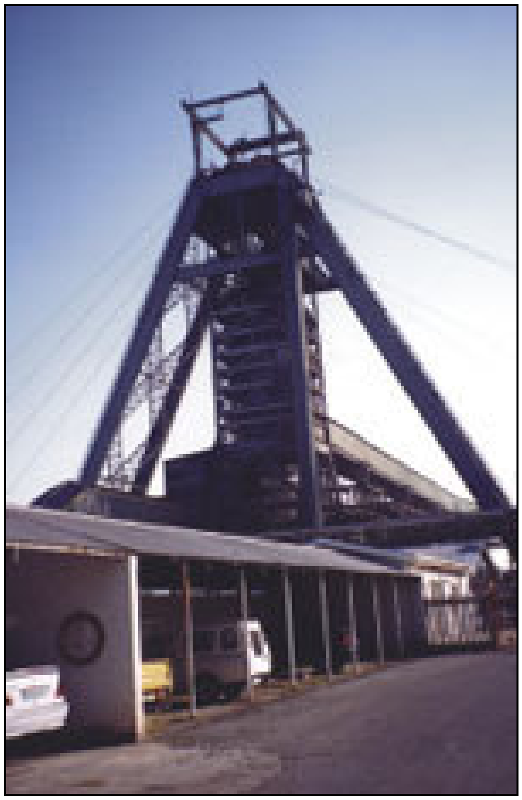

Figure 4-21: Bambanani gold mine (Harmony)

Table 4-10: Project details for Beatrix 4#

DSM Project name	Bambanani pumping system
Contract starting date	July 2004
Project completed	March 2005
Contractual load shift	5.80 MW
Performance assessment load shift	6.31 MW

Bambanani gold mine has performed well in the past. In most months the contractual evening load shift was achieved within the allowed contractual limits.

The water delivered to the mine is cooled water from surface fridge plants. This water has to be pumped out again. In July 2007 a collapse of the Ore Pass in the mine occurred, and production was halted. When production is stopped, the water flow into the mine is dramatically reduced. The electricity required for pumping operations is therefore also less. Figure 4-22 shows the electricity usage for the historical baseline, green line, a normal production day, blue line, and a non-production day, red line. The dotted lines are the ENBs for each day.

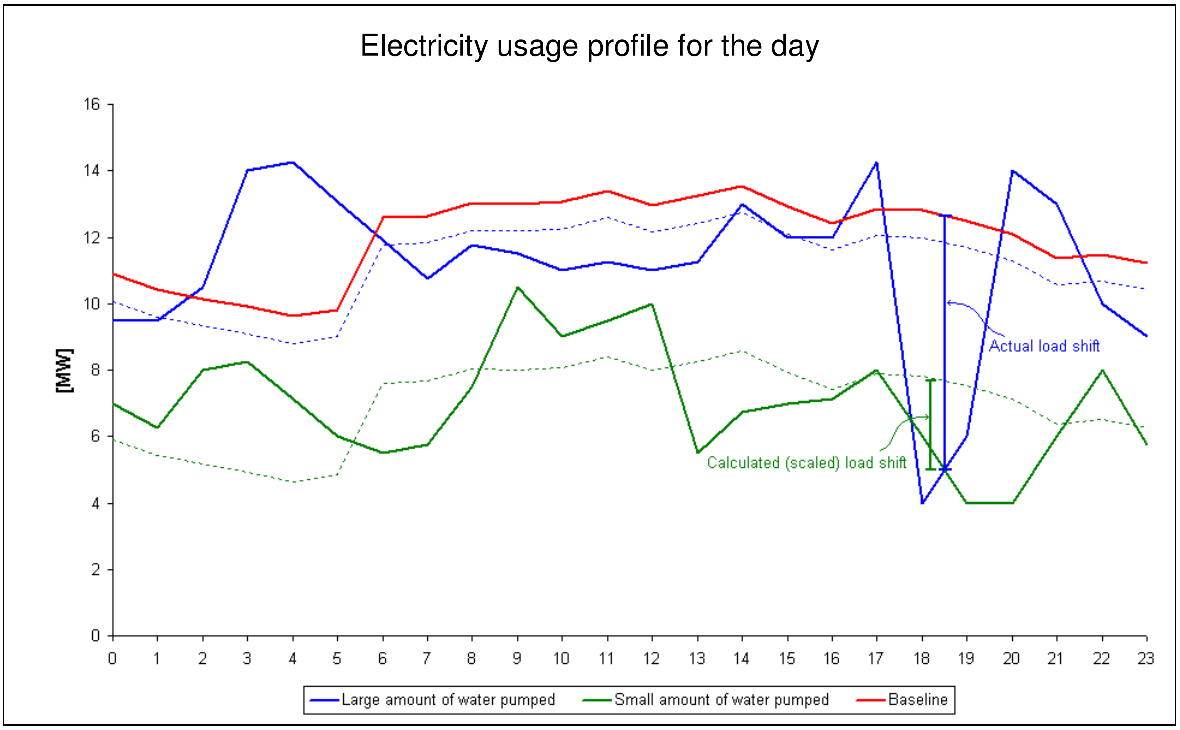

Figure 4-22: Calculated load shift and what the grid actually “sees"

On an average day the system would be pumping approximately the same amount of water as the historical baseline. If production increases, the larger amount of water that has to be pumped will require an increasing amount of electricity (Figure 4-24). This increases the potential to shift load. However, the peak electricity usage will also increase.

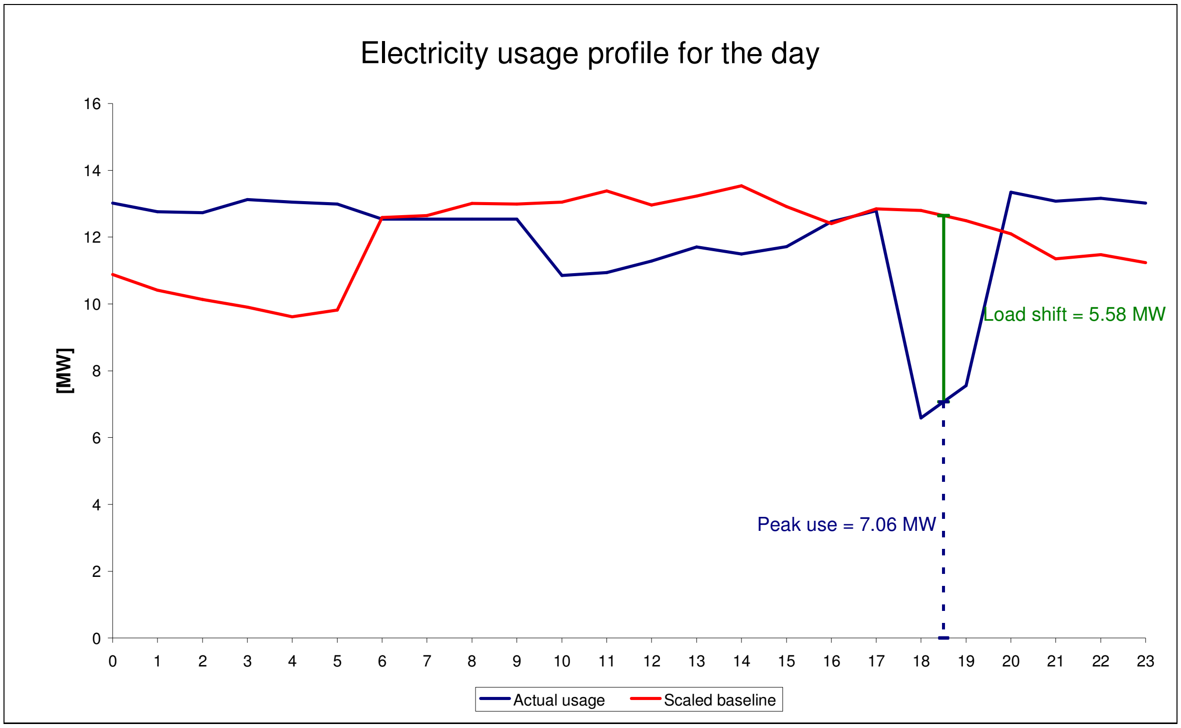

Figure 4-23: 100% Historical day

Although the mine has a higher load shift, and thus higher savings, the grid experiences an increased demand of 3.54 MW during the evening peak, in the case of a 150%-day as seen in Figure 4-24.

If, on the other hand production is reduced or halted, the potential for load shift will decrease to 2.79 MW for a 50%-day, and the peak-time electricity usage decrease to 3.53 MW. The grid now experiences a reduction of 9.11 MW. The mine can be penalised because it only shifted 2.79 MW if the load shift is calculated using the standard method. Clearly this method is unfair to the client and the ESCO and should be addressed. This will be discussed in greater detail in Chapter 5.3.

Table 4-11: Electricity usage and load shift for simulated days

	Total Electricity usage *kWh*	**Load shift** *MW*	**Peak electricity usage** *MW*	**Grid reduction** *MW*
Historical baseline	287 814	5.58	7.07	5.58
High Production	431 721	8.37	10.60	2.05
Low Production	143 907	2.79	3.53	9.11

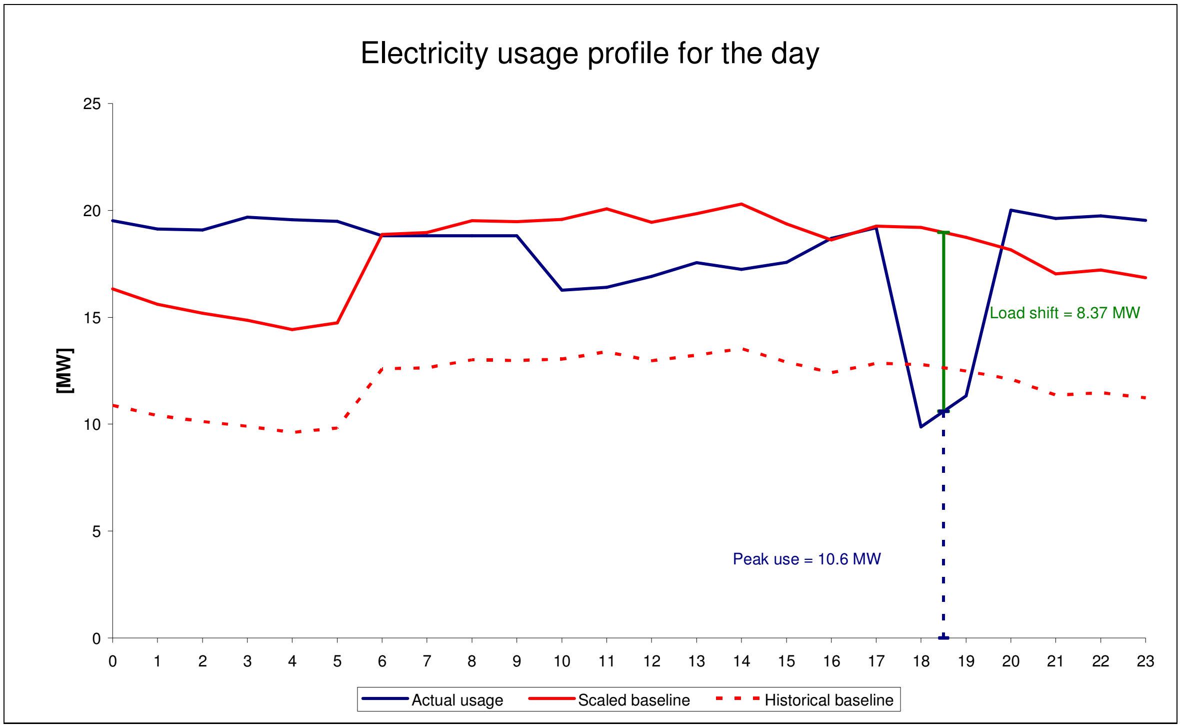

Figure 4-24: 150% Historical day (high production)

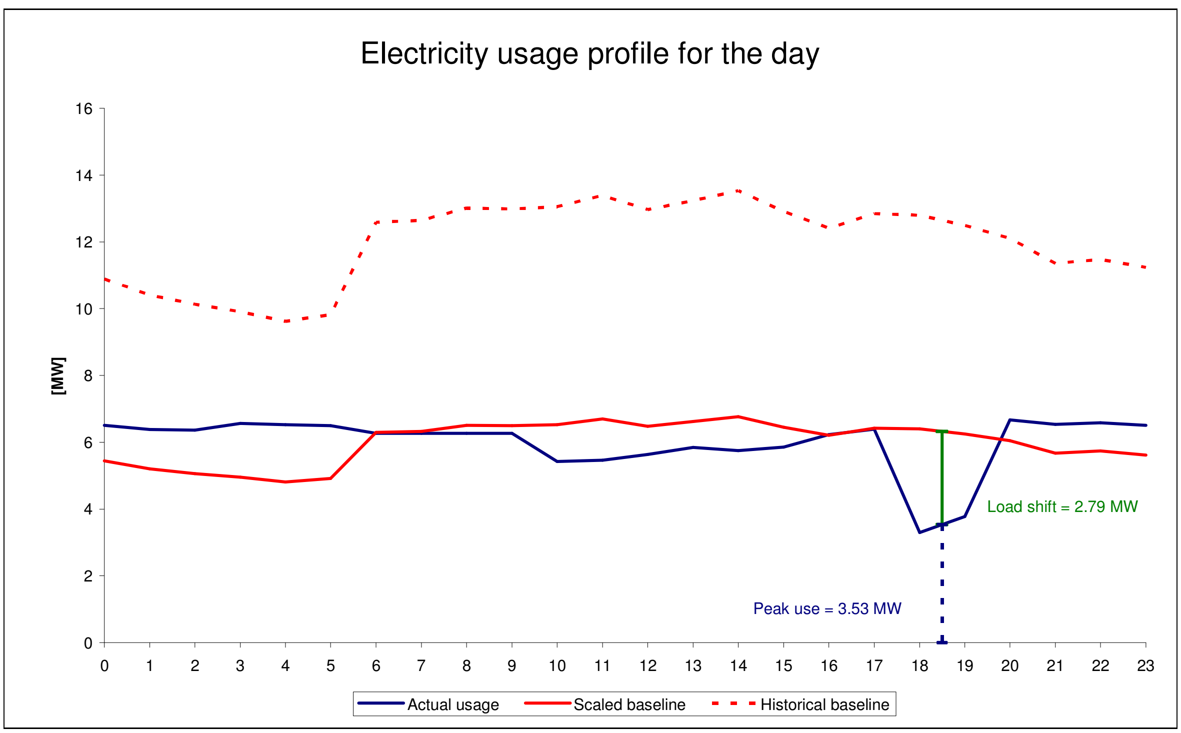

Figure 4-25: 50% Historical day (low production)

4.8 Realised financial saving for clients

Table 4-12 shows the historical savings realised by the EMS of the ESCO. These figures are the total savings until the end of December 2006. There was a total saving of R 8.9-million out of a possible R 12.2-million for the clients who formed part of this study. This means that there was an average 73% realisation rate.

Table 4-12: Total accumulated savings (implementation until end of December 2006)

Project	Proposed Savings	Actual Savings	Savings realised
Bambanani	R 1,821,000	R 1,154,000	63%
Beatrix 1,2,3	R 600,000	R 867,000	144%
Beatrix 4	R 1,281,000	R 1,022,000	80%
Elandsrand	R 1,348,000	R 457,000	34%
Evander 7	R 322,000	R 132,000	41%
Harmony 3	R 841,000	R 359,000	43%
Kopanang	R 3,102,000	R 1,903,000	61%
Masimong 4	R 740,000	R 491,000	66%
Mponeng	R 1,208,000	R 1,835,000	152%
Tshepong	R 977,000	R 679,000	69%
Total	**R 12,245,000**	**R 8,905,000**	**73%**

Beatrix 1,2&3# and Mponeng mines show larger than 100% realisation of savings because both these mines perform better than previously thought possible. At Mponeng the contractual load shift is only 6.2 MW, but the mine continuously shifts more than 10 MW out of the expensive evening period. For Beatrix 1, 2&3# the third shaft's savings were not proposed. Although this shaft does not perform well, it is still a bonus saving.

Table 4-13 shows the savings realised during the study period. Some of the mines show much better performances during this period. Beatrix 4#, Masimong 4# and Tshepong had very large increases in savings realised. Elandsrand and Kopanang have both shown large decreases in savings realised. This is because both projects missed the important winter period where the difference between peak and off-peak electricity prices are large.

Table 4-13: Total accumulated savings (January to August 2007)

Project	Proposed Savings	Actual Savings	Savings realised
Bambanani	R 636,000	R 337,000	53%
Beatrix 1,2,3	R 885,000	R 1,198,000	135%
Beatrix 4	R 1,375,000	R 1,321,000	96%
Elandsrand	R 720,000	R 42,000	6%
Evander 7	R 288,000	R 111,000	38%
Harmony 3	R 365,000	R 261,000	72%
Kopanang	R 806,000	R 168,000	21%
Masimong 4	R 719,000	R 500,000	70%
Mponeng	R 1,056,000	R 1,329,000	126%
Tshepong	R 1,246,000	R 1,604,000	129%
Total	**R 8,100,000**	**R 6,876,000**	**85%**

4.9 Conclusion

The following conclusions were made after the commissioning and verification studies of the feedback solution were completed:

- Although the EMS has saved the clients covered in this study an accumulated total in excess of R15.8-million there is still room for improvement. Average realised savings for the study period improved from 73% to 85% despite two projects that lost large savings.

- The feedback solution dramatically reduces the number of man-hours spent by project engineers from the ESCO on repetitive tasks. The time spent downloading and processing data is now automated and need not be done during office hours.

- The feedback solution provides reliable and accurate reports for the ESCO and clients. These reports are much more detailed than the original manually compiled reports.

- DSM results improved on most mines and made remarkable changes on some mines. Harmony 3# and Tshepong have improved the savings realised by large margins (60% and 19% respectively).

- The new system helped the ESCO and clients identify unforeseen problems on projects. For example, at Beatrix 4# the reports indicated SCADA failures from data that would have been difficult to interpret previously.

- One of the most common causes of poor DSM performance is poor maintenance. The feedback reports notify the client of problem areas quickly. Instead of reacting to poor savings from a monthly Eskom report, corrective action can now be taken on the next day and savings can be realised again in the next shift.

Chapter 5: Conclusion

A summary and conclusion of the study is given.

5.1 Summary of this study

Certain DSM projects in South Africa have been prone to poor sustainability. Furthermore, feedback of the system performance to the client and the ESCO was unreliable and, in some cases, unobtainable due to the sensitive nature thereof.

Poor sustainability was mainly due to manual intervention by the control room operators and poor maintenance. The primary objective of this study was to address these problems and provide a solution. This was accomplished by developing an automated feedback solution to facilitate the sustainability of DSM projects, particularly in the mining sector.

The study found that, to ensure sustainability, the system requires:

- Automation
- Reliability
- Accuracy
- Compatibility with and integration into existing infrastructure
- Broad range of reporting frequencies

A system was developed with the assistance of various parties, including the project engineers and management of the ESCO. Hardware and software systems were implemented to ensure automated data acquisition. This system was required to be compatible with various infrastructures, ranging from out-dated to state-of-the-art equipment.

5.2 Summary of all projects' performance

5.2.1 Key indicators

A few key indicators were selected to measure the impact of the reporting solution.

The key indicators were:

- Evening load shift improvement
- Over-performance improvement
- Savings-realised improvement
- Processing time improvements

These are only quantifiable parameters and do not take into account additional benefits such as better quality and more comprehensive reports. The additional benefits are discussed in 5.2.6.

5.2.2 Evening load shift improvement

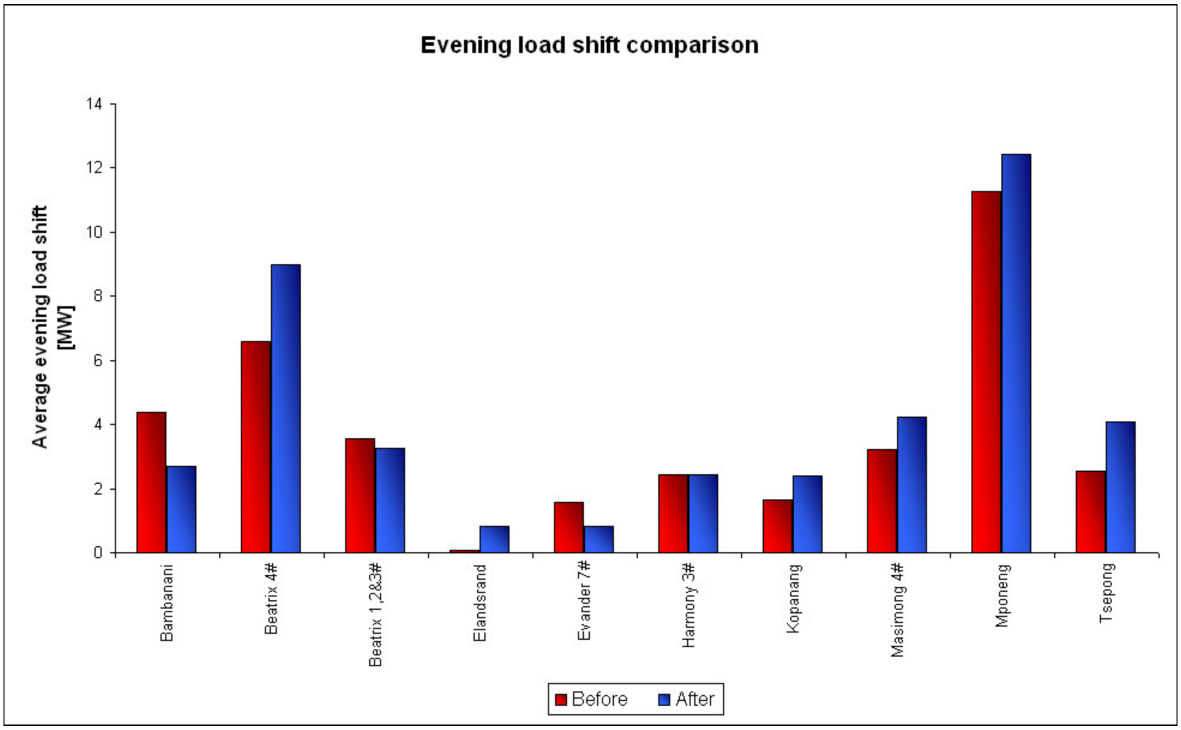

Figure 5-1: Evening load shift comparison for pre and post implementation

Figure 5-1 and Table 5-1 illustrate the effect of the feedback solution on DSM performance of the various projects used as case studies.

Table 5-1: Evening load shift in MW

Project	Before	After
Bambanani	4.36	2.69
Beatrix 4#	6.60	8.99
Beatrix 1,2&3#	3.57	3.26
Elandsrand	0.07	0.82
Evander 7#	1.59	0.84
Harmony 3#	2.43	2.42
Kopanang	1.66	2.39
Masimong 4#	3.22	4.23
Mponeng	11.26	12.42
Tshepong	2.53	4.07
Total	**37.27**	**42.12**

Five of the ten projects showed improved performance after implementation of the feedback solution, with one project maintaining constant performance. The total evening load shift for all the projects also resulted in an average 13% improvement.

5.2.3 Over-performance improvement

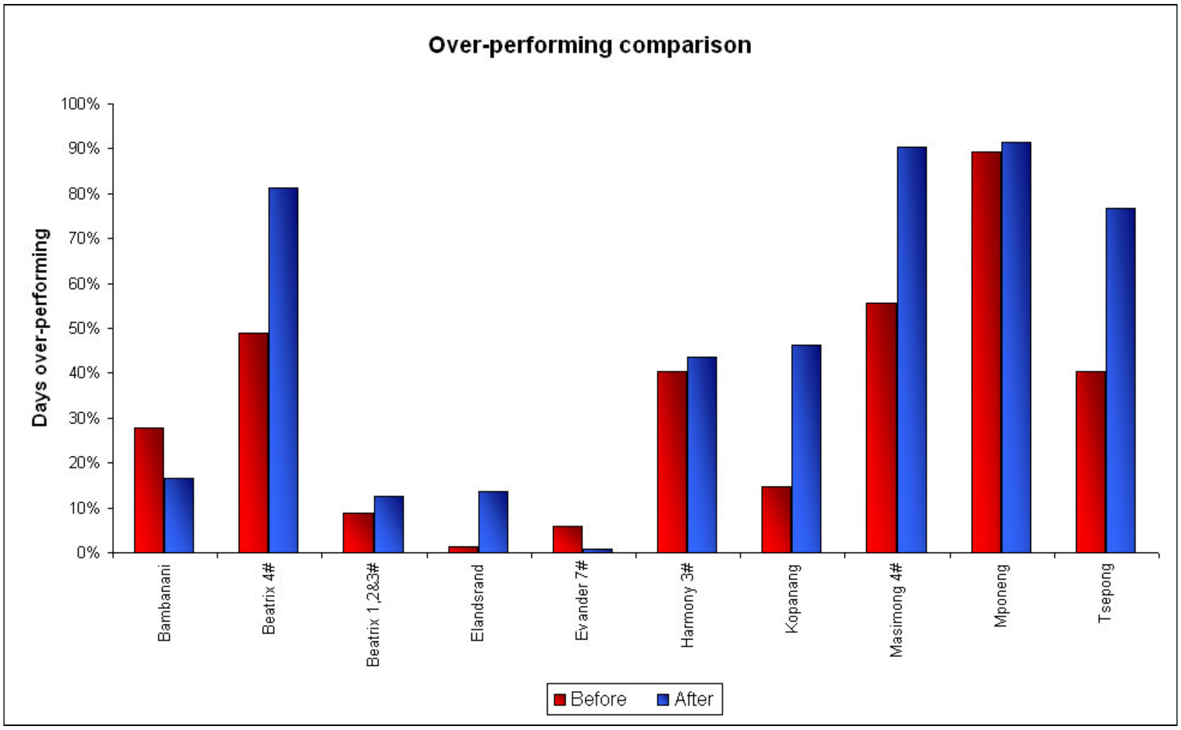

Figure 5-2: Over-performance comparison for pre and post implementation

In Figure 5-2 the percentage of days of over-performance on the contractual load shift can be seen.

Bambanani and Evander 7# are the only projects that did not show any improvement in this category. These mines experienced severe technical problems during this study period.

Beatrix4#, Kopanang, Masimong 4# and Tshepong experienced more than 30% improvement in DSM performance, although Kopanang also had problems during the winter months. On average there was a 12.8% increase in over-performing days, which is in line with the increase in evening load shift.

5.2.4 Savings-realised improvement

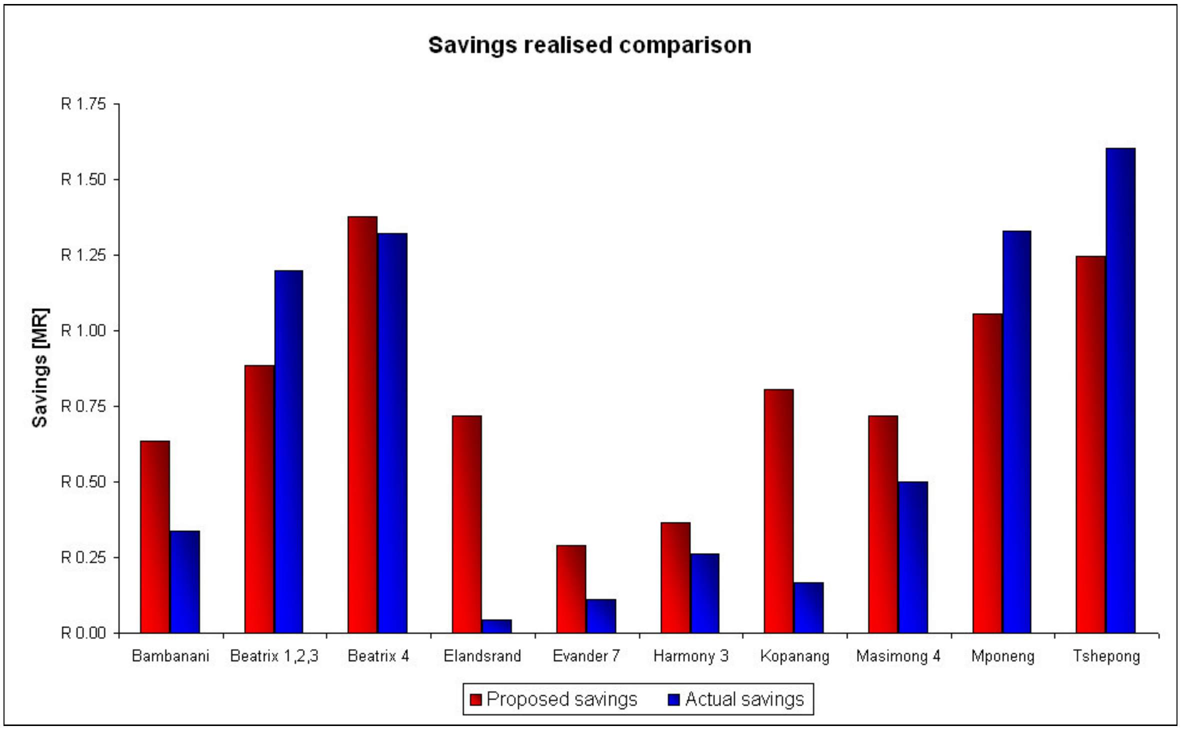

Figure 5-3: Realised savings

Figure 5-3 shows the realised savings during the study period. The average savings realised improved from 73% to 85%. This 12% improvement is also in line with the improvement in evening load shift and over-performing days.

Table 5-2: Improvement in financial savings

Project	Before	After
Bambanani	63%	53%
Beatrix 1,2,3	144%	135%
Beatrix 4	80%	96%
Elandsrand	34%	6%
Evander 7	41%	38%
Harmony 3	43%	72%
Kopanang	61%	21%
Masimong 4	66%	70%
Mponeng	152%	126%
Tshepong	69%	129%
Total	**73%**	**85%**

The ESCO has saved a total of R 15.7-million for the projects used in this study with the implementation of the EMS.

5.2.5 Processing time improvements

The time spent on data processing and generation of reports was reduced dramatically from 2 hours per project per day to 5 minutes per day for all the sites. Figure 5-4 indicates the time spent on key tasks before and identified in Chapter 2. The red bars indicate the typical time spent by an engineer before implementation of the reporting solution and the blue bars after. The little time that is needed from the engineer is just to interpret the results from the report and to form a conclusion of that data.

Reports on performance are now also available the next day, in order to improve performance if system faults occur. The client does not have to wait for the monthly Eskom feedback report to see if there were missed opportunities.

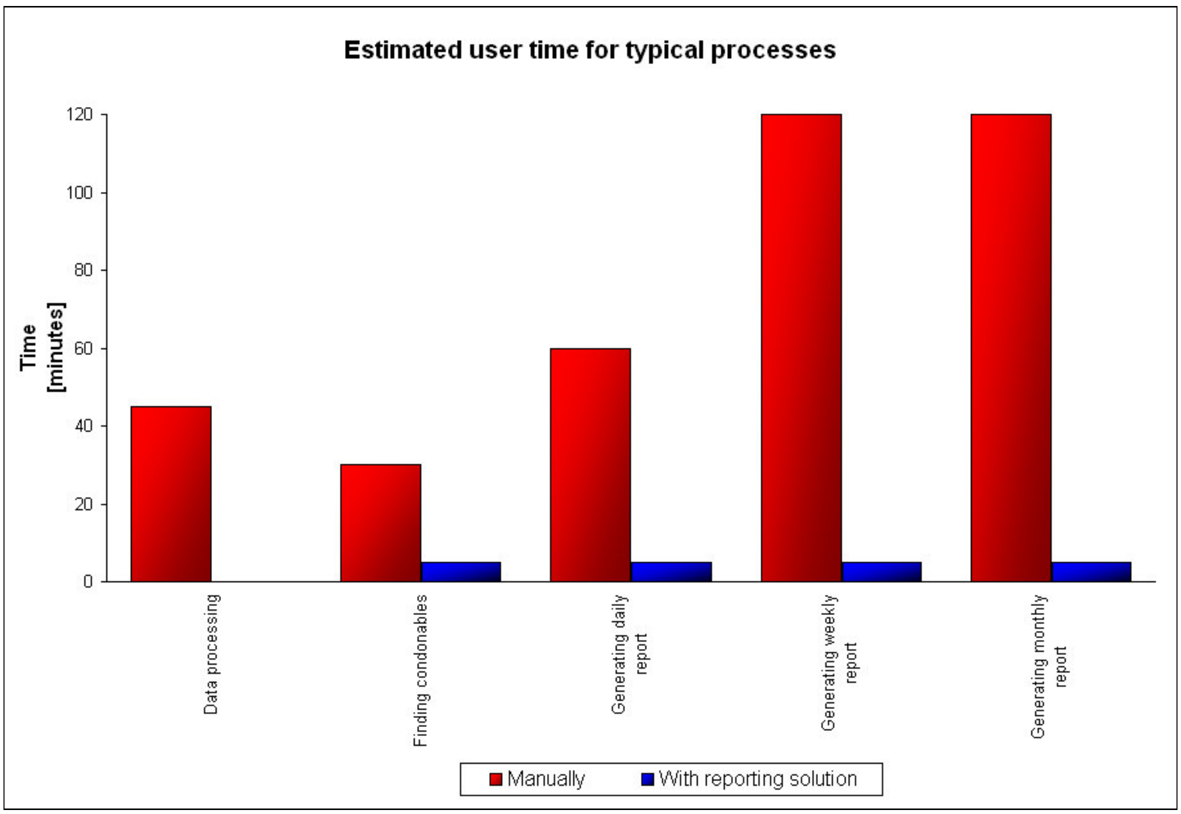

Figure 5-4: A comparison on time spent on key reporting tasks

5.2.6 Additional benefits

Additional benefits of the feedback solution are:

- Quantification of missed opportunities
- Indication of operator intervention
- Indication and reporting of SCADA failure
- Pump running times and other parameters required to aid the scheduling of maintenance

The feedback solution also demonstrated that many other opportunities exist to improve the sustainability of DSM.

5.3 Suggestions for further work

Throughout this document the focus was placed on DSM projects involving clear water pumping systems. The feedback solution has also been adapted to process other types of DSM projects. Further development possibilities on the feedback solution are:

- Generation of **condition-monitoring** reports that will assist the client with the maintenance of various systems. Data to be logged will include parameters such as bearing temperatures and vibration levels.
- **Efficiency determination** for the DSM systems. Some pumps may not be as efficient as other pumps in the grouping. If this information is available, suitable action can be taken to improve the overall performance of the system.
- Some mines will require less information on certain systems than others. Improved **customisation** of the actual reports would improve the readability of the reports.
- Improved **remote access** will allow real time data capture. Communication can be accomplished by cell phone or a web interface.

- **Alarms** and warnings if the system is unable to operate according to a required schedule as a result of infrastructure failure. This will enable the feedback solution to become a **preventative solution**.
- **Integration** with other types of projects, including fridge plants, CAM and industrial plants.
- The **baseline scaling** methods employed by the M&V team should be revised.

5.4 Conclusion

The reporting solution facilitated a 13.0% increase in the evening load shift of the ten DSM projects that were used as case studies in this thesis. Over-performance increased by 12.8% and the financial savings increased by 12%.

Furthermore, the reporting solution reduced the time spent by the ESCO to generate reports of DSM performance for its clients, the M&V team and Eskom. These reports were more detailed and accurate than the old reports.

The reporting solution also quantified missed opportunities which are a powerful motivational tool for clients to improve the reliability of their equipment and to reduce operator interference.

Appendix A: Reference

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Appendix B: Examples of Reports

B.1 Example of a daily report

REMS Daily report for Beatrix 4#

21 August 2007

HVAC
INTERNATIONAL

Generated by OSIMS on 17 November 2007

Confidential

REMS Daily report for Beatrix 4# for 21 August 2007 - Confidential

1 Load shift results for Beatrix 4# for 21 August 2007

Parameter	Value
Morning peak	9.46 MW
Evening peak	8.64 MW
Average evening peak for month	8.95 MW
Contractual MW	7.00 MW
Cost saving for this day	R 19 503
Energy usage for this day	256.74 MWh
System on manual	0 % of the day

Table 1: Summary of day

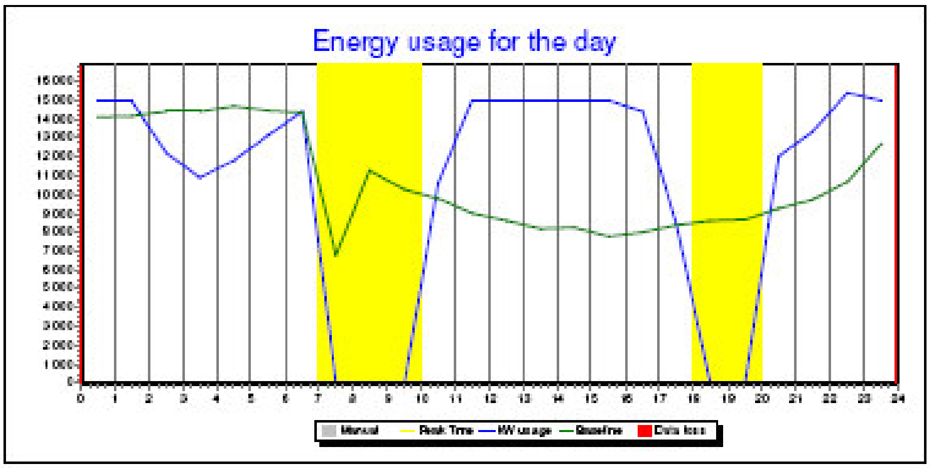

Figure 1: kW usage profile

The above graph shows the energy usage profile for the day with manual overrides (gray) and data loss (red) shown.

Generated by OSIMS

1

REMS Daily report for Beatrix #4 for 21 August 2007 - Confidential

2 Summary for 5 Level Pump Controller

The figure below shows a detailed description of the 5 Level Pump Controller for the day. The status is the actual number of pumps running, and the schedule is the amount of pumps requested by REMS.

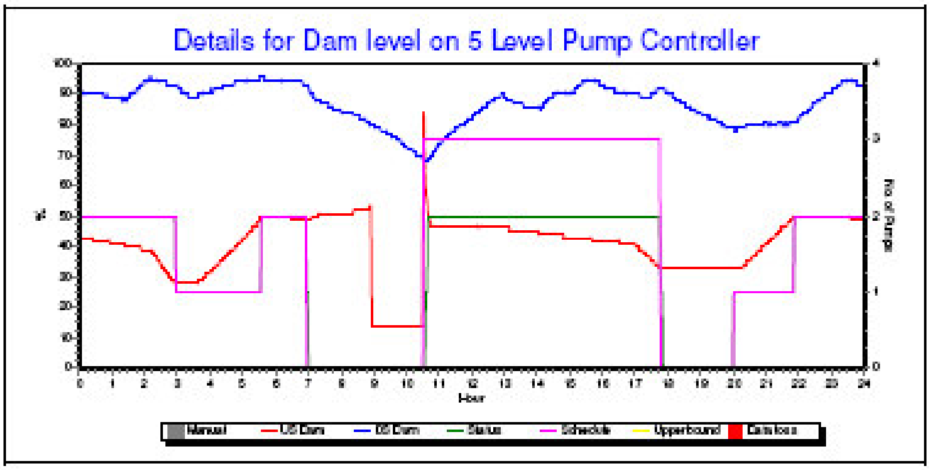

Figure 2: Dam levels, status and schedule for 5 Level Pump Controller

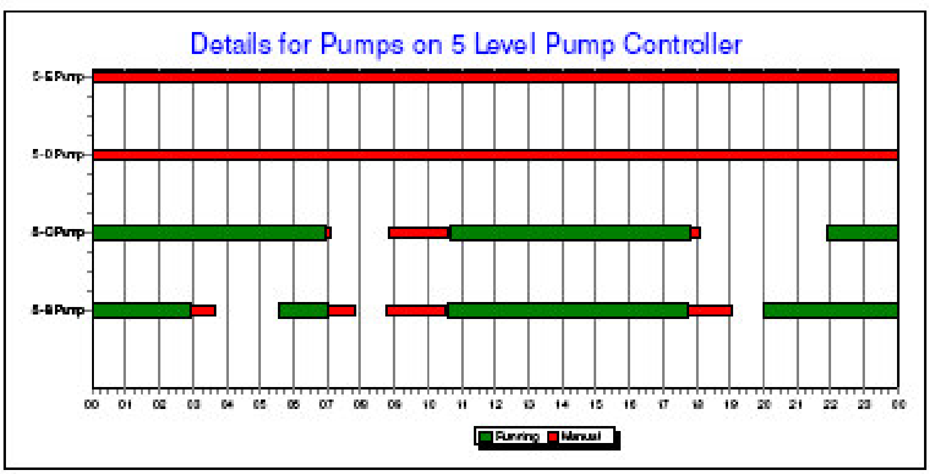

Figure 3: Runtimes for 5 Level Pump Controller

Generated by OSIMS

2

The above figure shows the actual runtimes for the pumps on this level. The green bars indicate periods where the pump was running. The red bars indicate periods where REMS did not have control of the pump.

3 Summary for 21 Level Pump Controller

The figure below shows a detailed description of the 21 Level Pump Controller for the day. The status is the actual number of pumps running, and the schedule is the amount of pumps requested by REMS.

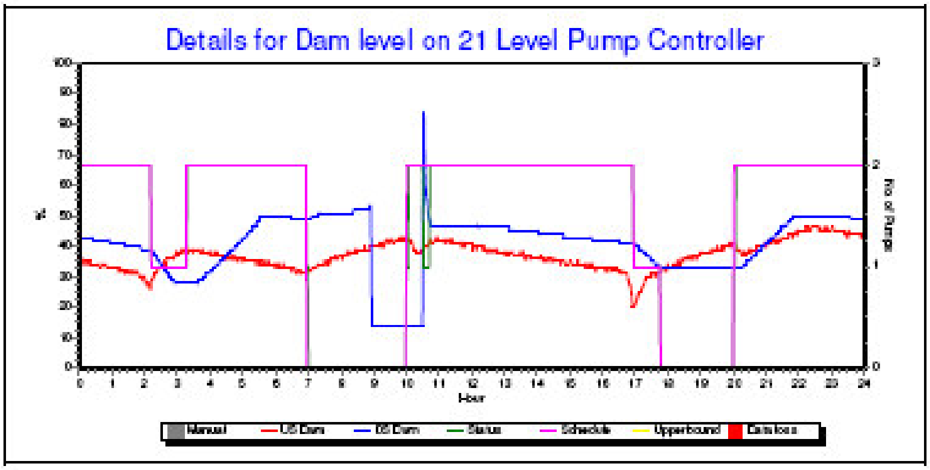

Figure 4: Dam levels, status and schedule for 21 Level Pump Controller

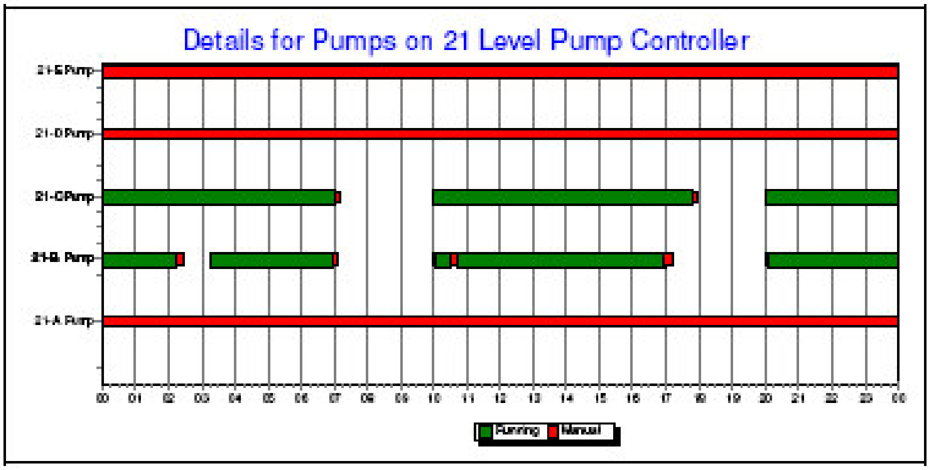

Figure 5: Runtimes for 21 Level Pump Controller

The above figure shows the actual runtimes for the pumps on this level. The green bars indicate periods where the pump was running. The red bars indicate periods where REMS did not have control of the pump.

4 Summary for 25 Level Pump Controller

The figure below shows a detailed description of the 25 Level Pump Controller for the day. The status is the actual number of pumps running, and the schedule is the amount of pumps requested by REMS.

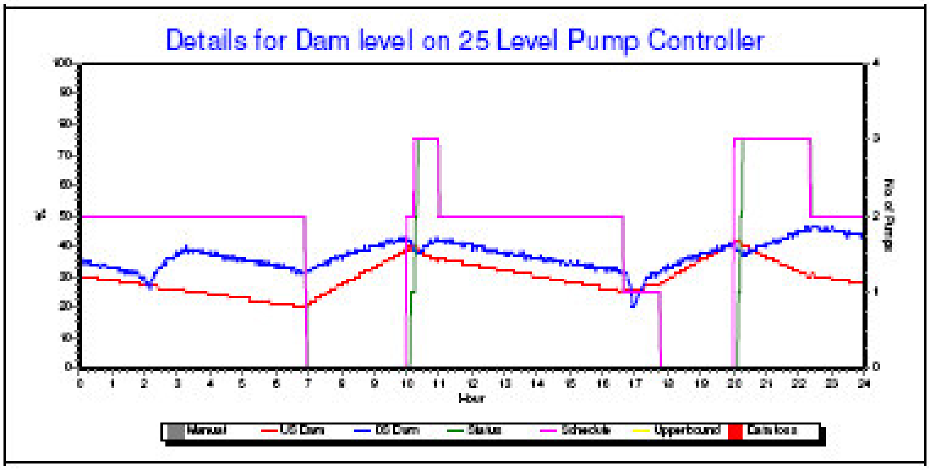

Figure 6: Dam levels, status and schedule for 25 Level Pump Controller

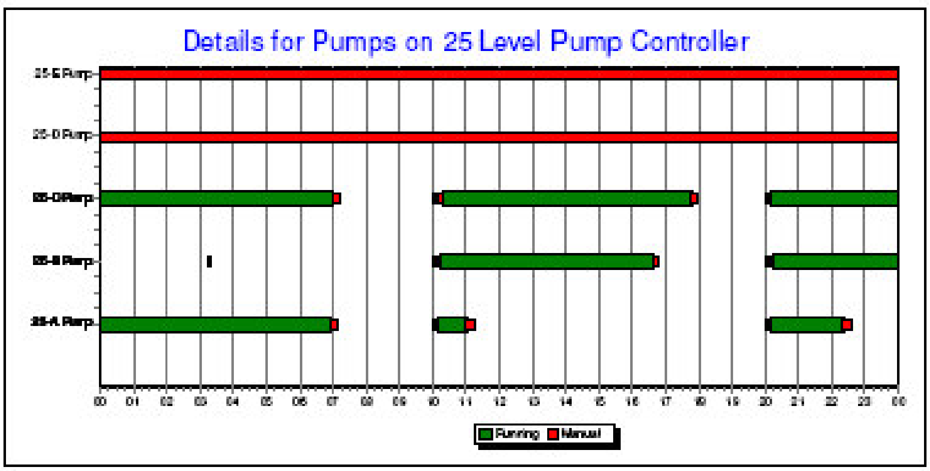

Figure 7: Runtimes for 25 Level Pump Controller

The above figure shows the actual runtimes for the pumps on this level. The green bars indicate periods where the pump was running. The red bars indicate periods where REMS did not have control of the pump.

B.2 Example of a weekly report

REMS Weekly savings report for Kopanang Pumps

19 August 2007 to 25 August 2007

HVAC INTERNATIONAL

Generated by OSIMS on 17 November 2007

REMS AngloGold Ashanti OSIMS

REMS Weekly report for Kopanang Pumps from 19 August 2007 to 25 August 2007 - Confidential

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1 Introduction 2
2 Eskom project information 2
3 Performance over project lifetime 3
4 REMS Savings 6
5 Energy used and peak time load shift 6
6 Daily performance 8
7 Report verification 9
8 Conclusion 9

Generated by OSIMS

1

1 Introduction

This weekly report gives the savings generated by the REMS and OSIMS systems that control Kopanang Pumps. The savings period covered in this report is from 19 August 2007 to 25 August 2007. Detail analyses are included to explain the under-performance of specific days. This information can be used to improve the availability of pumping equipment in order to increase savings.

Please contact HVAC International (Pty) Ltd at reports-info@rems2.com should there be any queries or suggestions.

2 Eskom project information

DSM Project name:	Kopanang pumping system
DSM Project number:	2003007
NEC Number:	4600002244
Project type:	Load shifting
M&V Team:	NWU, Potchefstroom
Proposal submitted:	01 August 2003
Eskom status:	Completed
Contract start date:	02 January 2004
Project completed:	31 March 2004
Contractual MW:	3.00 MW
Performance assessment MW:	4.18 MW
Target MW:	3.00 MW

3 Performance over project lifetime

The REMS system has been operational for 2 months. See Table 1 below for the savings achieved.

Month	Proposed saving	Saving achieved	Unrealised potential	Accumulated proposed savings possible	Accumulated actual savings	Accumulated performance
September 2001 to December 2001	R 536 503	R 463 503	R-73 000 (-14%)	R 536 503	R 463 503	R-73 000
January 2002 to December 2002	R 512 603	R 252 843	R-259 760 (-51%)	R 1 049 106	R 716 346	R-332 760
January 2003 to December 2003	R 308 469	R 186 001	R-122 468 (-40%)	R 1 357 575	R 902 347	R-455 228
January 2004 to December 2004	R 395 528	R 449 475	R 53 947 (14%)	R 1 753 103	R 1 351 822	R-401 281
January 2005 to December 2005	R 584 481	R 418 037	R-166 444 (-28%)	R 2 337 584	R 1 769 860	R-567 724
January 2006 to December 2006	R 764 949	R 133 706	R-631 243 (-83%)	R 3 102 533	R 1 903 566	R-1 198 967
January 2007	R 34 220	R 3 424	R-30 796 (-90%)	R 3 136 753	R 1 906 990	R-1 229 763
February 2007	R 31 328	R 3 806	R-27 521 (-88%)	R 3 168 081	R 1 910 796	R-1 257 285
March 2007	R 33 919	R 2 869	R-31 050 (-92%)	R 3 202 000	R 1 913 665	R-1 288 335
April 2007	R 28 979	R 2 239	R-26 740 (-92%)	R 3 230 979	R 1 915 904	R-1 315 075
May 2007	R 34 764	R 3 107	R-31 657 (-91%)	R 3 265 743	R 1 919 011	R-1 346 732
June 2007	R 208 658	R 38 415	R-170 243 (-82%)	R 3 474 401	R 1 957 425	R-1 516 976
July 2007	R 216 743	R 53 392	R-163 351 (-75%)	R 3 691 144	R 2 010 818	R-1 680 326
August 2007	R 218 097	R 60 829	R-157 267 (-72%)	R 3 909 241	R 2 071 647	R-1 837 594

Table 1: Actual savings

REMS Weekly report for Kopanang Pumps from 19 August 2007 to 25 August 2007 - Confidential

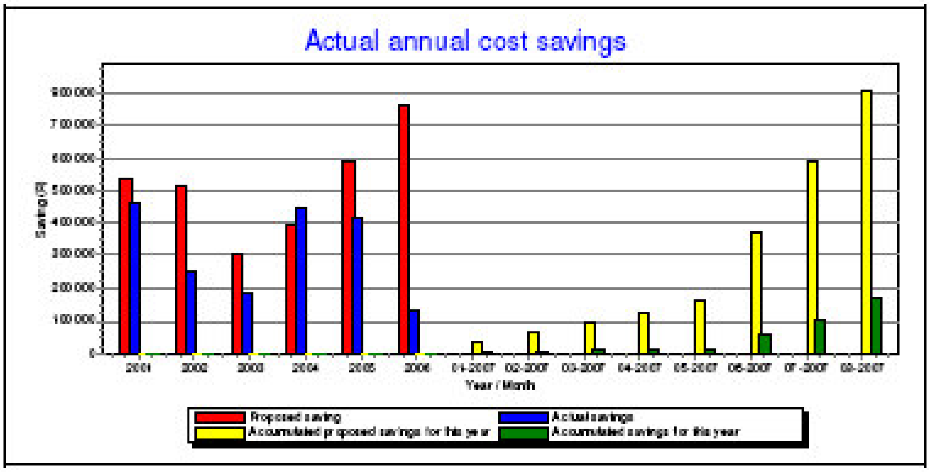

Figure 1: Yearly total actual and proposed savings for the duration of the project

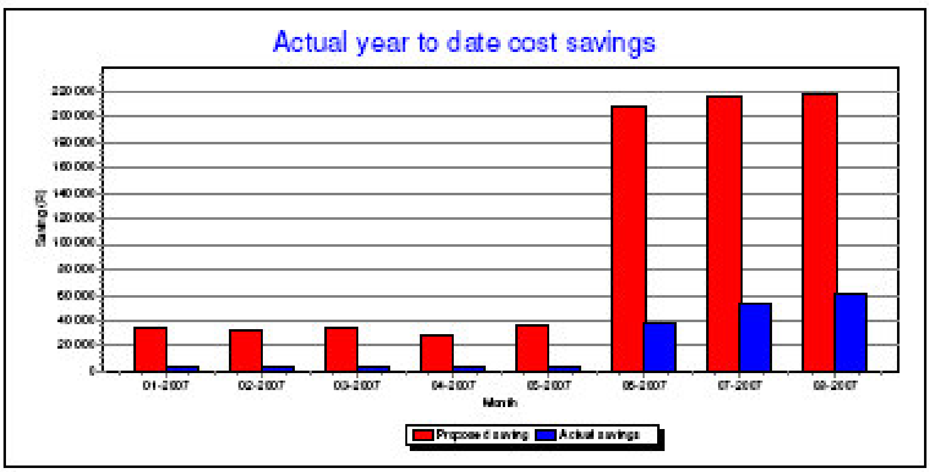

Figure 2: Actual and proposed savings for the duration of the project

Generated by OSIMS

4

REMS Weekly report for Kopanang Pumps from 19 August 2007 to 25 August 2007 - Confidential

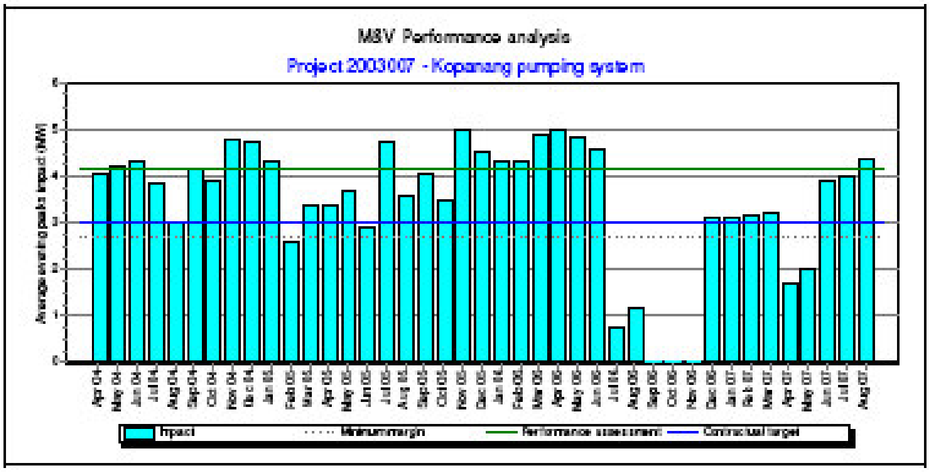

Figure 3: Historic performance analysis for Kopanang pumping system

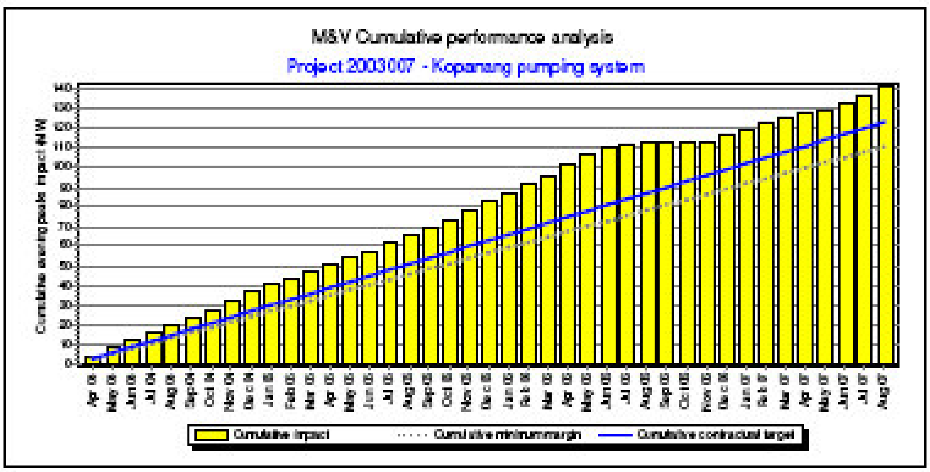

Figure 4: Historic cumulative performance analysis for Kopanang pumping system

Generated by OSIMS 5

4 REMS Savings

The total saving for the period from 19 August 2007 to 25 August 2007 is R 8 203. The figure below shows the daily cost savings.

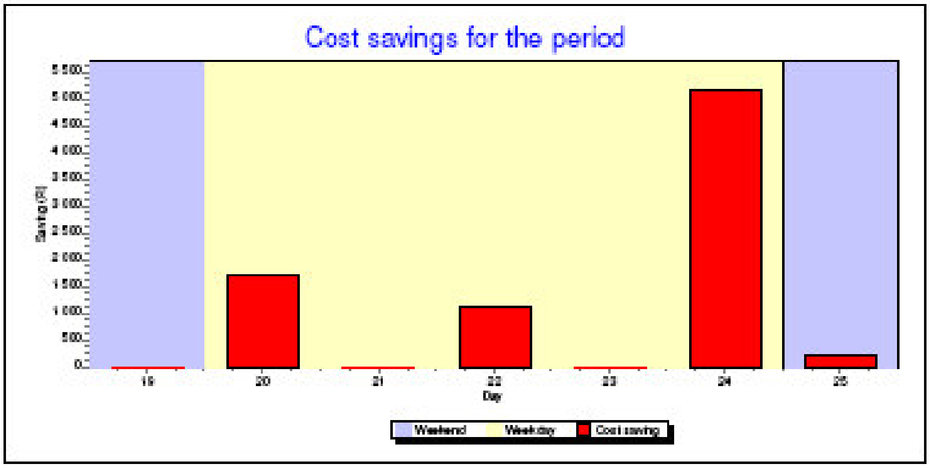

Figure 5: Cost savings from 19 August 2007 to 25 August 2007

5 Energy used and peak time load shift

The average load reduction for the evening peak, excluding condonable days, is 3.59 MW. The average morning load reduction, excluding condonable days, is -0.77 MW. Figure 6 shows the average load and baseline (MW) for 19 August 2007 to 25 August 2007. Please note that the baseline is scaled according to standard Measurement and Verification (M&V) practises. The morning and evening load shift (MW) for the same period are indicated in Figure 7.

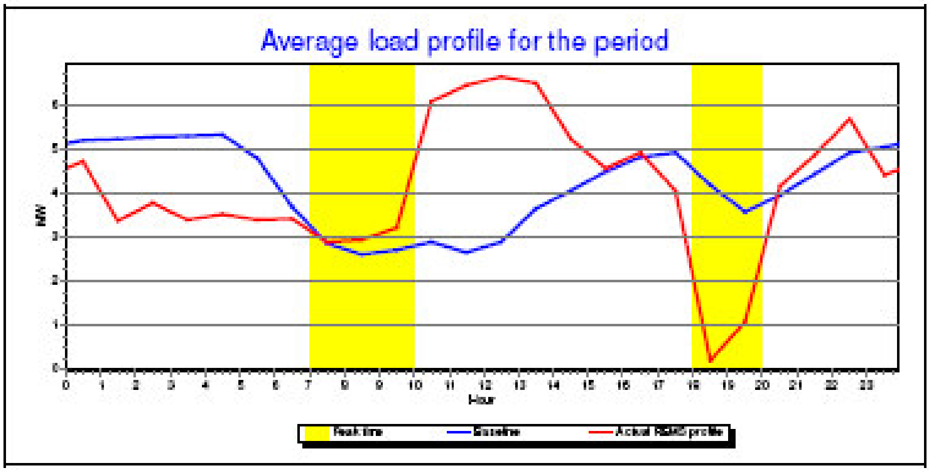

Figure 6: Average load profile and baseline from 19 August 2007 to 25 August 2007(including condonable days)

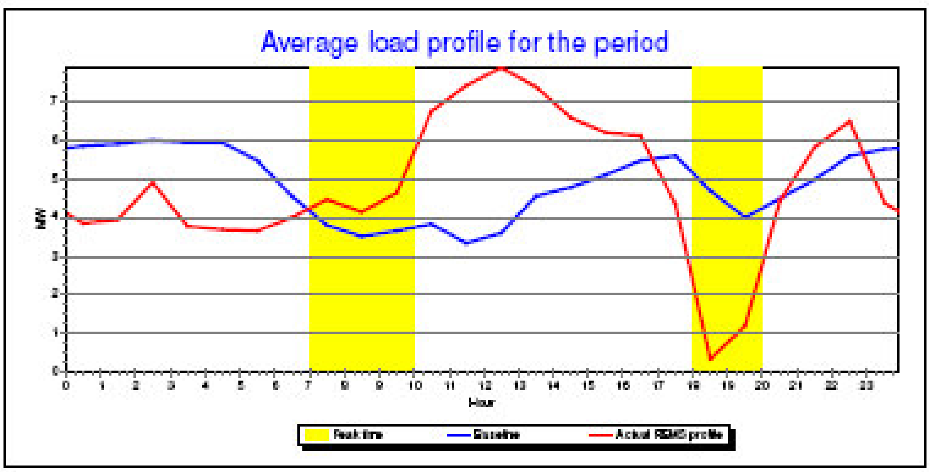

Figure 6: Average load profile and baseline from 19 August 2007 to 25 August 2007

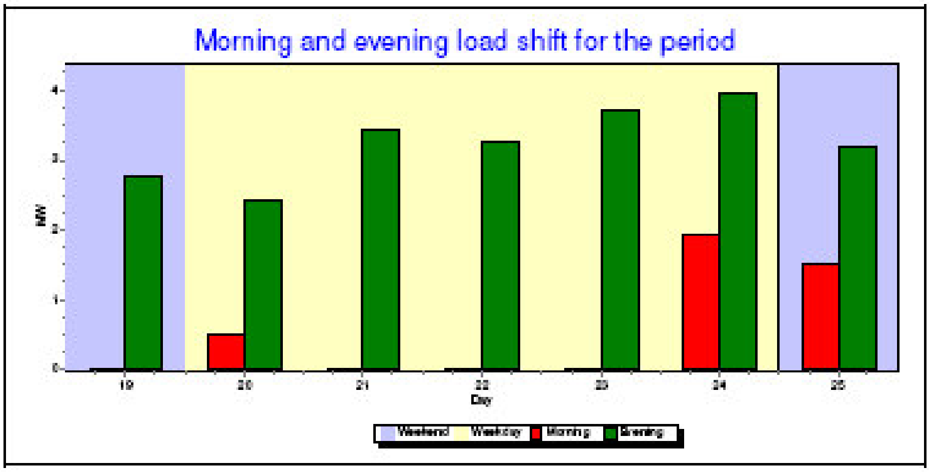

Figure 7: Morning and evening load shift from 19 August 2007 to 25 August 2007

6 Daily performance

The table below shows the breakdown of all the days in the period: 19 August 2007 to 25 August 2007.

Day	Actual saving	Missed opportunity	Reason/Condonable	System switched to manual [% of day]	Energy consumption [MWh]
19 August	R 0			0	44.80
20 August	R 1 704	R 4 630	75L dam too high	0	104.72
21 August	R 0	R 9 490	No morning load shifting attempted	0	126.08
22 August	R 1 112	R 3 990	No morning load shifting attempted	0	89.98
23 August	R 0	R 7 860	Communication error before morning peak	0	121.00
24 August	R 5 169	R 3 260	Low potential for morning load shifting	0	129.85
25 August	R 218	R 460		0	82.47
Total/Average	R 8 203	R 29 690		0	698.90

Table 2: Day performance for the period

If the missed opportunities were realised, the extra cost savings would have been R 29 690. The system achieved 21.65 % of the maximum possible savings.

7 Report verification

This report was generated by OSIMS and checked by:

Name: ________________________

Signed: ________________________

Date: ________________________

8 Conclusion

For the period from 19 August 2007 to 25 August 2007, REMS saved **R 8 203** on Kopanang Pumps. The average evening peak load reduction was **3.59 MW**. The average morning peak load reduction was **-0.77 MW**. If all the missed opportunities were realised, the costs saving would have accumulated to **R 37 893**.

B.3 Example of a monthly savings report

REMS Monthly savings report for Mponeng

1 August 2007 to 31 August 2007

ANGLOGOLD ASHANTI

06 September 2007

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2 Eskom project information 2
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1 Introduction

This monthly report gives the savings generated by the REMS and OSIMS systems that control Mponeng. The savings period covered in this report is from 1 August 2007 to 31 August 2007. Detail analyses are included to explain the under-performance of specific days. This information can be used to improve the availability of pumping equipment in order to increase savings.

Please contact HVAC International (Pty) Ltd at reports-info@rems2.com should there be any queries or suggestions.

2 Eskom project information

DSM Project name:	Mponeng pumping system
DSM Project number:	2004036
NEC number:	4600003126
Proposal submitted:	01 May 2004
Eskom status:	Completed
Contract start date:	01 July 2005
Load reduction target:	6.20 MW

3 Performance over project lifetime

The REMS system has been operational for 20 months. See Table 1 below for the savings achieved.

Month	Proposed saving	Saving achieved	Unrealised potential / Over performance R/c (%)	Accumulated proposed savings possible	Accumulated actual savings	Accumulated unrealised potential / over performance
December 2005 to December 2005	R 42 258	R 44 245	R 1 987 (5%)	R 42 258	R 44 245	R 1 987
January 2006 to December 2006	R 1 166 257	R 1 791 462	R 625 205 (54%)	R 1 208 515	R 1 835 707	R 627 193
January 2007	R 43 646	R 2 168	- R41 478 (-95%)	R 1 252 160	R 1 837 875	R 585 715
February 2007	R 39 953	R 58 779	R 18 826 (47%)	R 1 292 114	R 1 896 655	R 604 541
March 2007	R 43 261	R 0	- R43 261 (-100%)	R 1 335 375	R 1 896 655	R 561 280
April 2007	R 36 965	R 48 931	R 11 967 (32%)	R 1 372 339	R 1 945 586	R 573 247
May 2007	R 44 350	R 66 922	R 22 572 (51%)	R 1 416 689	R 2 012 508	R 595 819
June 2007	R 274 916	R 373 532	R 98 615 (36%)	R 1 691 605	R 2 386 040	R 694 434
July 2007	R 285 674	R 408 657	R 122 982 (43%)	R 1 977 279	R 2 794 696	R 817 417
August 2007	R 287 426	R 370 982	R 83 556 (29%)	R 2 264 705	R 3 165 678	R 900 973

Table 1: Actual savings

REMS Monthly report for Mponeng from 1 August 2007 to 31 August 2007 - Confidential

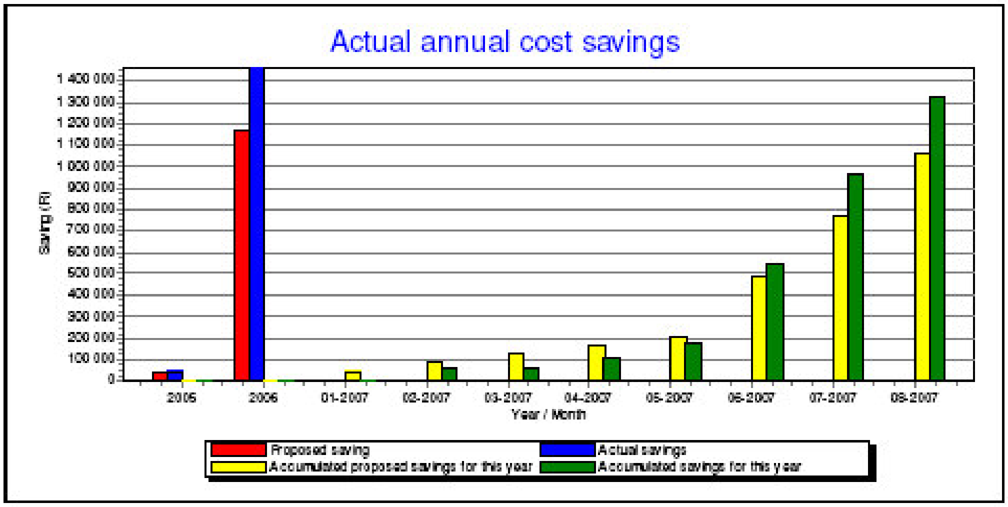

Figure 1: Yearly total actual and proposed savings for the duration of the project

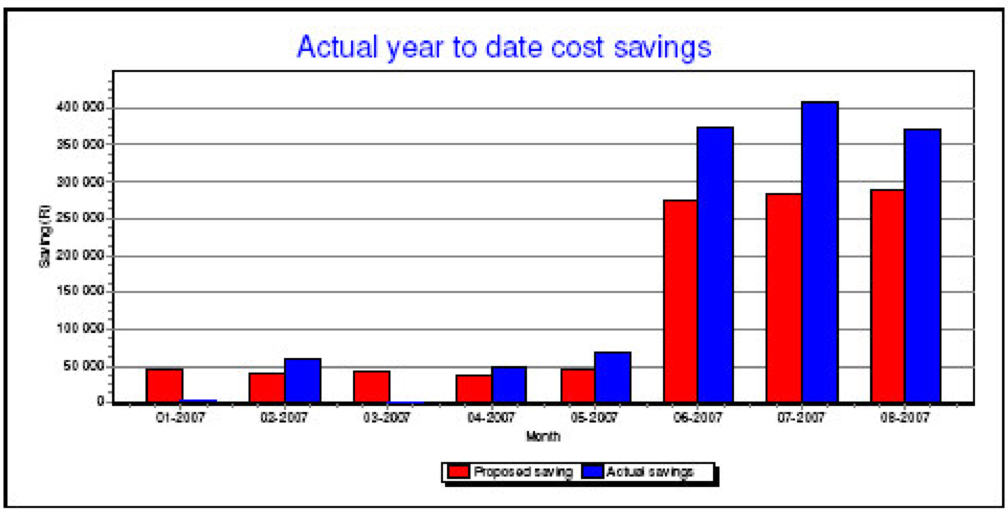

Figure 2: Actual and proposed savings for the duration of the project

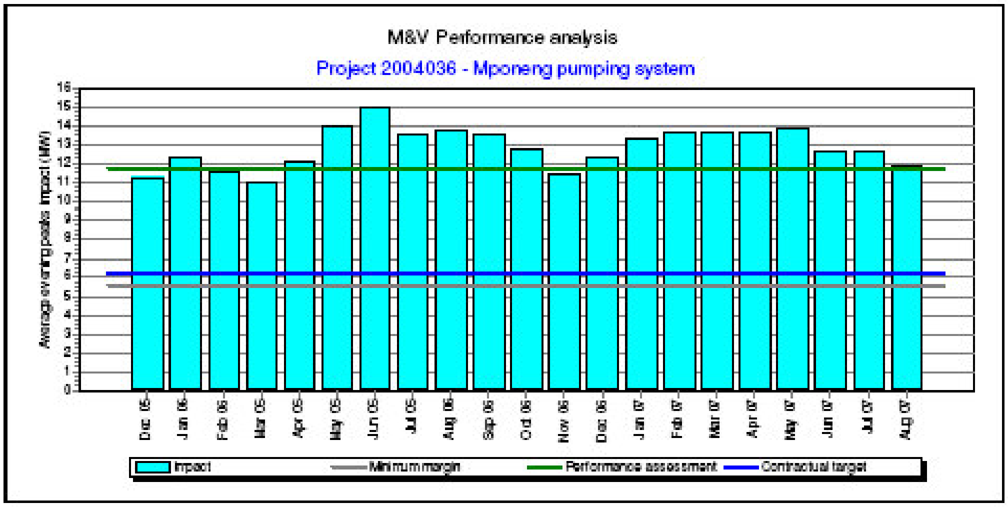

Figure 3: Historic performance analysis for Mponeng pumping system

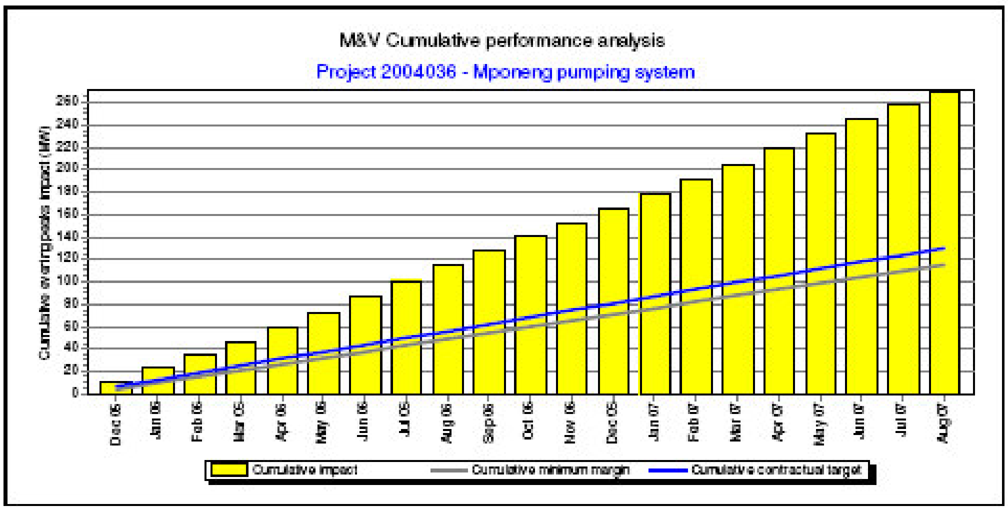

Figure 4: Historic cumulative performance analysis for Mponeng pumping system

4 REMS Savings

The total saving for the period from 1 August 2007 to 31 August 2007 is **R 370 982.** The figure below shows the daily cost savings.

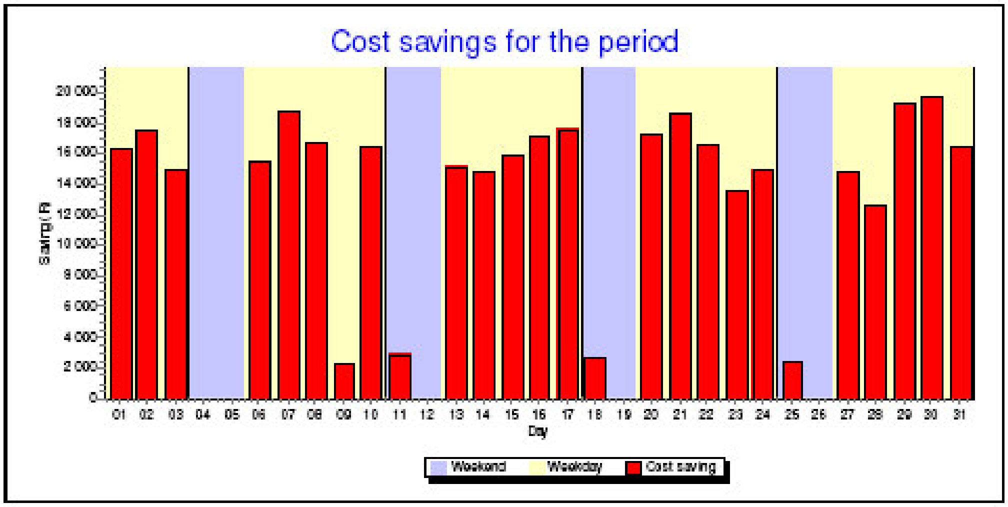

Figure 5: Cost savings from 1 August 2007 to 31 August 2007

5 Energy used and peak time load shift

The average load reduction for the evening peak, excluding condonable days, is **11.90 MW.** The average morning load reduction, excluding condonable days, is **5.33 MW.** Figure 6 shows the average load and baseline (MW) for 1 August 2007 to 31 August 2007. Please note that the baseline is scaled according to standard Measurement and Verification (M&V) practises. The morning and evening load shift (MW) for the same period are indicated in Figure 7.

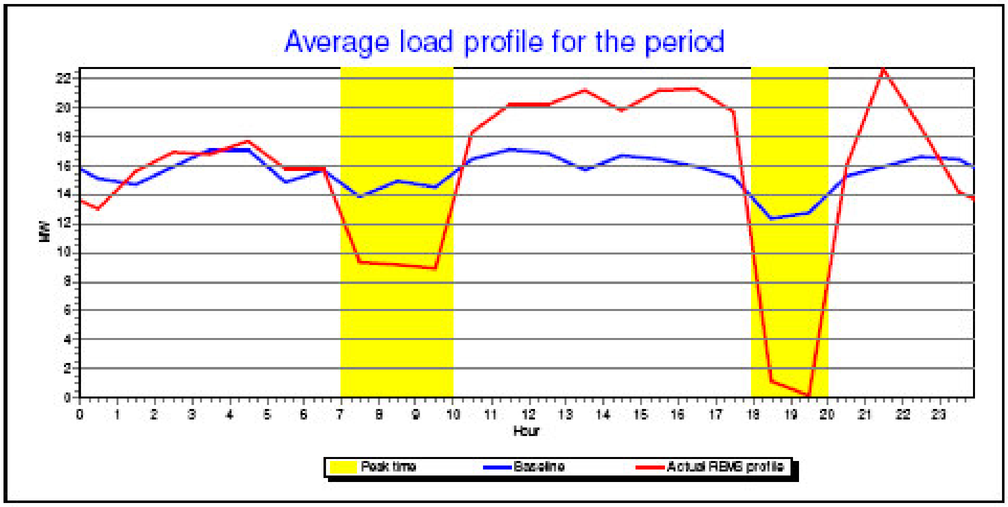

Figure 6: Average load profile and baseline from 1 August 2007 to 31 August 2007

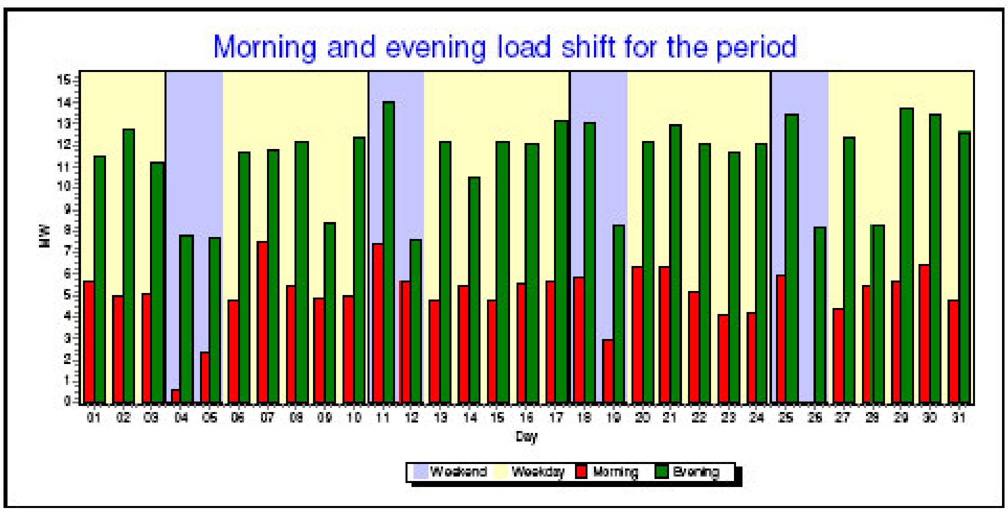

Figure 7: Morning and evening load shift from 1 August 2007 to 31 August 2007

6 Daily performance

The table on the following page shows the breakdown of all the days in the period: 1 August 2007 to 31 August 2007.

Day	Actual saving	Missed opportunity	Reason/Condonable	System switched to manual [% of day]	Energy consumption [MWh]
1 August	R 16 338			60	359.66
2 August	R 17 561			77	378.11
3 August	R 15 003	R 660		64	351.66
4 August	R 0	R 1 790		82	232.60
5 August	R 0			100	216.17
6 August	R 15 479	R 320		83	354.16
7 August	R 18 835			80	367.42
8 August	R 16 712	R 250		67	374.91
9 August	R 2 314			67	330.54
10 August	R 16 433	R 720		89	378.25
11 August	R 2 833	R 50		87	388.10
12 August	R 0			79	206.74
13 August	R 15 120	R 1 980	Maintenance on pumps	40	377.41
14 August	R 14 831	R 2 980	Maintenance on pumps	58	390.13
15 August	R 15 903	R 1 560	Maintenance on pumps	89	383.81
16 August	R 17 122	R 850		81	392.94
17 August	R 17 570	R 340		55	391.83
18 August	R 2 666	R 100		72	371.71
19 August	R 0			80	218.25
20 August	R 17 221			72	364.07
21 August	R 18 593			74	382.97
22 August	R 16 582			90	362.02
23 August	R 13 659	R 2 780	Maintenance	73	365.63
24 August	R 15 004	R 1 320	Maintenance	100	363.42
25 August	R 2 345	R 350		100	362.54
26 August	R 0			82	228.67
27 August	R 14 802	R 2 140		70	374.60
28 August	R 12 629	R 4 850	Maintenance on pumps	91	384.17
29 August	R 19 296			52	403.08
30 August	R 19 684			82	397.90
31 August	R 16 449	R 510		57	374.77
Total/Average	R 370 982	R 23 550		76	10 828.24

Table 2: Day performance for the period

If the missed opportunities were realised, the extra cost savings would have been R 23 550. The system achieved 94.03 % of the maximum possible savings.

7 Conclusion

For the period from 1 August 2007 to 31 August 2007, REMS saved **R 370 982** on Mponeng. The average evening peak load reduction was **11.90** MW. The average morning peak load reduction was 5.33 MW. If all the missed opportunities were realised, the costs saving would have accumulated to **R** 394 532.