

ANALYSING DSM OPPORTUNITIES ON MINE CONVEYOR SYSTEMS

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ABSTRACT

The demand for electricity around the globe is increasing at an alarming rate. South Africa is no exception with electricity demand that has increased to a point where it is close to the maximum available capacity. Most of the South African electricity consumers have already experienced supply shortages where the possibility of frequent load shedding has become part of their normal lives.

A big concern in the supply of electricity is the peak loads that are created by domestic users. These peak loads occur from 07:00 to 10:00 and again from 18:00 to 20:00. Load-shifting, which is part of Eskom's Demand Side Management (DSM) program, is aimed at reducing the demand for electricity during the two peak time periods.

The conveyor systems at coalmines in South Africa were studied to identify possible load-shifting interventions. These mines make use of long conveyor belts to transfer the coal from mining sections to surface bunkers. Some of these conveyor systems have installed electrical capacities of more than 15,000 kW.

One of the biggest constraints that were identified for these systems was the possible influence of load-shifting on production at the mining sections. This constraint was addressed by the use of simulation models that predict the bunker levels for different conveyor belt schedules and production inputs. The load-shifting capabilities of the conveyor systems were analysed using these simulation models.

The simulation models proved that it would be possible to implement load-shifting on the conveyor systems with a maximum potential of 3,600 kW during the evening peak at one of the mines that was considered. The estimated electrical cost savings for such an intervention is R 529,000 per annum. There is thus a possibility to reduce electrical load during Eskom peak times by implementing load-shifting techniques on conveyor systems.

SAMEVATTING

Die wêreldwye aanvraag na elektrisiteit is besig om teen 'n kommerwekkende tempo toe te neem. Suid-Afrika is geen uitsondering nie met die gevolg dat beurtkrag ("load shedding") op enige dag van die week kan plaasvind.

Die verbruikspatrone van huishoudelike elektrisiteitsverbruikers veroorsaak twee periodes gedurende die dag waar die aanvraag na elektrisiteit baie hoog is. Hierdie twee periodes is van 07:00 tot 10:00 en weer van 18:00 tot 20:00. Lasskuif vorm deel van Eskom se aanvraagreguleringsprogram "Demand Side Management (DSM)" en is gerig daarop om die aanvraag na elektrisiteit gedurende die piektye te verlaag.

Die vervoerbande van steenkoolmyne in Suid-Afrika was geïdentifiseer om lasskuif geleenthede te ondersoek. Die myne maak gebruik van die vervoerbande om die uitgemynde steenkool van die onderskeie produserende seksies na die bognondse steenkool bunkers te vervoer. Die geïnstalleerde elektriese kapasiteit van hierdie vervoerbandstelsels kan selfs meer as 15,000 kW wees.

Die moontlike impak wat lasskuif op die produksie by die verskillende seksies kan hê, was geïdentifiseer as die grootste beperking wat aangespreek moet word. Die gebruik van simulasiemodelle wat die inhoud van die steenkoolbunkers kan voorspel vir verskillende vervoerbandskedules het hierdie beperking aangespreek. Die moontlikheid van lasskuif op die vervoerbande is ook bereken met behulp van die simulasiemodelle.

Die simulasiemodelle het die moontlikheid van lasskuif op die vervoerbande uitgewys. Daar was bevind dat daar soveel as 3,600 kW las uit die Eskom aandpiek geskuif kan word by een van die myne wat ondersoek was. Hierdie beraamde lasskuif sal 'n elektrisiteitsbesparing van soveel as R 529,000 per jaar tot gevolg hê. Dit is dus bewys dat die implementering van lasskuif op vervoerbande 'n moontlikheid is en dat dit 'n bydrae kan maak tot die verlaging van die elektrisiteitsverbruik gedurende die Eskom piektye.

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NOMENCLATURE

ASD	Adjustable Speed Drive
AC	Alternating current
C	Conveyor friction factor
CECEAM	Conveyor Electricity Cost Efficiency Audit Methodology
cm	centimetre
CM	Continuous Miner
CO ₂	Carbon dioxide
d	Load depth on a conveyor system
DME	Department of Minerals and Energy
DOL	Direct On Line
DSM	Demand Side Management
ESCO	Energy Services Company
ESI	Electricity Supply Industry
f	Frequency of the supply current
g	Gravitational acceleration
GDP	Gross Domestic Product
H	Net change in elevation of conveyed material
HVAC	Heating Ventilation and Air Conditioning
IGBT	Insulated Gate Bipolar Transistor
IEP	Integrated Electricity Plan
INEP	Integrated National Electricity Program
IPMVP	International Performance Measurement and Verification Protocol Committee
kcal/kg	kilocalorie per kilogram
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
L	The centre to centre distance or the horizontal projection of the distance for incline or decline belts

L_o	Compensation length constant or terminal friction independent of conveyor length
ML	Mega litre
Mt	Million tons
M&V	Measurement and Verification
MVA	Mega Volt-Ampere
MW	Megawatt
MWh	Megawatt hour
N	Rotational speed of an induction motor
NER	National Electricity regulator
NERSA	National Energy Regulator of South Africa
OECD	Organisation for Economic Co-operation and Development
P	Amount of poles in an induction motor
P_{ec}	Power consumed to move an empty conveyor belt
P_h	Power consumed to move material horizontal on a conveyor belt
P_l	Power consumed to move material vertical on a conveyor belt
P_{sc}	Power consumption due to skirt boards on a conveyor belt
ppm	parts per million
PWM	Pulse Width Modulation
Q	Factor that represents the mass of the moving parts of a conveyor belt from centre to centre distance
R	South African Rand
S	Induction motor slip
SCADA	Supervisory Control And Data Acquisition
T	Material transfer rate (ton/hour)
TOU	Time Of Use
USA	United States of America
US\$	United States Dollar
V	Volt

INTRODUCTION

Chapter 1 starts with an overview of the electricity crisis facing South Africa. Load-shifting is discussed as a solution to limit the electricity demand during peak times. Current DSM projects are discussed briefly. The possibility of implementing DSM initiatives on conveyor belts is investigated.

1 INTRODUCTION

1.1 Background

The world's energy demand is forecasted to increase by 1.7% per year until 2030 [1]. An indication of this expected increase in demand for energy can be seen in figure 1. A significant increase in the use of fossil fuels for the creation of energy can be observed in this figure.

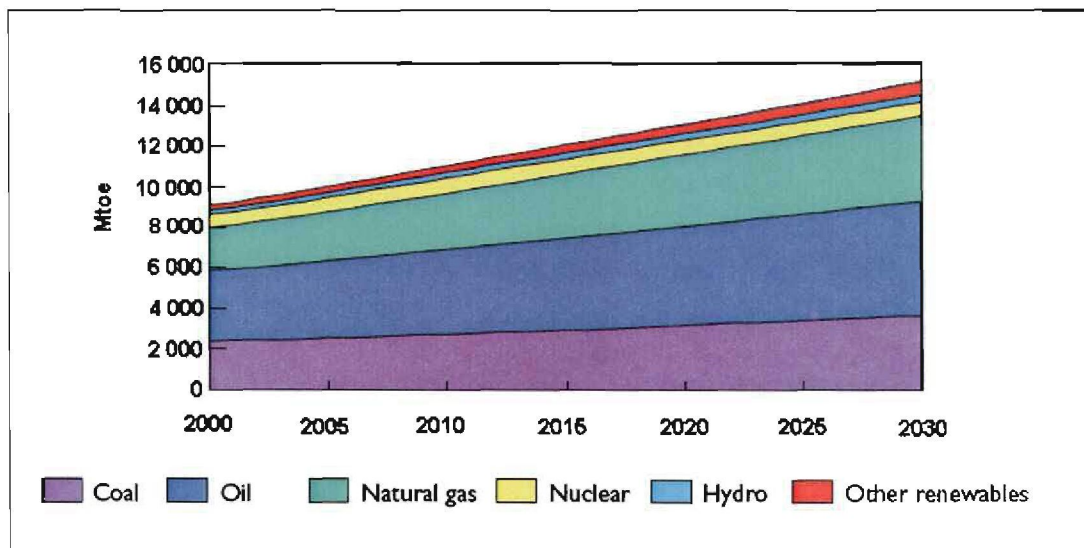


Figure 1 – Increasing demand for energy in the world [1]

It is predicted that power generation will contribute approximately 50% to the increase in global emissions up to 2030 [1]. The increase in demand for electrical power generation by fuel for the period from 1971 to 2005 can be seen in figure 2.

The energy transmitted by South African electricity suppliers has increased by 5.78% from 2003 to 2004 [2]. The South African government aims for a 6% Gross Domestic Product (GDP) growth per annum, which would require an annual electricity growth of 4.4% to supply the increased demand for electricity [3]. Eskom aims to deliver another 22,000 MW by 2017 to keep up with the growth in GDP [4].

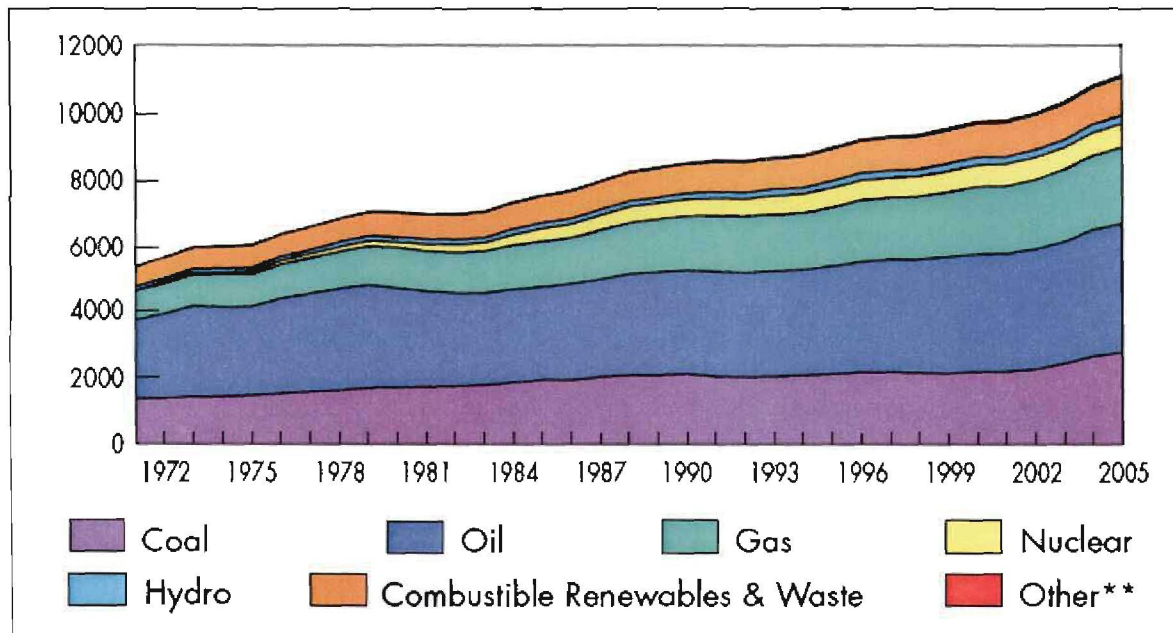


Figure 2 – Evolution from 1971 to 2005 of world electricity generation by fuel [5]

The negative environmental effects linked to energy consumption like harmful emissions and the depletion of natural resources are causes for great concern. Carbon dioxide (CO_2) is an example of a harmful gas that is emitted by the burning of fossil fuels. The use of fossil fuels for energy generation is one of the major sources of CO_2 emissions [1].

The amount of CO_2 that is emitted by coal fired electricity generators to generate 1 kWh of electricity is between 800 and 1,000 g. An estimated 50g to 300g of CO_2 is further emitted into the atmosphere in upstream and downstream processes like the mining and transport of the coal. Almost 90% of South Africa's power is generated by coal fired power stations. South Africa is said to emit 45% more CO_2 per capita than other developing countries [6] [4] [7].

It is known that greenhouse gasses in the earth's atmosphere trap heat. This effect where the atmosphere is heated by greenhouse gasses is termed global warming or the greenhouse effect. CO_2 is classified as a greenhouse gas and can be linked to global warming [8] [6].

The atmospheric CO₂ concentrations in the atmosphere have increased from about 280 parts per million (ppm) in 1750 to a level of 379 ppm in 2005 [9]. Antarctic ice core analyses indicated that the natural range of carbon dioxide over the last 650,000 years was between 180 and 300 ppm [9]. The CO₂ concentration measured for 2005 has thus exceeded the natural range by 79 ppm, or 26%.

The factor by which CO₂ tends to warm the planet has increased by 20% from 1995 to 2005 [9]. CO₂ emissions are set to increase by 69% up to 2030 if no new policies and measures are set into place [1]. It is expected that the global mean temperature could increase by as much as 4.5% by 2100 if CO₂ emissions is not limited [10]. Such an increase in temperature is said to result in an average increase in sea level of 50cm [10]. The predicted levels of CO₂ emissions for different places in the world are shown in figure 3.

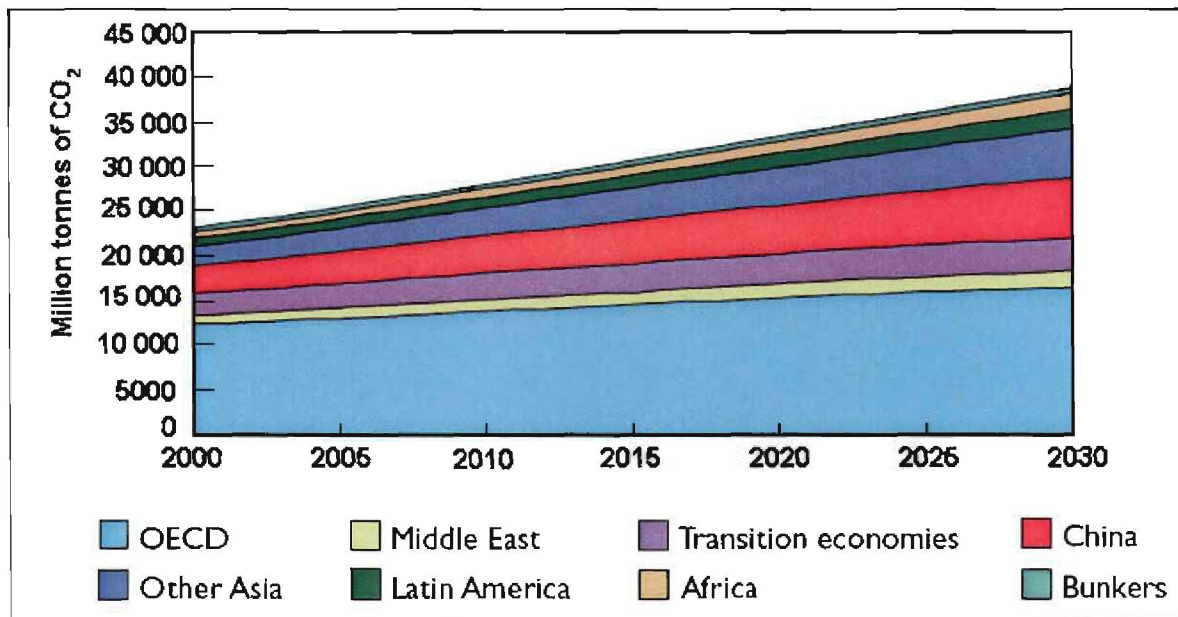


Figure 3 – Projected increase in CO₂ emissions in the world [1]

It is obvious from the above discussion that the use of electricity is contributing to global warming. It is even more disturbing that the demand for electricity is increasing so fast.

Eskom stated in its 2007 annual report that their reserve margin between supply and demand is between 8% and 10%, which is much lower than the 15% reserve that they aim for [4]. Eskom predicted in their 2006 annual report that they would run out of excess peaking capacity in 2007 [11].

It is important to have reserve capacity available on any electricity network to account for both planned maintenance and unplanned outages. An electricity network can become unstable when the network experiences supply shortages. This can result in the collapse of the network, causing blackouts [12].

On 14 August 2003 an electrical power outage of an estimated 61,800 MW occurred throughout parts of Northeast and Midwest United States and the Canadian province Ontario. The blackout spread through the states of Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, New Jersey, and Ontario, a province in Canada. The blackout affected an estimated 50 million people [13].

It took more than a week to restore full power to the system. The estimated cost of the blackout is between US\$ 4 billion and US\$ 10 billion for the United States alone. The Gross Domestic Product (GDP) for Canada was down by 0.7% for August 2003 [13].

The blackout was apparently caused by inadequate management of the reactive power and voltage supplied by the network. Certain policies that are set into place to successfully operate a power network were not adhered to. The system of events was triggered by the tripping of one of the generating units due to inaccurate input data. This led to the tripping of other transmission lines and caused 531 generating units at 263 power plants to shut down [13] [14].

A severe power outage occurred in Italy on 28 September 2003. The blackout was caused by a trip in the Mettlen-Lavorgo 380 kV Swiss transmission line. Italy uses the Mettlen-Lavorgo transmission line to import electricity from Switzerland, France, Germany or Poland through a meshed power network [15].

The Mettlen-Lavorgo transmission line was heavily loaded just before the incident occurred which caused the transmission losses to increase significantly. The losses in the cable caused the temperature of the cable to increase which caused the cable to stretch to a point where a flashover occurred to the trees underneath the line [15].

This increased the demand on the remaining power lines and caused them to overload and trip as well. It took 18 hours and 12 minutes to restore power to all of the consumers [15].

It is apparent that an unstable situation in any electricity network can disrupt the entire network. It takes a substantial amount of time to recover from such a power outage. Power outages result in economic losses. The estimated annual cost incurred by electricity consumers in the USA due to electricity interruptions is said to be US\$ 79 billion [16]. Preventative measures must therefore be put into place to prevent such an event.

Load shedding is a controlled way to distribute available electricity between electricity consumers. By making use of load shedding Eskom ensures that the electricity supply to affected areas does not get interrupted for more than two hours at a time. This means that certain areas would have electricity available while the supply to other areas is disconnected. After two hours the situation is reversed by connecting previously disconnected areas and disconnecting other areas [12].

Load shedding is said to be the last measure taken by Eskom to limit the demand on the electricity network. Hence load shedding is used when all other measures available to meet the necessary demand are not sufficient. During 2007 Eskom made use of load shedding to stabilise the demand for electricity. A few instances of load shedding during 2007 are given in the next paragraph. [12]

On 18 January 2007 Eskom experienced unplanned outages of 4,934 MW which forced Eskom to resort to load shedding to balance the demand with the available supply [17].

On 23 May 2007 the power to several parts of the Gauteng and Mpumalanga provinces was interrupted due to load shedding for about one hour due to instability in the transmission network [18].

During May 2007 several maximum demand records were broken, with a morning peak record of 34,361 MW on the 24th of May 2007 [28]. These are just some of the outages that occurred during 2007, various other power outages occurred during the year [19].

Eskom has the ability to supply 37,761 MW with another 4,200 MW available through imports from Mozambique and contracts with certain customers [11] [4]. This gives a total supply capacity of 41,961 MW. If this capacity included the 15% reserve there would have been a reserve of 6,294 MW available. This would have been more than enough to supply the 4,600 MW of unplanned outages.

It is apparent that the peak demand for electricity has increased to a point where Eskom can't supply the required electricity. It is also predicted that the electricity demand will increase even more in future. Consequently Eskom is forced to expand its current generating capacity.

Eskom approved a budget of R 97 billion for a capacity expansion programme in 2004 [20]. This budget has been increased to R 150 billion to provide for an electricity demand growth of 2.6% to 4.0% and covers the period from 2007 to 2012 [20].

Customers will be faced by tariff increases to fund the capacity increase program. Eskom has predicted tariff increases of 18% in 2008 and 17% in 2009 [4]. Eskom aims to deliver an additional 22,000 MW by 2017 in terms of the revised plan [20].

Eskom is, therefore in the process of expanding its supply capacity. However, the demand for electricity is increasing at an alarming rate. The additional power plants will place additional strain on the environment in terms of the emission of dangerous gasses, such as CO₂, and the depletion of energy sources.

The use of renewable energy sources such as solar power, wind energy, and bio-fuels are all part of the drive to use more environmentally friendly energy sources. The average cost to build a wind power station during 2006 was approximately US\$ 1,480,000 per MW of generating power and is expected to increase to about US\$ 1,800,000 in the near future due to an increases in turbine prices during 2006 [21].

Eskom stated in their annual report of 2006 that it costs approximately US\$ 1,000,000 per MW to build a coal fired power station [11]. It is obvious that the cost of renewable energy sources is much higher than traditional coal fired power stations. This cost might however be offset by cheaper running costs.

It is evident that the increase in electricity demand has contributed significantly to global CO₂ emissions. The realisation that CO₂ is changing global temperatures has led people around the world to research and implement actions to limit global warming [8].

To protect the environment and valuable resources, the increasing demand for electricity has to be slowed down. The demand must also be slowed down to prevent electricity prices from escalating due to the high demand for new power stations. By persuading consumers to limit their electricity usage the demand for electricity can be controlled.

One such an idea is the replacement of old inefficient electrical equipment with newer equipment that is more energy efficient. Another measure is to alter the usage patterns of electricity consumers. Both these measures form part of the Demand Side Management (DSM) program. DSM is a way of slowing the rapid increase in demand for electricity. DSM will be described further in the following sections [3].

1.2 Why Eskom is using DSM

Eskom is South Africa's primary supplier of electricity and accounts for about 96% of the country's electricity generation [2]. The peak demand for electricity in South Africa has increased by 7.1% from 2003 to 2004 [2]. The peak times for electricity usage are between 07:00 and 10:00 in the morning and between 18:00 and 20:00 in the evening [22].

This is because people are cooking their food, heating their homes and using hot water while getting ready for, or returning from work. Figure 4 indicates the electricity usage pattern in South Africa for a 24-hour period.

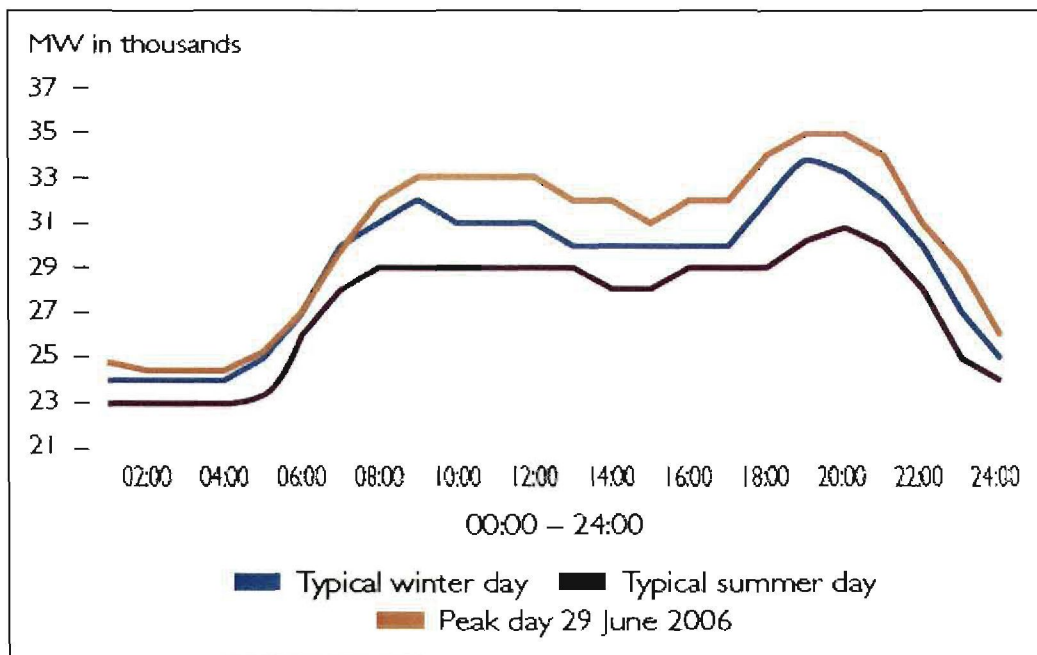


Figure 4 – Weekday electricity demand profile for South Africa [4]

The Integrated National Electricity Program (INEP) aims to achieve universal household access to basic electricity [24]. The INEP delivered connections to 232,287 households, 2,233 schools and 50 clinics by March 2005 [24]. A further 135,903 houses were connected in 2006 and 152,125 more in 2007 [4]. The great number of new connections place additional strain on the electricity network, especially during peak hours.

Demand Side Management (DSM) involves a range of load management initiatives that focuses on reducing the demand for electricity during peak periods. Load shifting is one of the measures that form part of DSM. [25]

Eskom is implementing DSM in South Africa through collaboration with the Department of Minerals and Energy (DME) and the National Electricity Regulator (NER) [26]. The NER regulated the Electricity Supply Industry (ESI) for the period from 1994 to 2004 when NERSA took over the functions of the NER [2]. Eskom is obliged to implement DSM in accordance with the NER regulation on DSM and the DSM Rollout Plan submitted to the NER [24].

The relationship between the various parties involved in DSM initiatives can be seen in figure 5. It can be observed from the figure that there are two other parties involved in the DSM process apart from Eskom, NERSA, and the end-user, namely Energy Services Companies (ESCOs) and Independent Measurement and Verification (M&V) companies.

ESCOs are private companies that are used to identify and realise DSM projects. The ESCO is responsible to submit proposals of projects to Eskom. The ESCO must establish a performance based project with the customer and implement the approved projects. The ESCO must also ensure that the project is sustainable [27].

The M&V company is used to verify the impact of the DSM project. The M&V-company must report the savings to NERSA. It is important that the M&V-company is an independent party in the DSM project [27].

The process whereby an electricity supplier influences the way electricity is consumed by customers is called DSM [22]. DSM means the planning implementation, and monitoring of end-users' activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand [22].

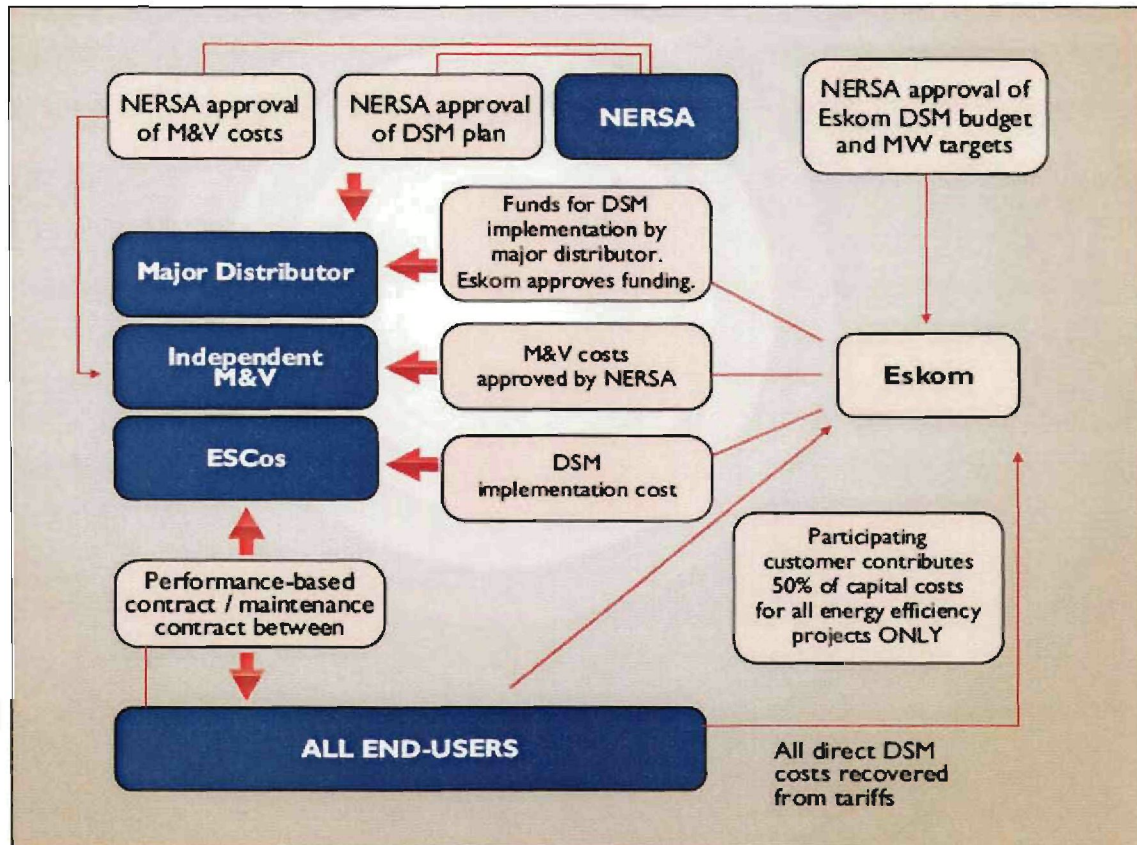


Figure 5 – Involvement of various parties in the DSM process [27]

Eskom achieved savings of 169.8 MW through DSM initiatives during 2007 which resulted in a saving of 289,000 ton of CO₂ emissions [4]. Eskom committed itself to save at least 153 MW every year from 2003 up until 2023 by making use of DSM [25].

The objective was to raise the demand saving to 4,200 MW in that period, equivalent to the output of a six-unit power station [28]. Eskom has increased this target to 8,000 MW between 2007 and 2025 which is an average target of 500 MW per annum [4].

It costs approximately R 80 billion to build a 4,500 MW thermal power station [4]. A comparison between the costs per MW incurred to build a coal fired power station or a pumped storage system and the costs for various DSM initiatives are shown in figure 6. It is obvious from the figure that the cost to implement DSM savings can be much lower than the cost to build new power stations [27].

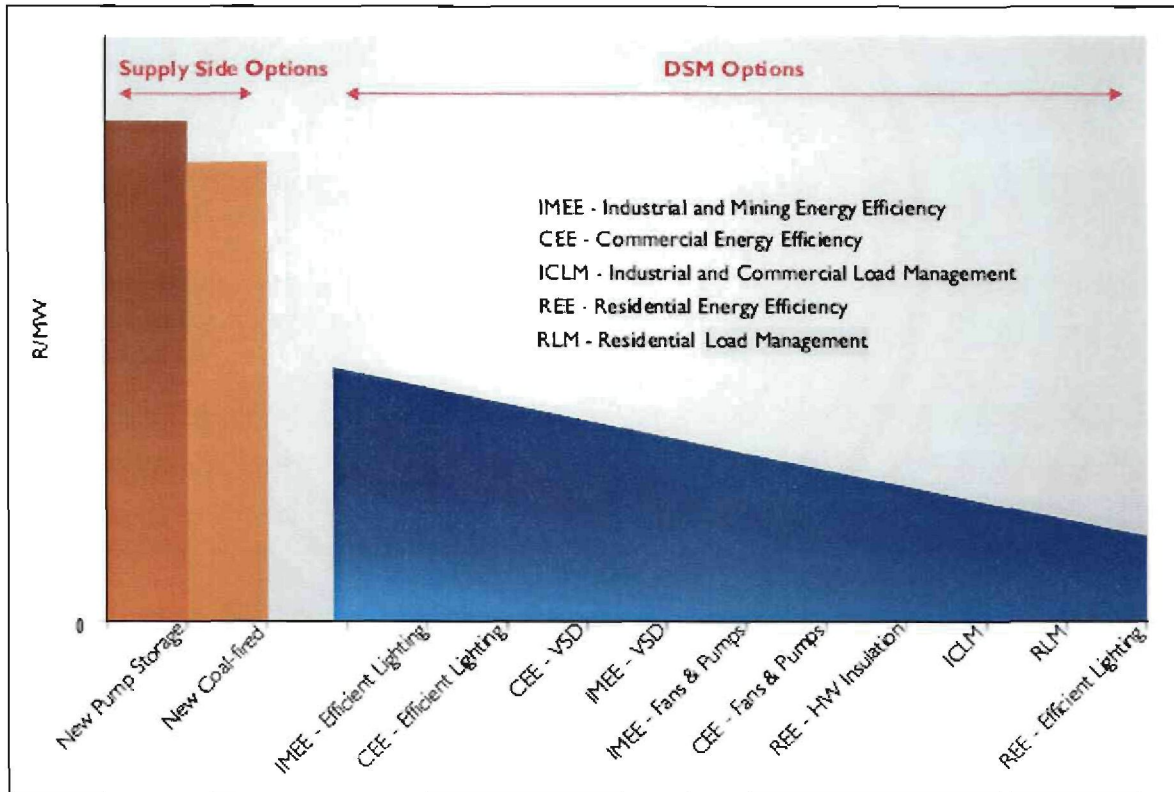


Figure 6 – Cost comparison between supply side and demand side options [27]

Every 1 kWh reduced through energy efficient measures, realises a saving of approximately 1 kg of CO₂ emissions. The water consumption of power plants is simultaneously reduced by approximately 1.2 litres [26]. Future carbon regulations is said to increase the cost of coal fired power generation by more than US\$10/MWh [29]. The costs that will be saved due to the reduced usage of coal is an added advantage for DSM.

It would not be easy to persuade customers to reduce their peak electricity usage without incentives and help. Eskom is prepared to pay up to 100% of the costs to implement load-shifting techniques for viable projects [30]. Customers can further save on their electricity costs by making use of cheaper off-peak periods and can also benefit from equipment installed that was paid for by Eskom.

The above-mentioned advantages are two of the main reasons why customers are willing to implement load-shifting techniques. Figure 7 indicates the Time Of Use (TOU) tariff times for Megaflex, Miniflex & Ruraflex tariff structures. The active energy charge is dependent on the time of day that the electricity is being used.

There is also a price difference between the high and low demand season, with June to August being classified as the high demand season [23].

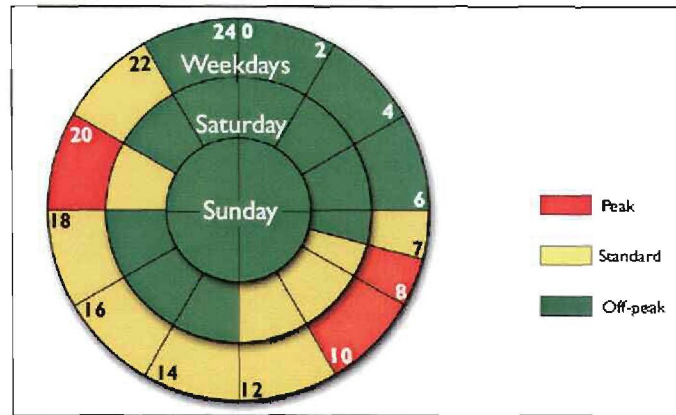


Figure 7 – Time Of Use (TOU) tariff times for Megaflex, Miniflex & Ruraflex tariff structures [23]

Megaflex is a tariff structure that is specifically suited for customers with a maximum notified demand of more than 1 MVA. Most of the consumers that are considered for DSM initiatives make use of the Megaflex tariff structure. The active energy costs for the Megaflex tariff structure is shown in table 1 [23]. The active cost per kW for the various periods can be seen in Table 1.

It can be seen from table 1 that it is almost 7 times more expensive to consume one kWh of electricity during peak time than during off-peak time in the high demand season.

High-demand season (June – August)	Period	Low-demand season (September – May)
55.30c + VAT = 63.04c/kWh	Peak	15.69c + VAT = 17.89c/kWh
14.62c + VAT = 16.67c/kWh	Standard	9.74c + VAT = 11.10c/kWh
7.95c + VAT = 9.06c/kWh	Off-Peak	6.90c +VAT = 7.87c/kWh

Table 1 – Active energy charge rate for Eskom Megaflex tariff structure for 1 April 2007 to 31 March 2008 [23]

The high cost during the peak periods are intended to persuade customers to consume electricity out of peak periods. There is thus a great opportunity for clients to save on electricity costs by not using electrical equipment during peak periods.

Eskom has provided R 450 million per year for energy saving measures, these funds can be used to implement DSM initiatives [31]. The cost of upgraded infrastructure for the realisation of load-shifting can also be recovered from these funds.

Load-shifting and energy efficiency are both DSM initiatives. Figure 8 indicates the effects of energy efficiency on the electricity demand profile of a typical electricity network.

It can be observed from figure 8 that the amount of electricity consumed over a 24-hour period is lowered with energy efficient interventions. Figure 9 indicates the effects of load-shifting on an electricity network.

It can be observed from figure 9 that the total amount of electricity consumed over a 24-hour period by the DSM intervention is almost the same as the total amount of electricity consumed before DSM.

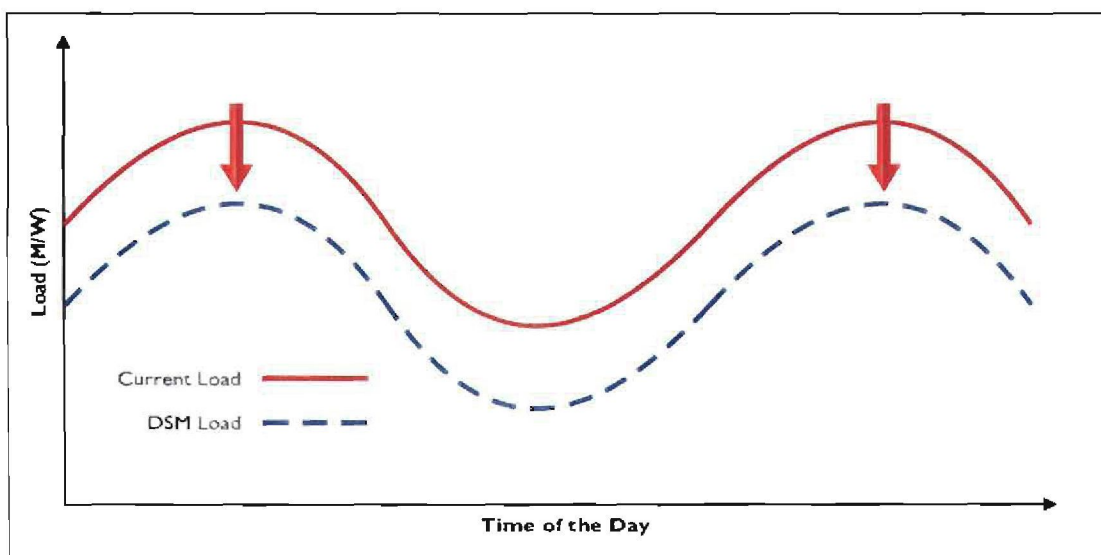


Figure 8 – DSM through energy efficiency [27]

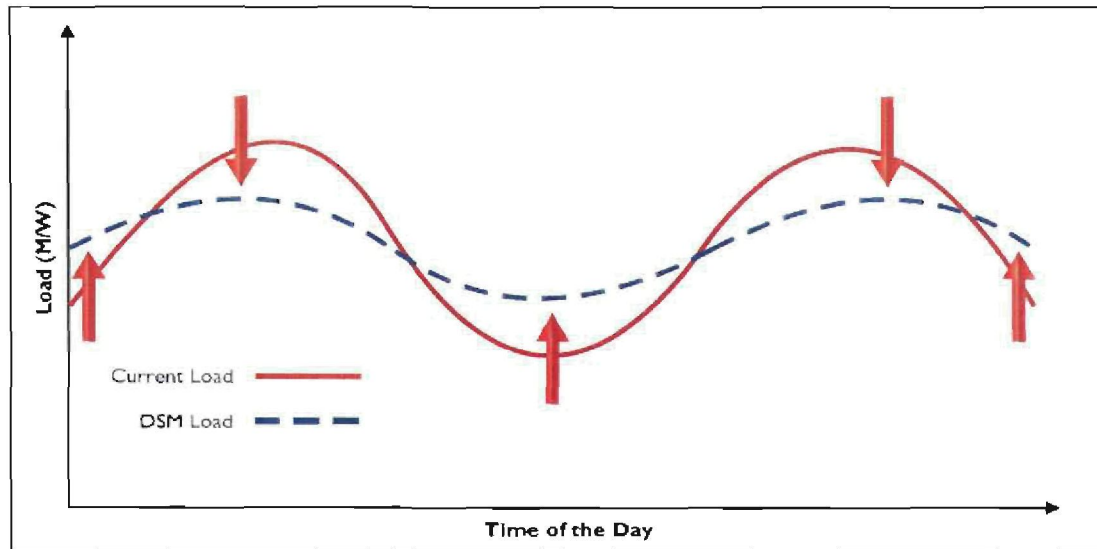


Figure 9 – DSM through load-shifting [27]

Figure 10 indicates the effect of DSM on the total electricity demand in South Africa. It can be seen in the figure that DSM has a considerable effect in reducing the overall electricity usage.

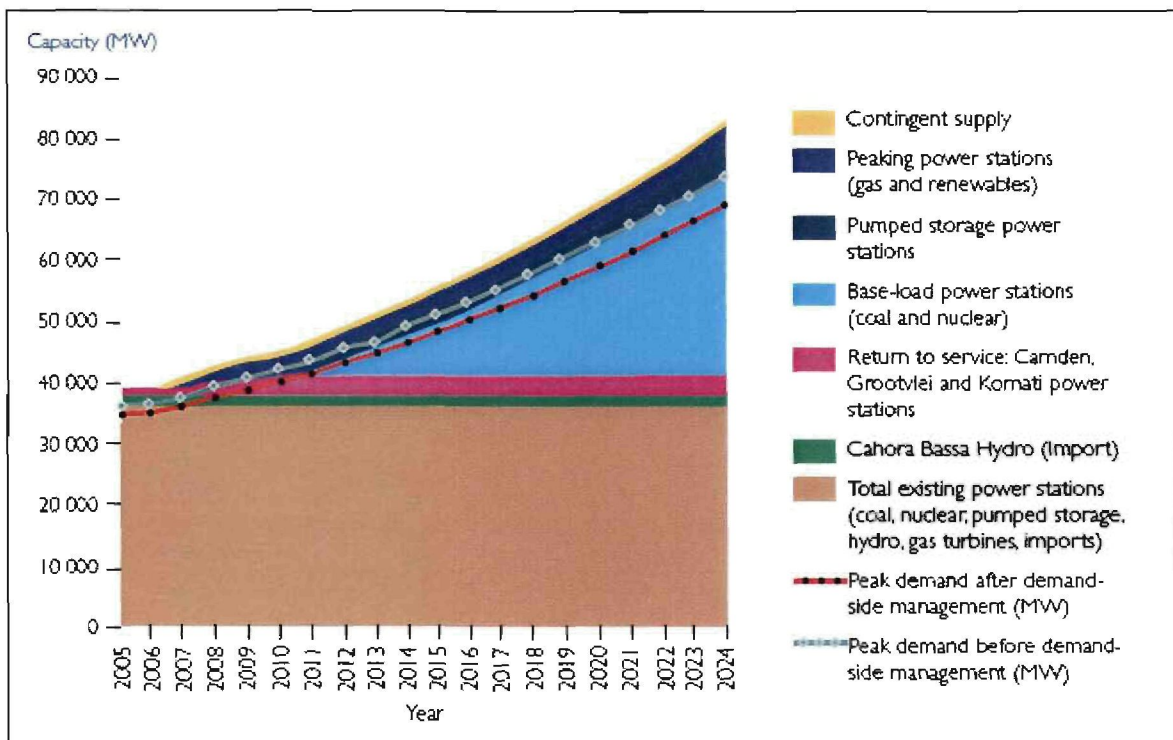


Figure 10 – South Africa's new capacity outlook [4]

1.3 Current DSM projects in South Africa

DSM based savings of 197 MW were contracted by Eskom during the 2004 financial year. This included a saving of 83 MW that was achieved through load management [32].

Figure 11 shows the electricity supply per sector for South Africa. It can be seen that manufacturing accounts for 44% and mining accounts for 26% of the total energy use in South Africa. This shows why the implementation of load-shifting in the mining sector can have a significant effect on the overall electricity consumption in South Africa.

A great focus for DSM projects in South Africa has been on equipment that is not directly linked to production. A decrease in production would result in decreased profits for a company. Big companies do not like the idea of scheduling equipment for load-shifting if the equipment is directly linked to production.

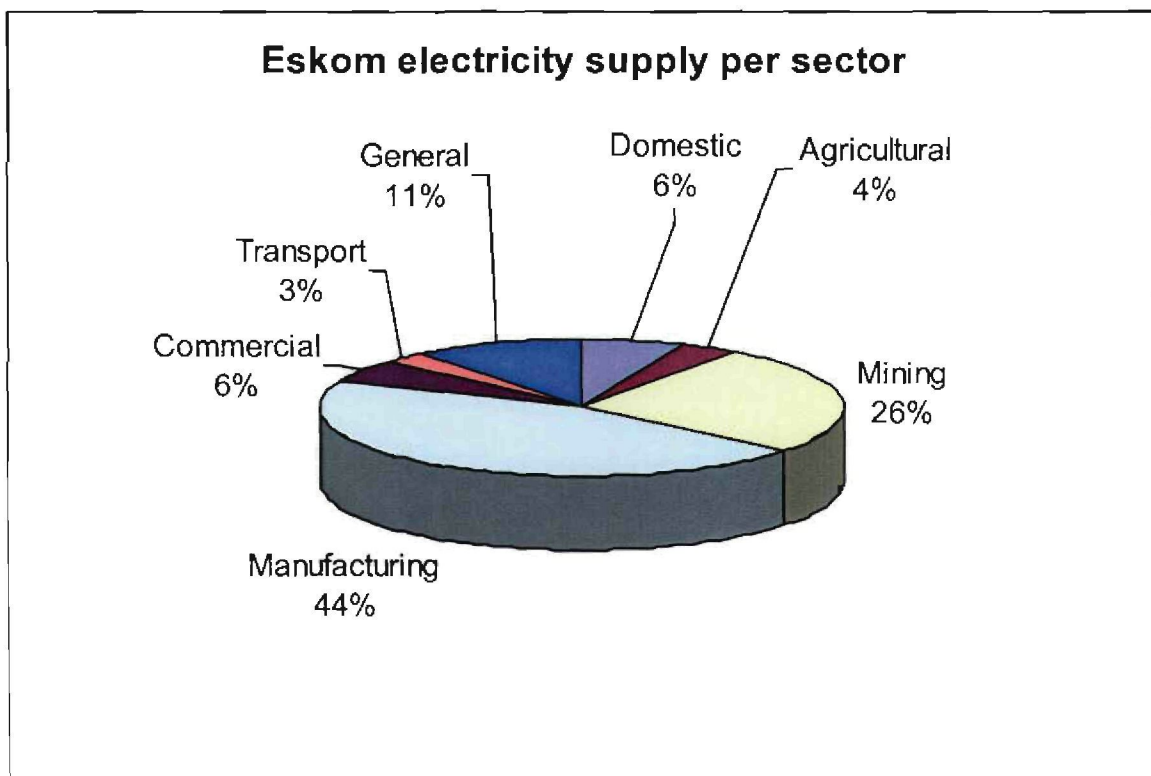


Figure 11 – Electricity supply per sector for Eskom supply [2]

Projects where water pumps in deep level mines in South Africa are scheduled to run in off-peak periods have proved to be very successful [33]. Kopanang mine in the North West province of South Africa is saving approximately R 300,000 per year by making use of load-shifting techniques on their pumping systems [33].

Elandsrand is a gold mine and part of the Harmony group of mines. A study indicated that there is a potential to move at least 3 MW of pumping load from Eskom's evening peak [34]. A saving of R 600,000 was projected for 2005 for the Elandsrand project [34].

Beatrix is a gold mine in the Free State province of South Africa. The mine consists of four different shafts and two metallurgical plants. A multiple shaft pumping system pumps the water from the various underground dams at Beatrix 1#, 2#, and 3# to the surface. The pumping system for the three shafts can be seen in figure 12. [35]

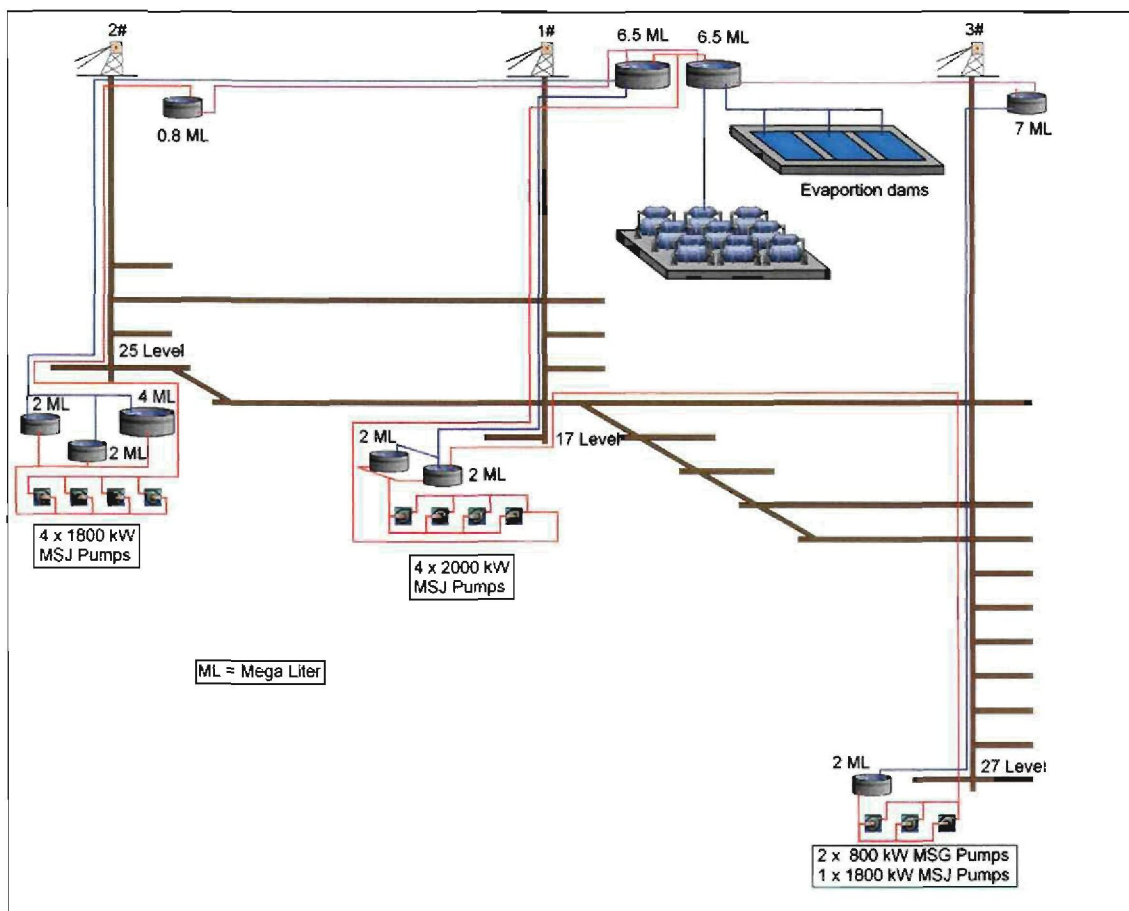


Figure 12 – Beatrix 1#, 2#, 3#- pumping system layout [35]

Water is articulated from the surface to the required levels for mining and cooling purposes. About 16 Mega litres of water enters the mine per day in the form of fissure water. Another 14.32 Mega litres per day is articulated to the mining levels for cooling and mining purposes. This gives a total of at least 30.32 Mega litres of water that needs to be pumped to the surface per day to avoid the flooding of the mine. [35]

The underground dams can hold a maximum of 14 Mega litres water before they will overflow. A study was done to determine the load-shifting possibilities on the underground water pumps. The underground dams were identified to be used for storage capacity during the peak time periods. The fissure water and the water for cooling and mining could thus flow into the underground dams without flooding the mine provided that the dam levels are kept below their maximum levels [35].

Simulation models were used to monitor the dam levels for certain load-shifting conditions. The dams were found to be big enough to make load-shifting possible. The pumps were scheduled to run during non-peak times as far as possible. The load-shifting possibilities on the pumping system of this mine were seen to be about 3.5 MW during the morning peak and 6.0 MW during the evening peak. This load-shifting intervention realised a client saving of R 170,000 per month during the high demand season and R 60,000 per month during the low demand season [35]

This proved that load-shifting could be implemented on multiple shaft pumping systems. Simulation models were used to determine the possibility of load-shifting on these multiple shaft systems. The mine benefits from electricity cost savings and from equipment that was installed at the cost of the Eskom and NER DSM funding incentives.

Research has also been done to determine the possibility of load-shifting techniques on equipment that are used in processing plants. It has for instance been proved that there is a possibility to implement load-shifting on the raw mills at cement factories. A raw mill at a cement factory is very crucial for production. [36]

The raw mills operate at a higher throughput than the systems that process the milled product. Silos are used to store the milled product before it is fed to the rest of the system. Simulations proved that the silos could be used to store enough material to allow load-shifting on the raw mills. [36]

Simulations specifically designed to modulate production in a specific application can be used to determine the effects that DSM would have on the piece of equipment. These simulations could then predict the effects of DSM on production.

Figure 13 indicates the contributions to maximum demand for different electricity consumers in the industrial sector. It can be seen in the figure that material handling contributes to about 10% of the total maximum demand in South Africa.

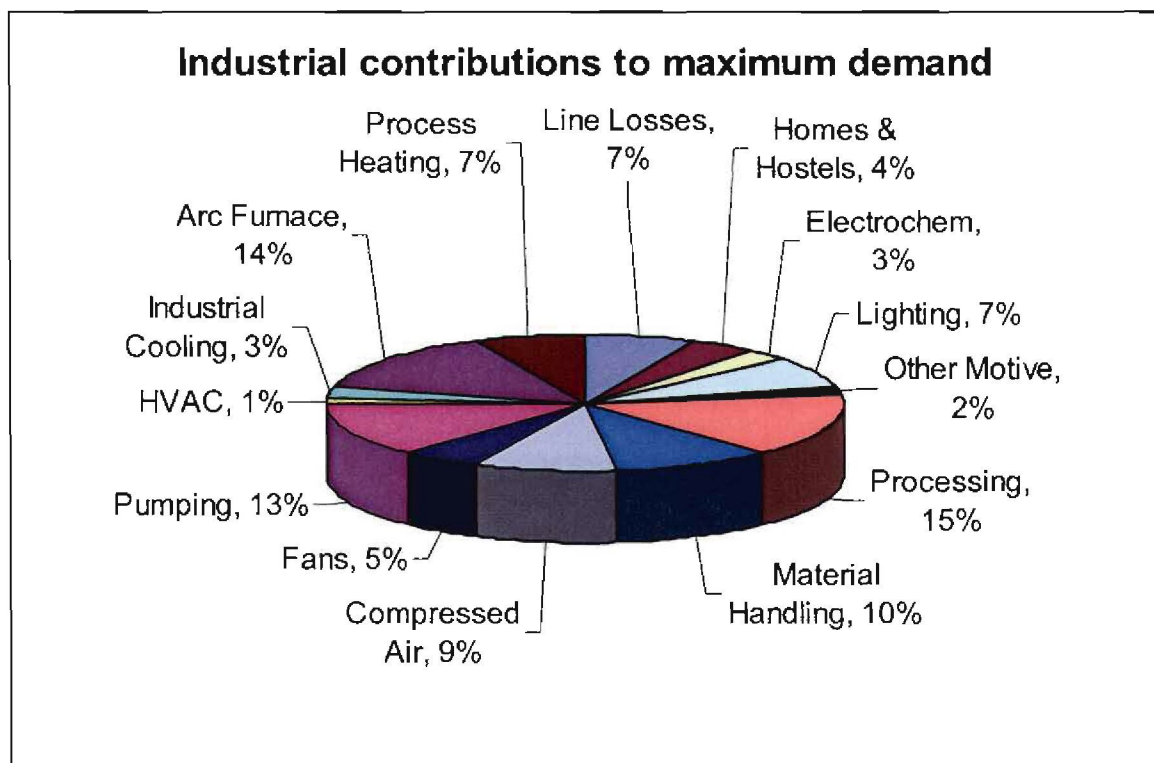


Figure 13 – Industrial contributions to maximum demand [32]

The implementation of load-shifting techniques on material handling equipment might be used to reduce South Africa's maximum demand. Conveyor belts are also classified as material handling equipment. The possibility of implementing DSM on conveyor belts will be described next.

1.4 DSM with conveyor systems

Conveyor systems are used to transport various types of material. These systems are used extensively in the mining industry. The type of material that is conveyed will depend on the type of mine or operation and include materials like ore, coal, limestone and waste.

Conveyor systems are part of a group of material handling systems. Other material handling equipment includes stackers, reclaimers, pocket elevators, and pneumatic systems. These other material handling systems are often used in conjunction with conveyor belts to complete the material handling process. Conveyor belts are used to transport material over long distances. Sometimes it can extend up to a few kilometres.

Conveyer belts make use of various parts like idlers, pulleys, gearboxes, and electrical motors that can contribute to energy losses in a conveyor system. Research has been done to improve the efficiency on large conveyor systems because they use substantial amounts of energy. Some energy saving ideas will be described briefly in the following paragraphs.

Energy efficient belt

When a conveyor belt passes over an idler pulley, energy is lost at the contact point because of an indentation that occurs on the underside of the rubber cover [37]. Extra energy is consumed to convey the material past the point of indentation [37]. This means that there is a certain amount of energy loss for every idler pulley in the system.

Goodyear, a leading conveyor belt manufacturer has introduced a conveyor belt that is said to be more energy efficient. The belt is called the "Goodyear Easyrider" conveyor belt [37]. The belt shape is said to recover faster than conventional rubber compounds. This means that the belt is able to move more efficiently over the idlers, thus reducing the amount of energy required to move the material [37].

The Goodyear Easyrider is said to reduce the operating costs of conveyor systems by up to 12% [37]. The amount of electrical cost savings that can be saved by using this belt could not be determined. The cost for this belt was also not available. The use of such an energy efficient belt may help to reduce the electricity consumed by the belt. The study focuses on lowering the demand for electricity during Eskom peak times. Such an energy saving belt can be used to increase the demand savings of conveyor belts.

Motor sequencing controllers

Oversized motors are used on conveyor belts because of the high starting torque required to start a conveyor belt. Figure 14 indicates the relationship between both the power factor and the current drawn versus the load for a typical 55 kW induction motor. The current drawn by a conveyor motor will decrease when the conveyor belt reaches its required running speed.

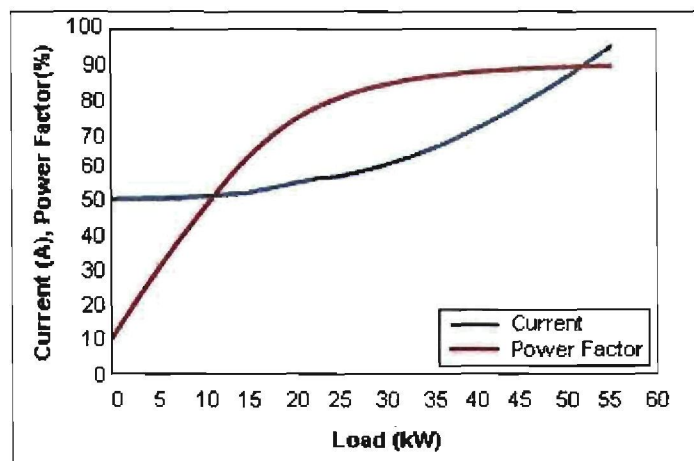


Figure 14 – Current and power factor vs. load relationship for a 55 kW conveyor belt motor [40]

Conveyor belt motors will typically run at values between 30% and 50% of their rated capacity when the belt is not accelerating [38]. Figure 14 indicates that the power factor is in the region between 0.6 and 0.8. A low power factor will increase the reactive power consumed by the motor. Certain electricity tariff structures are also dependant on the reactive energy used by a consumer [23]. Reactive power does not contribute to any work being done by the motor and is thus dissipated through heat and noise. This reduces the efficiency of the motor.

Motor sequencing controllers have been installed to improve the efficiency of the motors by ensuring that the motors operate at values that are closer to their rated capacity [39]. These motor-sequencing controllers read the current of a master motor. The power supply to a secondary motor is disconnected as soon as the master motor's current falls below a certain minimum value. More secondary motors are disconnected until the master motor operates within its preferred parameters.

The power supply to a secondary motor will be connected again as soon as the master motor's current reaches a certain maximum level. More secondary motors will be connected up to the point where the master motor's current is within the preferred parameters. Any running motors will operate at high efficiencies because the motors are running within their optimum range.

The above study proved that the use of motor sequencing controllers could reduce the reactive power consumed by a conveyor system. Eskom's DSM initiatives are aimed at reducing the active power consumption of equipment. The use of such a controller would, therefore, be mostly beneficial to the consumer in terms of the reactive cost savings achieved [30].

Variable speed drives

Research has been done to estimate the power saving on conveyor belts by making use of Variable Speed Drives (VSDs) [40]. VSDs generate variable output frequencies and voltages to change the rotation speed of induction motors. The basic operation of VSDs is described in Appendix A. Most of the energy savings achieved with VSDs on conveyor belts can be attributed to better starting procedures, minimising maximum demand and lowering the power factor [40].

The major benefits of VSD type conveyors include easier start-up, better control and increased belt life because of a smooth start-up. These advantages of VSD type conveyors can be used to implement other load-shifting techniques and will be discussed later in this document.

Regenerative energy savings with a downhill conveyor system

A 12.7 km downhill conveyor system is used to transport coarse copper ore at the Minera Los Pelambres mine [42]. Minera Los Pelambres is the world's fifth largest copper mine and is located in Chile [43]. The ore is transported at a rate of 8700 ton per hour with a total drop of 1.3 km [42].

By making use of regenerative braking to limit the speed of the conveyor system, a total of 25 MW of electricity can be generated [42]. Figure 15 shows the drive end of one of the conveyor belts at the Minera Los Pelambres mine in Chile.

The idea of generating electricity from the conveyor system at the Minera Los Pelambres mine was seen to be beneficial. The advantages of the steep decline made this project viable. Conveyor systems that are not declined can't be used to generate electricity.



Figure 15 – Drive end for the Minera Los Pelambres downhill conveyor [42]

All of the above methods are energy efficient measures. The use of load-shifting on pumping systems and the raw mill at a cement plant was seen to reduce the peak electricity usage of the equipment that resulted in electricity cost savings.

The following study optimised the material loading on conveyor belts to realise electricity cost savings. Storage capacities in the conveyor system were utilized to reduce the electrical consumption during peak times.

Optimising loading on conveyor belts to improve energy efficiency

A study was done to evaluate the energy efficiency on conveyor belts by changing the loading on the conveyor belts [41]. The study proved that it is possible to increase the efficiency of a conveyor belt by loading the belt according to optimised parameters [41]. By changing the loading on the conveyor belt, the electricity cost per ton of conveyed material can thus be altered [41].

The above mentioned study made use of a belt schedule to run the conveyor belt at different speeds during various times of the day [41]. The study took advantage of the TOU tariff structure where the electricity costs vary depending on the time of the day. The study showed a potential energy cost saving of up to 66% [41].

The conveying rate on the conveyor systems was changed to optimise the savings achieved. This method relied on variable feed rate conveying systems. Not all conveying systems have variable feed systems installed. It might be viable in certain conveying systems to upgrade the systems to make use of the savings achieved by varying the conveying rate. [41]

Load-shifting on conveyor belts

DSM opportunities on mine pumping systems and DSM at cement plants were described in the previous section. It was seen that the presence of storage facilities might be used to schedule electrical equipment to run during cheaper electricity periods. The presence of storage facilities in conveyor systems may therefore, also be used to schedule conveyor equipment to run during off-peak periods.

Conclusion

It was seen that there are various ways to reduce the electricity usage of conveyor belts. A 66% savings was achieved on a conveyor system by optimising the loading on the conveyor belts [41]. The possibility of implementing load-shifting on conveyor belts was also identified provided there are sufficient storage capacities available.

1.5 Objectives of this study

The main objective of this study is to determine the possibility of implementing DSM on conveyor belts. Previous load-shifting projects made use of available storage facilities to make it possible for electrical equipment to be stopped during peak times without serious side effects.

There is a possibility that available storage capacities on conveyor systems can be used to implement DSM initiatives on these systems. The focus area of this study is the rescheduling of conveyor belts to run out of Eskom peak periods. The constraints applicable for the proposed interventions will be discussed to determine if it would be viable to implement the interventions.

The impact of load-shifting on production will be simulated to determine whether it would be viable to implement DSM or not. Certain case studies will be conducted to determine the feasibility on different coalmines.

Summary of contributions

- Identifying DSM possibilities in conveyor systems
- Developing and identifying techniques to assess the implications of DSM on the conveyor system
- Analysing the effects of the proposed DSM interventions on other systems linked to the conveyor system

1.6 Overview of the dissertation

A brief overview of the dissertation is given below.

Chapter 1 gives an introduction to the study. A short summary is given as to the increased energy demand for the world and the problems that are imposed by the demand. DSM as a measure to reduce the electricity demand is discussed in this chapter. Certain DSM initiatives that are used to reduce energy consumption during peak times are given. The possibility of implementing DSM on conveyor belts is also discussed briefly in this chapter.

Chapter 2 focuses on DSM possibilities with regards to conveyor systems. An introduction is given to the applications of conveyor belts. The operation of a typical conveyor system is described in this chapter. Possible focus areas for DSM on conveyor systems are pointed out. Constraints that would hinder the implementation of DSM are also pointed out in this chapter.

Chapter 3 entails the development of simulation models to be specific to mine conveyor systems. Simulation requirements are identified in this chapter. The simulation models are verified to test their accuracy. The benefits of this simulation model are also described in this chapter.

Chapter 4 gives an overview of case studies that were investigated to determine the possibility of load-shifting on conveyor systems. Various load-shifting scenarios are investigated. The load-shifting possibilities and cost savings for each scenario is discussed. Infrastructure requirements for the proposed interventions are described.

Chapter 5 gives a summary of the findings of the study. Various possibilities for infrastructure upgrades are discussed. Suggestions for expanding the load-shifting possibilities on conveyor belts are discussed.

DSM POSSIBILITIES WITH CONVEYOR SYSTEMS

A detailed understanding of conveyor belts and their operation will assist in identifying DSM opportunities and is discussed in this chapter. Focus areas for DSM are identified in this chapter.

2 DSM POSSIBILITIES WITH CONVEYOR SYSTEMS

2.1 Introduction

Conveyor belt systems are used to transport material. There are many different types of conveyors each designed for a specific purpose. Some mines use conveyor belts to transport ore from the mining sections to the surface. Conveyor belts are also used to distribute ore to different sections above surface for instance beneficiation plants, blending stockpiles, waste stockpiles, and silos.

Previous studies regarding energy efficiency on conveyor belts were also discussed. These studies included energy efficient belts, motor sequencing controllers, variable speed drives and optimising the loading on conveyor belts. Load-shifting techniques as an alternative means for energy savings will be discussed in this chapter.

Several approaches for DSM were discussed in the previous chapter. It was identified that the presence of storage facilities may be used for load-shifting opportunities. The possibility to use storage facilities in conveyor systems to implement DSM will be investigated.

2.2 Operation of typical conveyor systems

A typical conveyor belt consists of the following [41]:

- Belt
- Impact idlers
- Return idlers
- Take up pulley
- Tail pulley
- Head pulley
- Conveyor drive

Different applications require different conveyor belt configurations. Figure 16 shows a diagram of a very basic conveyor belt.

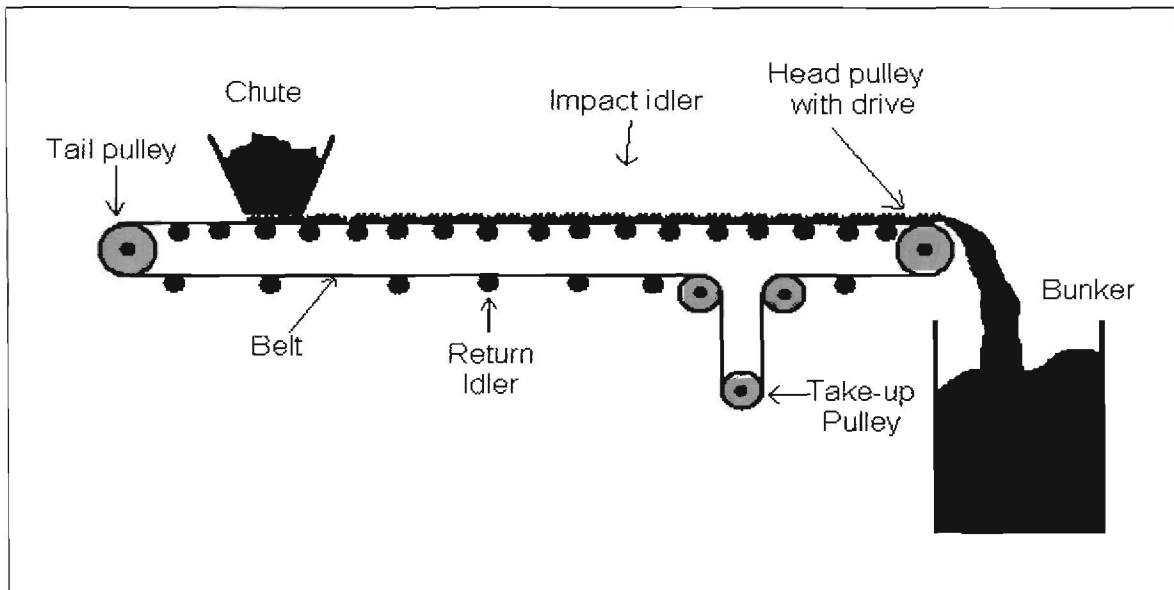


Figure 16 – Diagram a basic conveyor belt system

There are various factors that determine the conveyor belt configuration used. These factors include the type of material, physical space available, transfer rate, safety regulations, etc. It is common for conveyor belts with high transport volumes to use multiple drives.

The material to be transported is normally loaded into a bin from where the material is fed through a chute to the conveyor belt. The material is then transported on the conveyor belt to the desired location. More than one conveyor belt is often used in series to transport material over long lengths. The first conveyor belt discharges its contents into a chute that feeds the next conveyor belt.

Stackers and reclaimers are used to manage stockpiles and are used in conjunction with conveyor belts for material handling. There are many variations to the different types of stackers and reclaimers. One of the things that various stackers and reclaimers have in common is the fact that they are used to store and extract material on/from stockpiles.

A conveyor system is normally followed by a storage facility for instance a bunker or a stockpile. These storage facilities provide better control over the material handling system and can come in handy when conveyor belt breakdowns occur. The breakdown of a conveyor system that feeds a beneficiation plant could easily force a plant to shut down if there is no storage capacity between the conveyor system and the plant.

Most coal processing plants make use of complex processes that require a constant coal supply. These plants have complex start up procedures that require a considerable amount of time before the plant is running at optimum capacity after a shut down.

Silos and stockpiles are therefore used to create buffer capacity between the conveyor system and downstream systems. Stockpiles and silos are also used to create a buffer capacity between different sections of a conveyor system. Buffer capacities are normally used where the conveyor system is preceded by mining operations. Potential income is lost when mining is stopped for any reason. This means that a conveyor system breakdown can result in a loss of income.

The basic operation of conveyor belts was discussed. It was seen that the optimum operation of conveyor belts are crucial for maximum production. DSM may not interfere with production. The influence on production and all possible side effects that can affect the conveyor system must be properly evaluated before implementation DSM. Focus areas for implementing DSM will now be discussed.

2.3 Possible focus area for DSM

Consumers that make use of the Megaflex electricity tariff structure can benefit from electricity savings by scheduling electrical equipment to operate during cheaper time periods. Certain deep level mines in South Africa are saving on electricity costs by scheduling water pumps to run during non-peak hours.

These mines make use of storage capacity between pumping stations in conjunction with automated control systems to schedule the running times of pumps. [33] [34] [35].

Load-shifting techniques on pumping systems make use of dams to store water during load-shifting interventions. The similarity between dams in pumping systems and silos or bunkers in conveyor systems identified the use of bunkers to implement load-shifting on conveyor systems. These bunkers can be used to store the conveyed material during peak periods.

Conveyor schedules can be structured in such a way that the conveyor belts will run during less expensive electricity periods. This will result in electricity cost savings on conveyor systems.

Figure 17 shows a conveyor belt configuration with storage capacity available between various conveyor sections. Suppose that the plant in figure 17 requires a constant flow of material from the mining area.

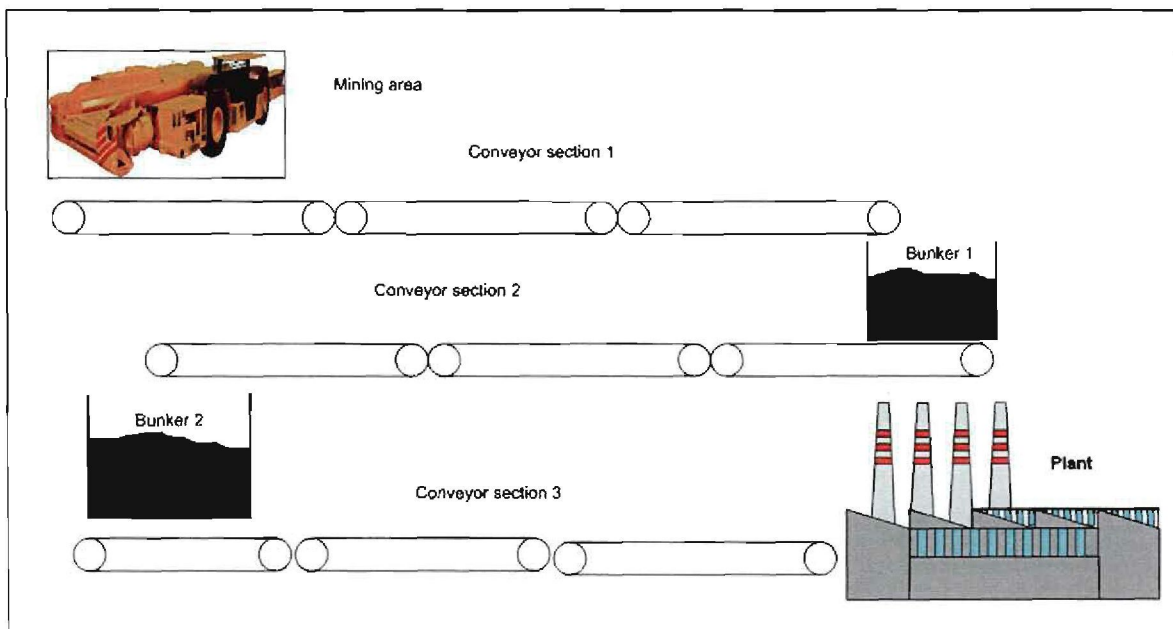


Figure 17 – Conveyor belt configuration with storage capacity between conveyor sections

Bunker 1 can be used to store the mined material if sufficient capacity is available. Mining can thus continue if conveyor sections 2 and 3 are not running as long as conveyor section 1 is running and bunker 1 has sufficient capacity.

The plant can also continue with its operations if the bunker level of bunker 2 is sufficient and conveyor section 3 is operational. This means that the production at the plant will not be affected by a stoppage of conveyor sections 1 or 2, provided that bunker 2 has sufficient material to supply the plant.

There is therefore a possibility to implement DSM on conveyor section 2 without affecting production at the plant or the mining area. However, it is very important to manage the bunker levels efficiently. The effects that DSM might have on bunker levels must be determined to avoid production losses. A simulation model can be used to modulate the bunker levels. The constraints applicable to conveyor systems must be determined to create accurate models.

2.4 Identifying constraints

Conveyor belts are used to transport material and / or people between various locations. Many conveyor belt applications form part of production processes. The optimal operation of such conveyor belts is crucial to maintain maximum production.

Various coalmines in South Africa were visited to evaluate the load-shifting possibilities at the mines. The names of the mines may however not be mentioned due to confidentiality agreements.

This study concentrates on researching the possibility of DSM on conveyor belts. The effects of the constraints introduced by DSM into a system that was not designed to take DSM into consideration must be kept in mind to determine the DSM possibility of a system.

The crucial role that conveyors play in production made it necessary to determine all the constraints relevant to conveyor belts. Some of the constraints that were identified during the visits to the coalmines are the following:

- Maximum transport rate
- Starting and stopping procedures
- Conveyor section start-up time
- Loading constraints during start-up
- Mechanical wear during stopping and starting

The information in terms of the constraints listed above were obtained from the mine's representatives. Other information like system layouts and electrical capacities were also obtained from the mine's representatives. Electronic data that was available on the Supervisory Control and Data Acquisition (SCADA) systems were used to evaluate load-shifting possibilities at the various mines.

The principle behind load-shifting interventions is to reduce the energy consumed by electrical equipment during Eskom peak periods. The biggest savings are achieved when the equipment is stopped during peak periods. Big electrical motors require intricate start-up procedures that complicate the load-shifting process.

Breakdown torques of up to 2.8 times the rated torque is generated during the start-up of conveyor belts that make use of Direct On Line (DOL) starting methods [41]. These high torques produces strain on the system that increases the wear on the components. This cost of repairing components worn by the increased start-ups might be much higher than the savings achieved by the load-shifting interventions.

Stopping of conveyor belts that are driven by DOL drives must therefore be limited to prevent strains on the conveyor equipment. The replacement of the DOL drives by VSDs is an option that will limit the wear introduced during start-up. This is an important constraint that must be considered while investigating the possibility of load-shifting.

Another important constraint that was identified was the minimum bunker levels that must be adhered to. Coal entering a completely empty bunker may damage the feeder equipment at the bottom of the bunker. A bunker with very low levels would also result in coal breakage due to the distance that the coal will fall into the bunker. This decreases the value of the coal and must thus be limited. Coal breakage can also occur at conveyor transfer points and during stacking and reclaiming processes. [44]

A bunker must thus never be emptied completely as a result of load-shifting. The handling of coal must also be limited to reduce coal breakage [44]. The minimum bunker level that is preferred by the mines considered in this dissertation is 20%.

The maximum bunker level to be used for load-shifting is another important constraint that must be considered. A full bunker would result in the loss of production because mining would have to be stopped. The choice of a maximum bunker level is, therefore, very crucial and requires careful consideration.

All of the above constraints must be considered when identifying load-shifting procedures. The simulation model used in determining the load-shifting possibility on conveyor belts will be described in chapter 3.

2.5 Conclusion

It was seen in the previous sections that there exists a possibility to implement DSM on conveyor belts. The possibility of DSM on conveyor belts must be researched in greater detail to determine the viability of such projects. The importance of managing the bunker levels was identified to be one of the aspects that require attention before implementing load-shifting.

Chapter 3 will concentrate on developing simulation models to determine the effects of DSM on conveyor systems. The primary focus of the simulation models will be to prevent DSM initiatives from interfering with the production of the relevant processes. The simulation models developed in Chapter 3 will be applied to different case studies to determine the DSM possibilities on actual systems.

SIMULATION OF CONVEYOR SYSTEMS

This chapter is concerned with the development of general simulation models to determine the effects of DSM on conveyor systems. All the constraints, variables and requirements for the model are determined in this chapter.

3 SIMULATION OF CONVEYOR SYSTEMS

3.1 Introduction

Conveyor belts are used extensively in mining and manufacturing processes. These conveyor belt applications are generally used to transport material between different production processes. This implies that the correct operation of these belts is crucial to prevent production losses. Unplanned conveyor stoppages in such applications could therefore result in production losses.

This study concentrates on opportunities for DSM on conveyor belts. Stoppages due to the rescheduling of conveyor belts for DSM purposes may result in production losses. The effects of these stoppages must be evaluated before the introduction of the DSM interventions to prevent production losses.

A simulation model must be developed to determine the effects of proposed load-shifting interventions on the conveyor systems. The possibility of DSM can then be evaluated using the simulation model that would eliminate experimentation on conveyor systems.

The constraints and variables relevant to conveyor systems are very important and must be considered when developing accurate simulation models. These constraints and variables should then be used to obtain the simulation requirements. The constraints relevant to conveyor systems were identified in Chapter 2.

A unique simulation model was developed to evaluate the DSM possibilities on conveyor systems. The principle of storage facility management that was used on the DSM projects at the pumping systems and cement plants were used to develop this simulation model. The requirements for the simulation model will now be described in more detail.

3.2 Simulation requirements

A simulation model can be used to simulate the bunker levels for various input parameters. It is necessary to obtain the relevant system constraints and variables to simulate the system. A generic load-shifting simulation model can be described using a flow diagram as indicated in figure 18.

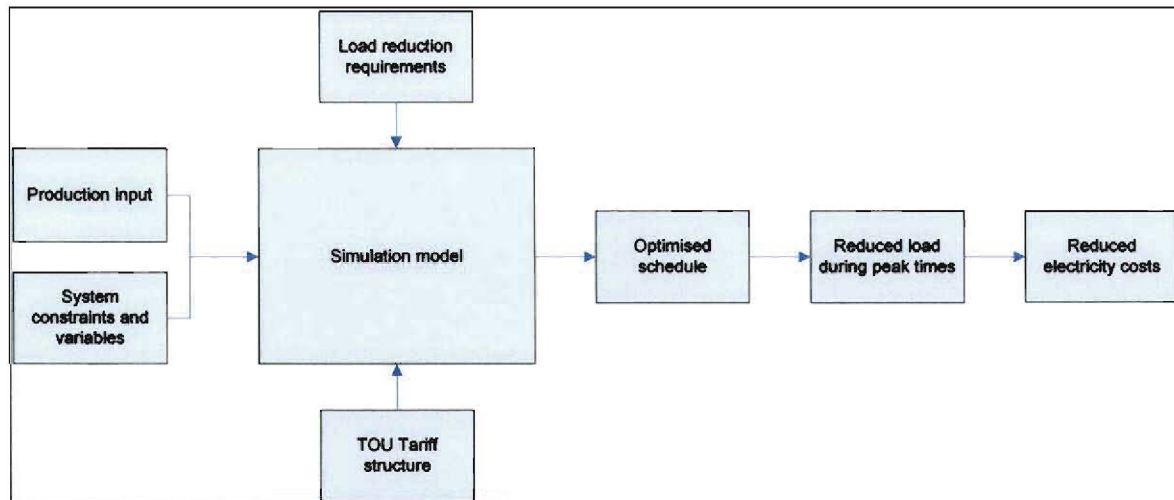


Figure 18 – Simplified block diagram for a generic load-shifting simulation model

The simulation model in figure 18 indicates that the model will use the production input in conjunction with the systems constraints and variables to give an optimised schedule as a result. The optimised schedule will then result in reduced electrical load during peak times. Electricity costs will also be reduced due to load-shifting.

One of the most important requirements of a simulation model is accuracy. A simulation model would not be worth much if it is inaccurate. It is therefore vital to take all the necessary constraints into consideration when developing the simulation model. The constraints relevant to the conveyor systems studied in this dissertation were given in Chapter 2 [27].

It is important to assess all the risks that might be introduced by the proposed intervention. These risks can include things like health and safety risks and loss of production [27].

Production is the driving force behind industrial and mining processes. A production loss results in the loss of income. Production losses will be evident if load-shifting is implemented without considering all the possible influences of such load-shifting measures. It is therefore very important to determine production losses before DSM intervention [27].

A major benefit of TOU tariffs is the cost savings achieved when taking part in load-shifting initiatives. The simulation model must also determine the electrical cost savings that will be realised from the proposed intervention.

Simulation models can be used to determine the effects on production. An accurate simulation model would take all the relevant constraints and variables into consideration to model the effects of certain inputs. Things like electricity tariffs, production profiles, process limitations, and buffer systems are all important information that must be considered when developing simulation models. [41]

The simulation model must also calculate the electricity usage profile for the proposed load-shifting intervention and must then compare it with the baseline profile to determine possible cost savings. The information that is needed to determine the electricity cost savings and the amount of load-shifting achieved are the following [45]:

- Electricity usage before the proposed intervention
- Installed electrical capacity of the system
- Electrical energy required to convey a certain amount of material at a proposed transport rate and distance
- Tariff charges paid by the customer

Many production processes and operations are in operation 24 hours a day. This leaves little room to shift electrical load out of Eskom peak times. In some systems it is possible to model the effects of load-shifting throughout an entire month in daily intervals.

Certain systems have enough storage capacity available to sustain a shutdown of the feeding or the extraction part of the system for several hours at a time. The critical levels of such a system will not be easily affected by a shutdown of two to three hours for DSM purposes. Daily shutdowns for DSM purposes might however impose critical levels after a few days or even weeks [36].

The influence of DSM on systems with large storage capacities can be simulated on a daily basis since lost time can be made up over weekends when the cost of electricity is much less than during the week [36]. The conveyor systems used in this study has limited storage facilities that made the introduction of DSM more complicated. Most of the storage facilities will only support production for a few hours. This implies that the simulation models must modulate the system on an hourly basis

The simulation model used in this study was developed to modulate the bunker levels in hourly intervals to make sure that they are kept between their maximum and minimum operating levels. Different maximum bunker levels were used as variable constraints to obtain different running schedules for the conveyor belts. Various running schedules were obtained from these simulation models.

3.3 Simulation procedures

The need to use simulation models were identified when it was realised that DSM might influence production on conveyor belts. The core use of the simulation model is to simulate the bunker levels of the system and to determine the electrical power usage on an hourly basis.

The simulation of the bunker levels will give an indication of the influence of DSM on production. Load-shifting would be proved possible if the bunker levels are kept between the minimum and maximum levels. The amount of load that can be shifted from peak times must also be calculated for every scenario. This information will then determine the feasibility to implement DSM on the system.

The simulation model must, therefore, simulate the bunker levels, give a prediction of the electricity cost savings and indicate the amount of load that will be removed from the peak period.

A typical conveyor system was described in chapter 2 and can be seen in figure 19. The possible focus areas for load-shifting in this system were discussed in chapter 2. Conveyor section 2 was identified to have the best possibility for load-shifting in this system due to the presence of storage capacity before and after the conveyor section.

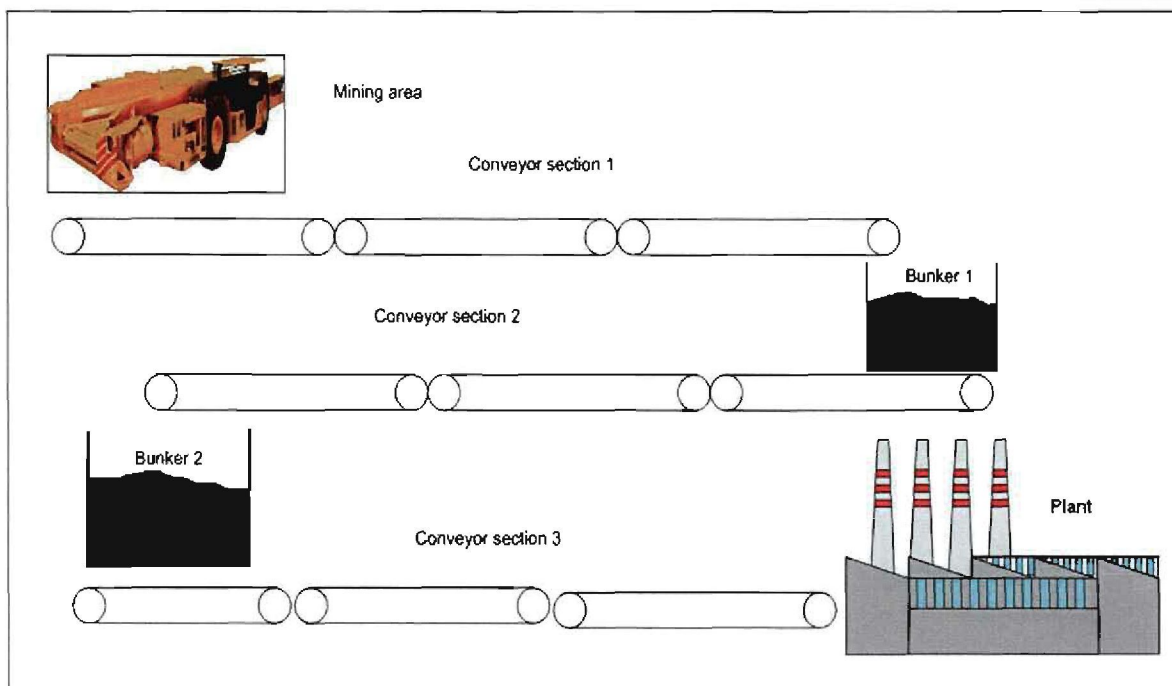


Figure 19 – Conveyor belt configuration with storage capacity between conveyor sections

Management of bunker levels will surely play a significant role when implementing load-shifting on conveyor systems. It was identified during the investigations at the coalmines that bunker levels are influenced by the following key factors:

- Bunker capacity
- Haulage rates into and out of the bunkers
- Conveyor belt availability
- Running schedule of the belt

The simulation model must use these key factors as fixed constraints to evaluate the effects of any load-shifting intervention. Production parameters will be used as input parameters for the system. The simulation model can then be used to determine the optimum running schedule for the conveyor system [27].

The simulation models used in this study were developed using information that was gathered from the various coalmines, including the following:

- System layout
- Installed capacities of the electrical motors on the conveyor belts
- Maximum conveying rate on the various conveyor belts
- Conveyor belt availability
- Maximum feeding rate from the bunkers
- Maximum storage capacities of the storage bunkers
- Time required to start a conveyor section
- Production targets set per mining section
- Current electrical power usage for the conveyor belts

The current 24 hour electricity profile for the conveyor system will give an indication of the present operating procedures. This electricity profile before the implementation of load-shifting initiatives is often called the baseline [27] [45].

The profile obtained after load-shifting intervention can then be compared to the baseline profile and can be used to calculate the results achieved. Results that are of key importance is the electrical cost savings achieved as well as the amount of electrical load that was removed from the peak times [45].

The simulation model was developed to determine the best conveyor schedule for optimum load-shifting and cost savings. All of the constraints relevant to the load-shifting interventions were taken into account in the simulation model. A simplified flow diagram of the operation of the simulation model can be seen in figure 20.

The flow diagram in figure 20 indicates the basic operation of the simulation model. The simulation model uses certain inputs to simulate the bunker levels. By changing the running times during which the conveyor belts must be operational, the conveyor belt schedule is optimised. The bunker levels for the specific conveyor belt schedules are simulated to determine if the bunker levels exceed their maximum usage levels.

The conveyor belt schedules were changed along with maximum bunker usage levels. The conveyor schedule that resulted in the lowest operating times during peak periods was taken as the preferred schedule for the specific maximum bunker usage level. However, the bunker level must always be below or equal to the maximum bunker usage level.

The electrical cost savings incurred for the specific conveyor schedule is calculated using the Megaflex tariff structure. The amount of electrical load removed from the peak periods is also calculated for the proposed conveyor belt schedule.

A baseline electricity profile must be obtained to determine the electrical power consumption before the implementation of a DSM project. This baseline will be used to measure the savings that is realised as a result of the DSM interventions. The baseline must meet certain criteria to be accepted by the M&V-company that will verify the savings [45].

Simulation of conveyor systems

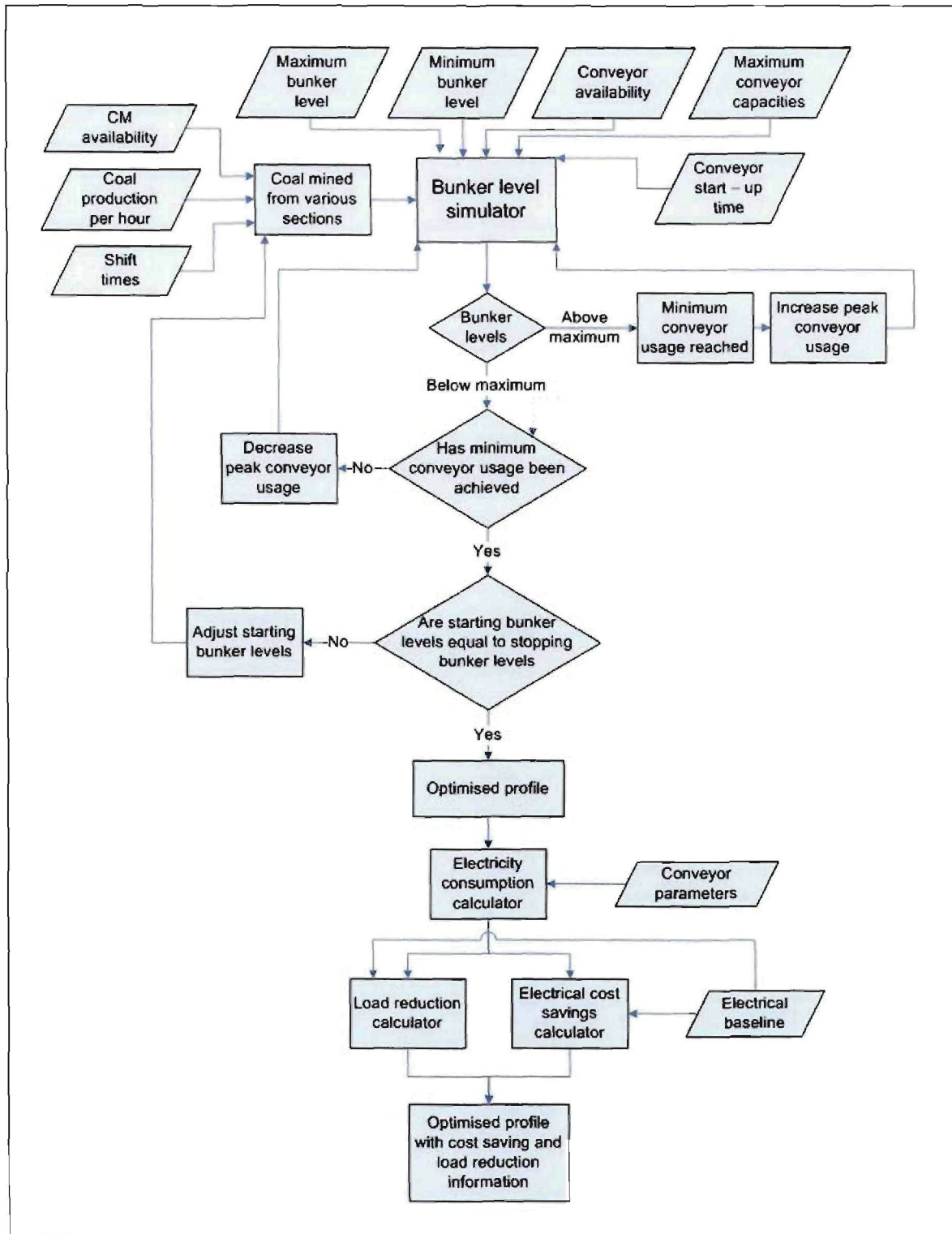


Figure 20 – Flow diagram of a load-shifting simulation for a conveyor system

The following four points are ways of obtaining the baseline for energy savings according to the International Performance Measurement and Verification Protocol Committee (IPMVP) [46]:

1. Option A: partially measured retrofit isolation

This option is used when the equipment affected by the energy conservation measure can be partially isolated from the rest of the facility. The measured values will include the measurement of other equipment that does not form part of the energy conservation measures. Certain parameters might be stipulated rather than measured.

The effects of other equipment or parameters that does not form part of the energy conservation measures must be accounted for. It must also be proved that the effects of the other equipment will not influence the reported savings.

2. Option B: retrofit isolation

The procedures for the partially measured retrofit isolation are similar to the procedures of the retrofit isolation. The main difference between option A and option B is that there may be no stipulations when using option B. This means that the measurement must only be applied to the equipment affected by the energy conservation measures.

3. Option C: whole building

Utility meters or whole building sub-meters are used to measure energy consumption of an entire building. This option will give an indication of the impact of any energy conservation measures that are applied to the building. Individual measures can not be determined when this option is used. This option is normally used when the installation of dedicated meters are too expensive for the application, or in the case of high interaction between various energy conservation measures

4. Option D: calibrated simulation

This option makes use of computer software to predict the energy use for the pre-implementation, and/or the post implementation energy conservation measures. The simulation model must be calibrated to so that the predicted consumption would match the actual consumption of the equipment with sufficient accuracy. This option may be used when sufficient baseline energy consumption values are not available for the equipment in question.

Any of the above-mentioned methods may be used to determine a baseline for a DSM initiative, provided that it meets all the necessary criteria set by the M&V-company. The electricity consumption of the conveyor belts must be available for a 24-hour profile, logged in at least hourly intervals. It is important to gather enough data to obtain a good representative baseline for the normal operation before DSM interventions [45].

Historical data was available from the SCADA systems at the coalmines considered for this dissertation. This data proved to be sufficient to determine the baseline energy usage.

It was realised during the development of the simulation model that it would be necessary to calculate the power consumption of the conveyor belts for certain running schedules. A relationship between the power consumed and the amount of material conveyed was required to calculate the power consumption of the belts for the proposed running schedule.

A proposed concept to calculate the power consumption of a conveyor belt is to make use of various conveyor parameters. A conversion model that calculates the power consumption of a conveyor belt based on parameters like the friction between components, the mass of moving parts, and length of the belt was used in the load optimisation study that was described earlier. [41]

The above mentioned concept divided the power consumption of a conveyor belt into the following components:

- Power to run the conveyor belt without material
- Power to move the load horizontally
- Power required if skirt boards are used
- Power to move the load vertically [41]

The power to run an empty conveyor can be calculated by making use of the following formula [41]:

$$P_{EC} (kW) = \frac{gCQ(L + L_o)}{1000} \quad (1)$$

where:

g = Gravitational acceleration = 9.8 m/s²

C = Friction factor

Q = Factor that represents the mass of the moving parts of the conveyor from centre to centre distance (kg/m)

L = The centre to centre distance or the horizontal projection of the distance for incline or decline belts (m)

L_o = Compensation length constant or terminal friction independent of conveyor length (m)

It was seen in equation 1 that power is required to overcome friction, rotate the conveyor parts, and to move the empty belt. The power consumed by the conveyor belt during no load conditions can be attributed to various losses and can be both mechanical and electrical. Mechanical losses include inefficiencies in the gearbox, motor, idler pulleys, drive drums, etc.

Electrical losses include normal motor inefficiencies and can be worsened by over or under designed motors in the specific application. The loading on the belt may influence some of these losses, but most losses are fixed for the specific conveyor system regardless of the load.

The conveyor belt will consume additional electricity to transfer material. The power consumed to transfer material a certain height and distance can be calculated by using the following equations.

The power to move material horizontally can be calculated using the following formula [41]:

$$P_h (kW) = \frac{gC(L + L_o)T}{3600} \quad (2)$$

where:

T = Transfer (ton/hour)

Additional power will be required to move the material if the conveyor belts have skirt boards. The power required to overcome the friction of the skirt boards can be calculated with the following formula [41]:

$$P_s (kW) = \frac{0.2gd^2 LMS}{1000} \quad (3)$$

where:

M = Material density

d = Load depth

The power required to lift the load or the power that can be generated to lower the load can be calculated with the following formula [41]:

$$P_l (kW) = \frac{gTH}{3600} \quad (4)$$

where:

H = net change in elevation

The total amount of power required to convey the material can be obtained by adding all the above mentioned power components together. The coalmines that were investigated in this study had up to 26 main belts at one mine. It would be a difficult task to obtain all the parameters required by the above mentioned equations. Another method that proved to be less time consuming was found and will be described next.

The energy efficiency effect of motor sequencing controllers on conveyor belts was discussed briefly in section 1.4. The aim of the study was to determine the amount of electricity savings achieved on conveyor belts by making use of motor sequencing controllers [39].

The electrical cost savings achieved with these controllers were determined by an M&V-company. The partially measured retrofit isolation method was used to develop a baseline for the study. The M&V-company made use of the relationship between the power consumption of the conveyor belt and the material load on the conveyor belt [39].

The relationship between the electricity consumption of the conveyor belt and the load as determined by the M&V-company can be seen in figure 21. The consumption for a certain load on that specific conveyor belt can be calculated by using the following formula [39]:

$$\text{kWh} = 0.0801 \times \text{Ton} + 38.031. \quad (5)$$

Regression analysis was used to develop the baseline [39]. The regression method used by the M&V-company was changed to be used for the various conveyor belts considered in this study [39]. Historical data was used to determine the relationship between the material flow and the power consumption of one of the conveyor belts used by a case study. The relationship for a 24-hour period for one of the conveyor belts studied can be seen in figure 22.

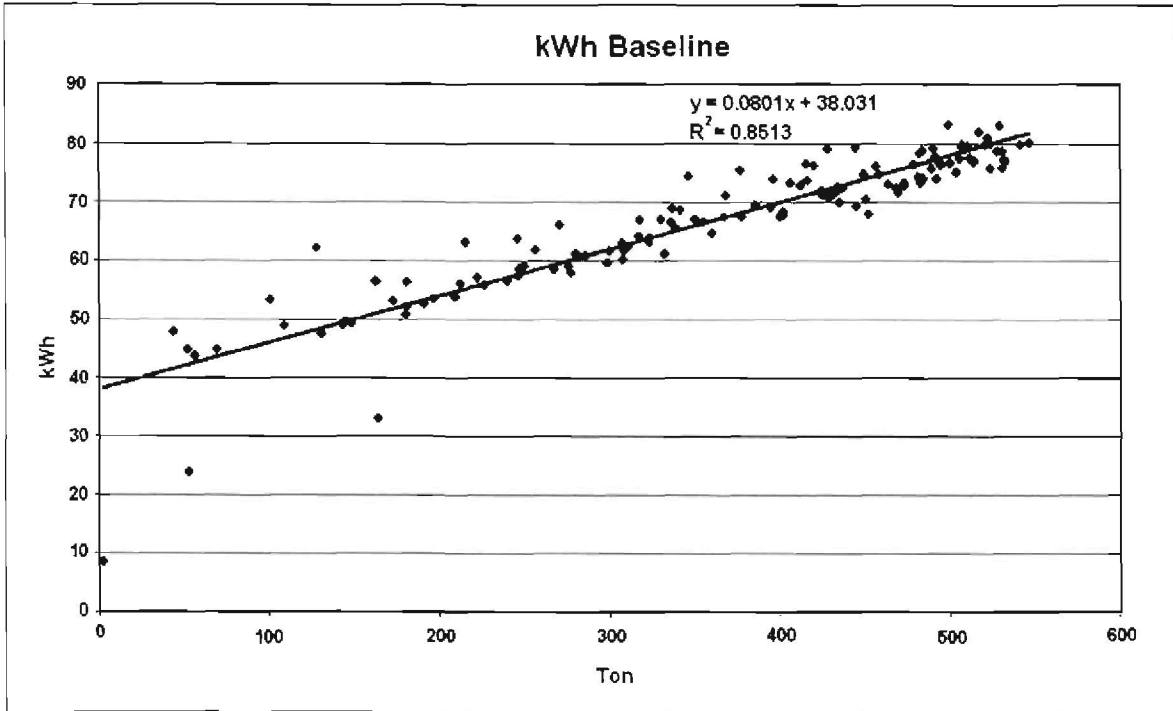


Figure 21 – Relationship between the electrical consumption of a conveyor system and the load on the belt [39]

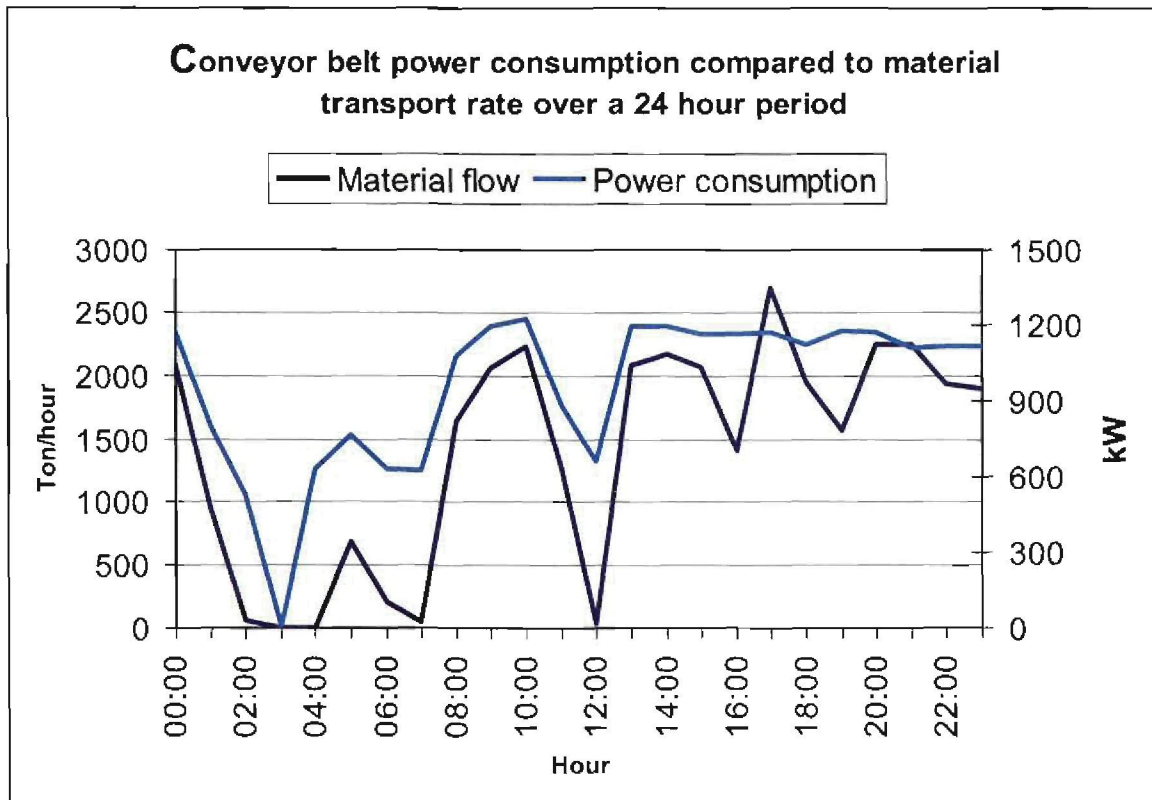


Figure 22 – Conveyor belt power consumption compared to material transported over a 24-hour period

It can be seen in figure 22 that there is a relationship between the power consumed by a conveyor belt and the amount of material that is conveyed over a 24 hour period. It can also be seen in the figure that the conveyor belt consumes a considerable amount of power to move an empty conveyor belt. This can be seen at 02:00, 07:00 and 12:00 where about 800 kW is consumed to move the empty belt.

The relationship between the material conveyed and the power consumed by the conveyor belt over a wide range of conveying rates can be seen in figure 23. It is clear in the figure that power is consumed even when no material is being transported. This confirms the previous observations that the conveyor belt uses a considerable amount of power even when empty.

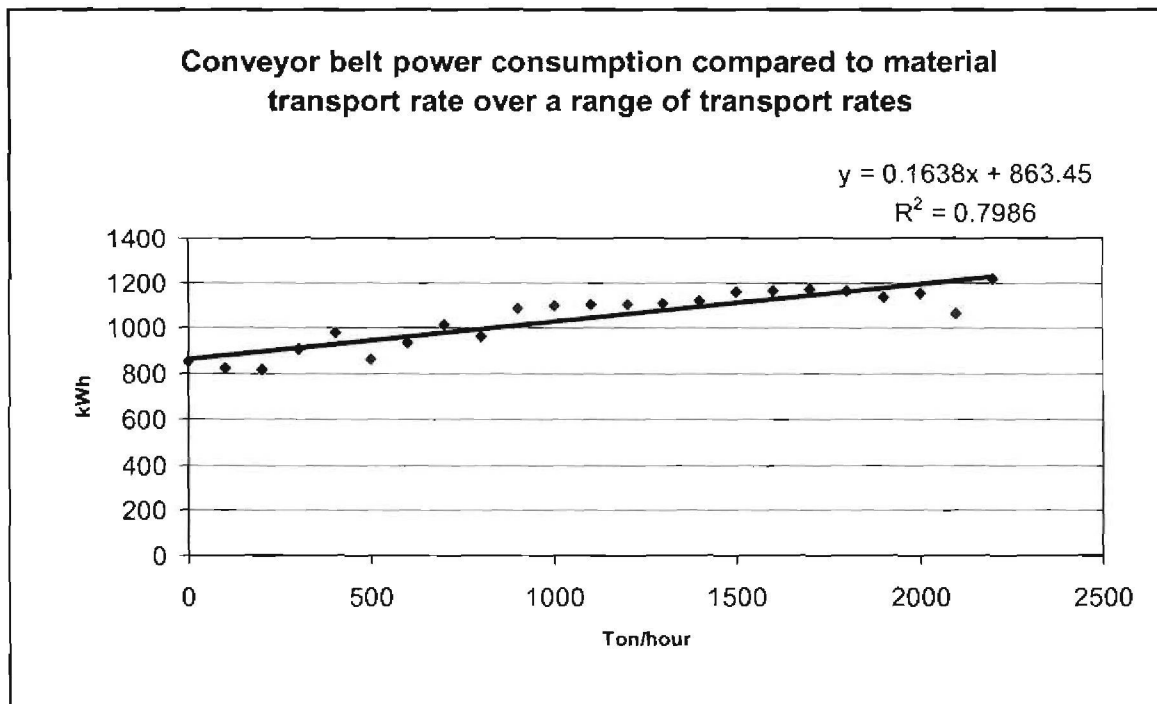


Figure 23 – Conveyor belt power consumption compared to material transport rate over a range of transport rates

The power consumption for the specific conveyor belt can be estimated by the following formula:

$$\text{kWh consumption} = 0.16382 \times (\text{ton/hour}) + 863.45 \quad (6)$$

The various parameters that influence the relationship between the power consumption and the material conveyed will be different for every conveyor belt. This is due to the fact that the conveyor belt can vary in length, width, and the belt may be inclined, declined or level. The idlers, pulleys, driving drums, gearboxes electrical motors, coupling devices etc. are all factors that will influence the power consumption of conveyor belts and can differ between various belts.

The power consumed by conveyor belts will therefore vary from one belt to the other. All of these factors will be evident in the baseline electrical power consumption of the conveyor belt. These factors will automatically be considered when the historical data is used to characterise the conveyor belt. Historical data was used to determine the relationship between the power consumed and the load that is transported for every belt in this study.

All of the assumptions made in developing the simulation procedures must be verified to determine the accuracy of the simulation model. The verification process is, therefore, very important and will be discussed in the next section.

3.4 Verification of the simulation model

The accuracy of the simulation model must be verified to ensure that the model will accurately modulate the effects of the different load-shifting scenarios. Simulation models can be verified using different procedures. One of these procedures would be to compare the results obtained from the new simulation model with results obtained from previously verified simulation models.

No simulation models were however found to be similar to the systems used for the case studies. The parameters required by the simulation models used by Marx were not available and could thus not have been used [41]. This eliminated the possibility of verifying the simulation model by making use of previously verified simulation models.

Another way of verifying a simulation model would be to monitor the output of a system in real time under certain set conditions. These conditions can be used as input variables for the simulation model. The results obtained from the model can then be compared to the actual real time results. The difference between the modulated output and the actual output can then be used to give an indication of the model's accuracy.

The above-mentioned procedure would be an ideal opportunity to verify the simulation model. The risks involved in using the above-mentioned procedure were found to be high for the coalmines considered in this study. This called for the use of another method of verifying the simulation.

This simulation model was verified using historical data from one of the case studies investigated during this study. The mine provided data that included material flows, bunker levels and power consumption data. The data was extracted in one-minute intervals from the SCADA systems. The hourly averages were calculated and used as input data for the simulation model.

The accuracy of the bunker level measuring equipment and the flow-rate meters on the conveyor belts are not known. The inaccuracy of this measuring equipment reflected in the verification of the simulation models.

The material flow rates were fed into the simulation models. The bunker levels obtained from the simulation model were compared to the actual bunker levels obtained from the data. A comparison between the calculated bunker levels and the actual bunker levels can be seen in figure 24. The average error between the simulated bunker levels and the actual bunker levels were in the order of 15%. This proved to be efficient enough considering that the bunker level and flow rate measuring equipment can't be 100% accurate.

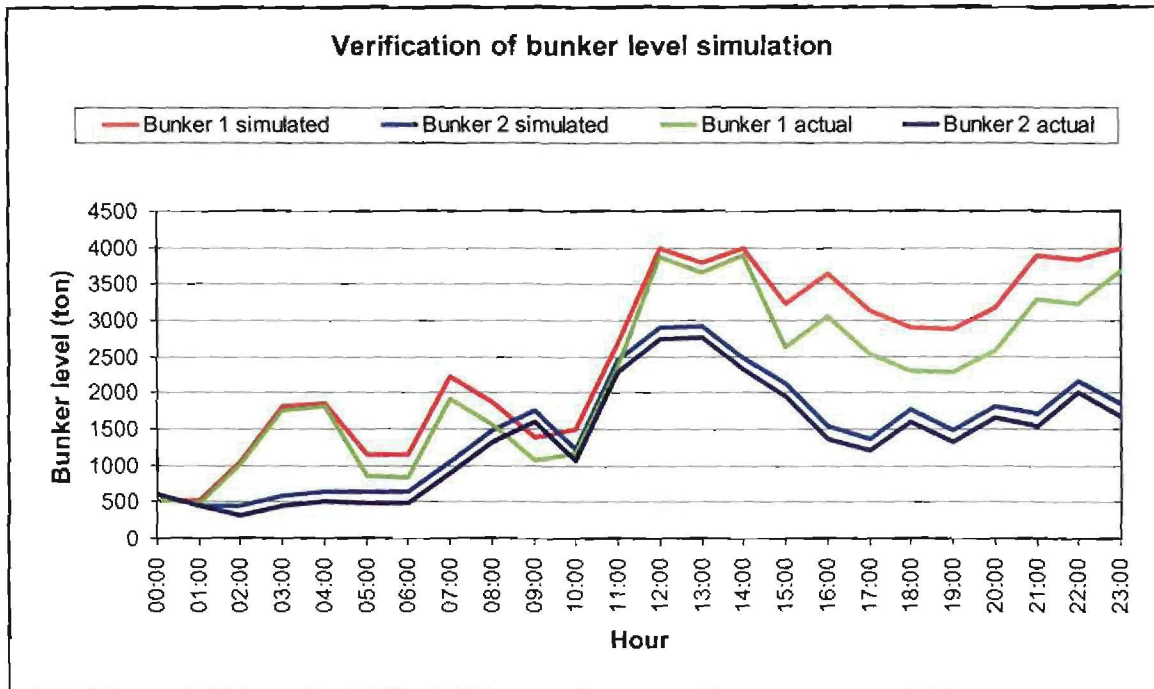


Figure 24 – Bunker levels during simulation verification

The electrical consumption of the conveyor belts was calculated using the simulation model. The calculated consumption was compared to the electrical consumption obtained from the retrieved data to determine the accuracy of the calculations. A comparison between the calculated power consumption and the actual power consumption can be seen in figure 25.

A big difference between the calculated electrical consumption and the actual electrical consumption is evident at 02:00 and 06:00 in figure 25. The following discussion will give an explanation for the big difference at the two time slots.

It is known that the conveyor belts at this coalmine will not be automatically stopped when running empty. The bunker levels are controlled by activating or deactivating the feeders that feed the material from the bunkers to the conveyor belts. The conveyor belts can then run empty for hours on end without any coal on the belts. This is very inefficient due to the unnecessary electricity that is consumed by the conveyor belts under no load conditions.

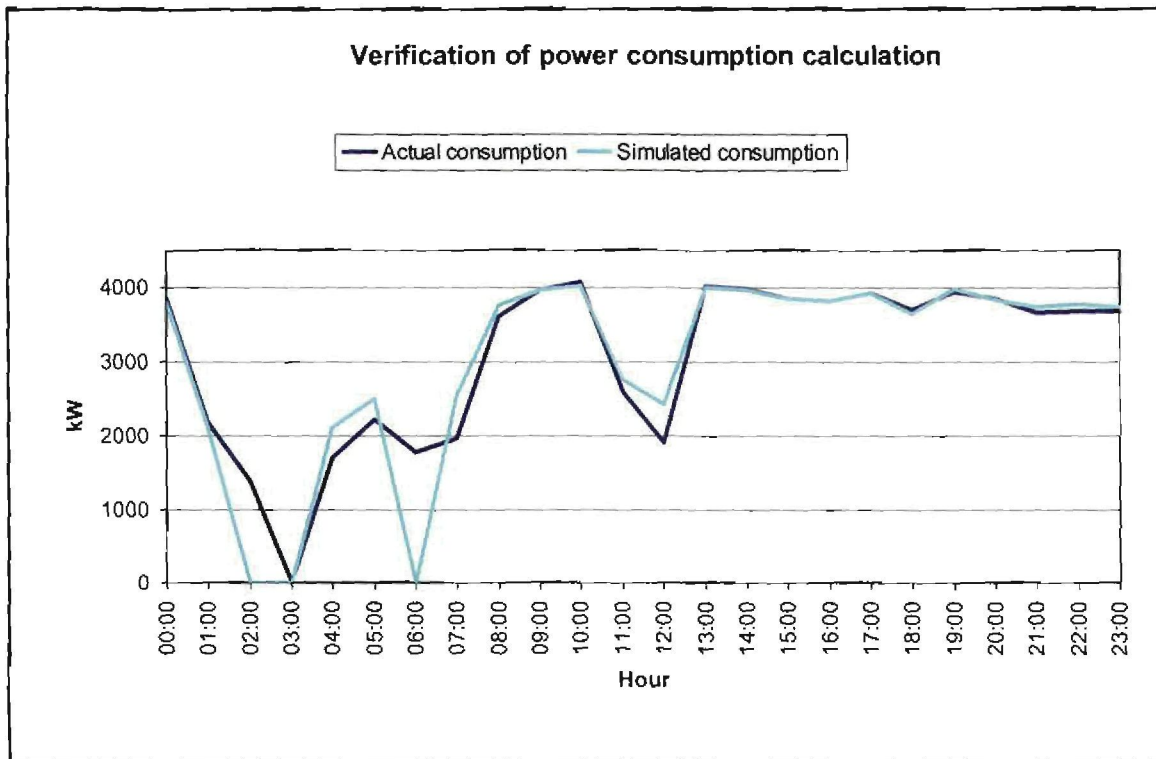


Figure 25 – Verification of power consumption calculation

The simulation models used in this study simulates that the conveyor belt will be switched off when no coal is transported for more than 30 minutes. This implies that there might be situations in the verification process where the simulation models predicts that a conveyor belt will be off where it will in fact be running empty.

The fact that the conveyor belt is empty at those times can be verified by the fact that the bunker levels are increasing at the same time slots in figure 24. The same phenomena were observed in figure 25 and figure 26, where the flow-rates were zero but power was still consumed by the conveyor belts.

The historic data indicated that the conveyor belts consumed about 20% of their installed power when running empty. These empty running consumption values were used to replace the values at 02:00 and 06:00. The result of this compensation can be seen in figure 25.

The average error between the actual electrical consumption and the calculated electrical consumption was calculated to be in the order of 14% when the empty running conditions were compensated for. The simulation model was proved to give an accurate representation of the bunker levels and the electrical consumption for any given material flow input.

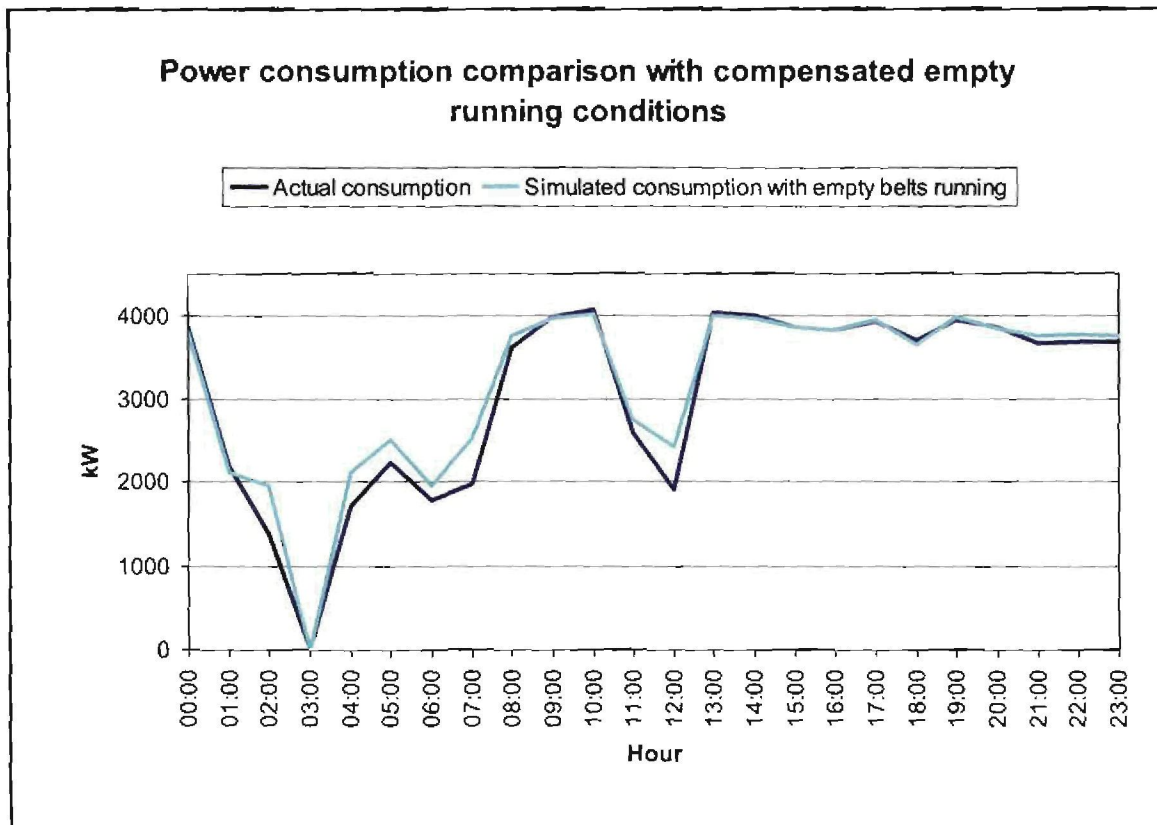


Figure 26 – Power consumption with compensated empty running conditions

The effects on the bunker levels for various load-shifting schedules can, therefore, be determined by making use of the simulation models. The amount of electrical load that can be moved from the Eskom peak times can also be determined with the simulation model.

3.5 Benefits of new simulation model

It was verified that the new simulation can accurately represent the bunker levels and the electrical power consumed by the conveyor systems. The simulation models can, therefore be extended for use in various conveyor belt applications to simulate load-shifting interventions on the systems. The simulation model can use actual production figures as inputs to simulate the bunker levels and electrical power consumption for different belt schedules.

The belt schedules can be optimised to reduce the electrical load during peak times, thereby decreasing electricity costs. The simulation model will calculate the electrical load, predicted to be removed from peak times, and the electricity savings for a given scenario. The simulated bunker levels will give an indication of the viability of a project.

The amount of load reduced during the peak periods will determine the amount of funding made available by Eskom to pay for infrastructure costs to upgrade the system. The amount of cost savings applicable for a certain scenario will serve as an incentive to the client to implement the proposed load-shifting interventions.

The simulation model can be used to determine load-shifting possibilities on conveyor systems. This simulation model can be adapted to simulate other conveyor belt systems and also other systems that use the same operating principles.

3.6 Conclusion

A simulation model was developed for conveyor belts and the mentioned simulation model was verified to give an accurate representation of the system. The simulation model can now be applied to different case studies to determine the DSM possibility on various systems.

The DSM potential at different coalmines can be determined by using the simulation models. Further investigations can be done if potential is identified on a conveyor system. System upgrades might be necessary to implement the proposed load-shifting interventions. The amount of load removed from the peak periods will determine the amount of funding that will be made available for the projects from Eskom. Different case studies will be discussed in the next chapter.

CASE STUDIES: APPLYING THE SIMULATION

Different case studies will be investigated in this chapter to identify conveyor systems with load-shifting capabilities.

4 CASE STUDIES: APPLYING THE SIMULATION

4.1 Introduction

It was identified in the previous chapters that there might be load-shifting potential on conveyor systems. A big concern regarding load-shifting on conveyor systems was the possible influence on the production of the conveyor system. This gave rise to the use of simulation models that can predict the bunker levels to prevent production losses

Chapter 3 focussed on the development and verification of simulation models to predict the influence on the production of the system. These simulation models can now be applied to the conveyor systems at different mines to determine the load-shifting possibility on these systems.

The simulation models were used to determine the load-shifting possibility on six different case studies. These case studies are coalmines in South Africa that makes use of conveyor systems to transport the coal from the mining sections to surface stockpiles and bunkers. The names of the coalmines will not be revealed in this study due to confidentiality agreements with the mines. Consequently, the mines will be referred to as Mines A, B, C, D, E, and F.

All of the above-mentioned mines were visited to investigate the DSM potential on the conveyor systems. The layout and system information was obtained from the employees of the mine. Historic data was retrieved from the SCADA systems to determine the baselines and the relationship between the conveyor belt power consumption and the transfer rates.

All of the mines that were investigated in this study operate on a 3-shift system. There are two production shifts and one maintenance shift. The first production shift is between 06:00 and 14:00. The second production shift runs from 14:00 to 00:00. Only one morning shift operates on a Saturday. This is the only mining that takes place over weekends.

The preferred shift change entails a so-called hot seat change over. One operator will hand over the machinery to the next person resulting in minimum stoppages of the machine in such a hot seat change over. Backup drivers and operators are available if a driver or operator requires a break. This produces a constant material flow to the bunker levels.

There is a daily maintenance, or preparation shift, between 00:00 and 06:00. This time is used to do planned maintenance work on the mining and peripheral machinery. It was evident from the electrical baseline that the conveyor belts run during the preparation shifts. Certain inspection work might require that the belts are running during the maintenance shift. Maintenance on certain equipment might require empty conveyor belts and/or empty bunkers.

This would require the emptying of bunkers during the preparation shift before maintenance work can commence. It might also be possible that the conveyor belts are running empty for no apparent reason. This is very inefficient and might be eliminated by better control of the system.

Coal is mined at the different collieries by making use of (Continuous Miners) CMs. A CM is an electrical machine that cuts the coal by using a rotating drum with spikes attached to it. This drum spins at a high speed when cutting coal. A picture of a CM can be seen in figure 27.

The coal that is cut from the coal surface falls on the floor underneath the rotating drum. This coal is gathered from the floor by a scraper and is then fed to a shuttle car using a conveyor. A shuttle car is an electrical car that transports the coal from the CM to a feeder breaker. A picture of a shuttle car can be seen in figure 28. A feeder breaker is used to crush the coal to smaller sizes before it is fed to section belts.

Sections belts transfer the coal from the sections to the main belts. The main belts transfer the coal to the incline belts, which move the coal to the surface. The conveyor layout differs between the various mines. The belt lengths and the drive sizes vary for every belt depending on the requirements. Bunkers and silos differ from mine to mine and will be discussed separately for each case study.

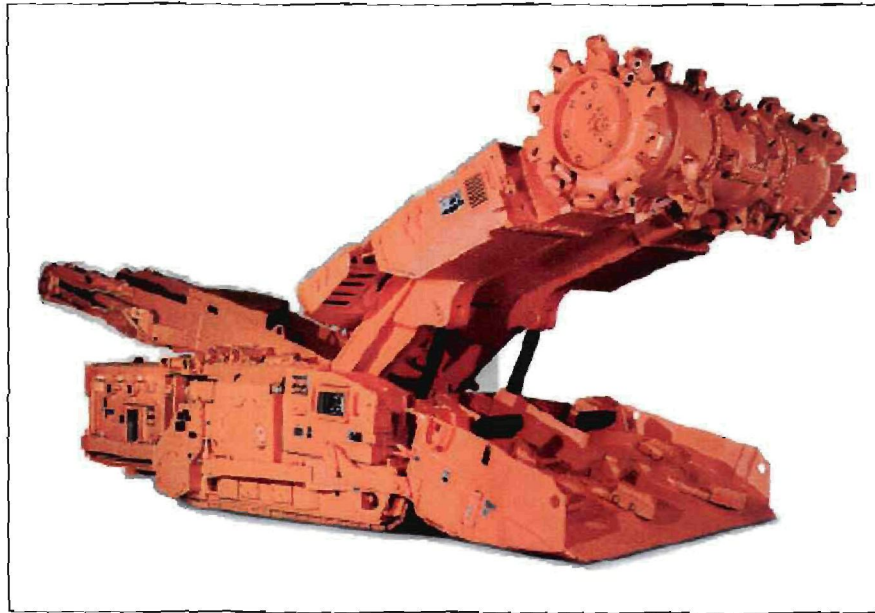


Figure 27 – Continuous Miner (CM) [47]

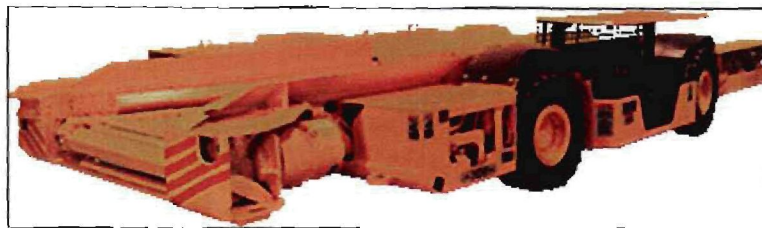


Figure 28 – Shuttle car [48]

Different maximum bunker levels were used as variable constraints to determine the savings for each scenario. These maximum levels are the maximum levels that will be used for load-shifting purposes. A minimum bunker level of 20% was used during the simulations for all of the coalmines to prevent coal breakage and damage to the feeding equipment.

The rest of the bunker capacities will be made available for unplanned breakdowns of conveyor belts or other equipment. The various maximum bunker usage levels that were used as variable constraints will be discussed separately for each case study.

The coal produced by each mine in this study is not dependant on any seasonal changes. The plant that is fed by the mines requires a constant feed of coal throughout the year. Production may fluctuate at the mines between the various days of the week. This can vary from low production due to unplanned breakdowns and very high production due to good coal cutting conditions with very few breakdowns.

The production data that was used as input is above average production where few to no breakdowns occur during any production shift. The simulation model will thus predict the silo levels for a day with above average production. A day with lower production than expected would result in increased load shift possibilities. There would thus be a margin of over performance in terms of load shift on such days. This further implies that the simulation results can be extrapolated to be valid for every day of the year and that over performance would occur rather than under performance.

The simulation is used to monitor the silo levels on hourly intervals. The silo level at the end of every hour of a day is displayed by the simulation's graphs. The silo levels at the end of the day must thus be equal to the silo levels at the start of the day to prevent material build. If these levels are equal it would prove that there will be now material build up in the silo when load shifting is applied for consecutive days. The different case studies will be discussed in the following sections.

4.2 Mine A

4.2.1 Background information

Conveyor belts with load-shifting potential can be identified by available storage capacity and process flow constraints. The various mining sections at Mine A are shown in figure 29. Production may not be stopped at any of these mining sections as a result of load-shifting measures. It is therefore important to identify possible production losses that will result due to load-shifting interventions on the conveyor belts.

The most important constraint to consider at this mine is the production at the various mining sections. Conveyor belts A13 and A14 are used to convey the coal mined at sections 1 and 2 to bunker 3. Sections 1 and 2 would have to halt production if conveyor A13 or A14 is stopped. Conveyor belts A13 and A14 must thus both be in operation while sections 1 and 2 are in production.

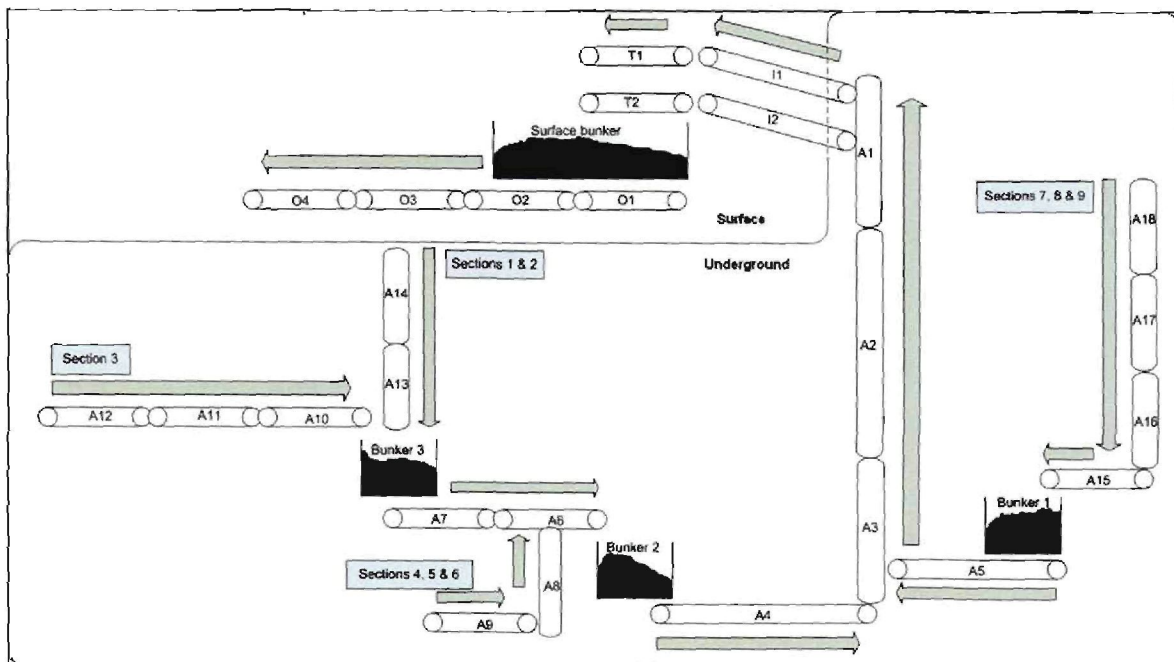


Figure 29 – Conveyor system layout at Mine A

Conveyor belt A7 has the possibility of load-shifting, because bunker 3 precedes it. Conveyor belt A8 empties its load onto conveyor belt A6, Sections 4, 5 and 6 will thus not be affected by a stoppage of belt A7. Conveyor belts A10, A11, A12, A13 and A14 would have to be stopped as soon as bunker 3 reaches its capacity. Uncontrolled stoppages of conveyor belt A7 would result in bunker 3 reaching its maximum capacity and would then result in the stoppage of sections 1, 2 and 3. The effects on bunker 3 due to load-shifting on conveyor A7 must be simulated to determine conveyor belt A7's load-shifting capability.

There are 22 main belts at Mine A. A process of elimination must be used to identify the conveyor belts with load-shifting potential. The available storage capacities and conveyor transfer rates were analysed for the conveyor system of Mine A. The bunkers with their capacities are summarized in table 2. The conveyor belts that were identified to have load-shifting possibility are summarized in table 3.

Bunker name	Bunker capacity (ton)
Bunker 1	4,000
Bunker 2	3,000
Bunker 3	4,000
Surface bunker	12,000

Table 2 – Bunker capacities at Mine A

The surface bunker at Mine A has a maximum capacity of 12 000 ton. The coal transport rate from the surface bunker is 2,200 ton/hour. The surface bunker is normally only emptied over weekends. This is due to the constraints of the overland conveyor system. Conveyor belts O1, O2, O3 and O4 are some of the overland conveyors that run from Mine A and are not controlled by the mine.

It is not unusual for the surface bunker to get filled to maximum capacity during normal mining operations. The extra coal is stored on stockpiles adjacent to the surface bunker. It is not likely that the implementation of load-shifting on the underground belts will result in low surface bunker levels.

Conveyor belt	Conveyor capacity (ton/hour)	Installed electrical capacity (kW)
T1	1,500	150
T2	1,500	150
I1	1,500	1,200
I2	1,500	1,200
A1	3,000	1,680
A2	3,000	1,120
A3	3,000	2,240
A4	2,400	440
A5	3,000	440
A7	2,400	1,120
Total		9,740

Table 3 – Mine A conveyor information on relevant conveyor belts

The simulation model developed in chapter 3 was adapted to be specific for Mine A. The simulation model was changed according to the conveyor system layout taking all the conveyor capacities, bunker sizes, and other constraints into consideration.

Production information was gathered as input for the simulation model. There are 9 coal-producing sections at Mine A. Each section produces an average of 2,000 tons per shift. The amount of coal per hour varies according to the distance between the section conveyors and the CM. The distance travelled by the shuttle cars can be significant resulting delays at the CM. This would lower the production at that specific section.

It was, however, observed that average hourly production values could be used to simulate the production per section. This was due to the fact that it is very unlikely that all of the sections would be mining close to the section conveyors at the same time. A high production rate at one section would be evened out by a low production rate at another section.

The simulation model will make use of the bunker capacities and the conveyor parameters in conjunction with the system layout to simulate the load-shifting effects.

4.2.2 50% Maximum bunker usage

Only 50% of the maximum bunker capacity was used for load-shifting purposes as a first attempt at Mine A. The conveyor belt schedule for a 50% maximum bunker usage at Mine A is given in table 4.

The simulated bunker levels for a 50% maximum bunker usage for Mine A are shown in figure 30. It is evident from figure 30 that the bunker level will not exceed a 50% maximum bunker level. The belt schedule for such an intervention would result in the electrical profile shown in figure 31.

Hour	Conveyor belt schedule for a 50% maximum bunker usage at Mine A (Minutes)			
	T1, T2, I1, I2, A1, A2, A3	A4	A5	A7
00:00	60	60	60	60
01:00	60	60	60	60
02:00	60	60	60	60
03:00	60	60	60	60
04:00	60	60	60	60
05:00	60	60	60	60
06:00	60	60	60	60
07:00	0	0	0	0
08:00	60	60	30	30
09:00	60	60	60	60
10:00	60	60	60	60
11:00	60	60	60	60
12:00	60	60	60	60
13:00	60	60	60	60
14:00	60	60	60	60
15:00	60	60	60	60
16:00	60	60	60	60
17:00	60	60	60	60
18:00	60	60	30	30
19:00	60	60	0	0
20:00	60	60	60	60
21:00	60	60	60	60
22:00	60	60	60	60
23:00	60	60	60	60

Table 4 – Conveyor belt schedule for a 50% maximum bunker usage at Mine A

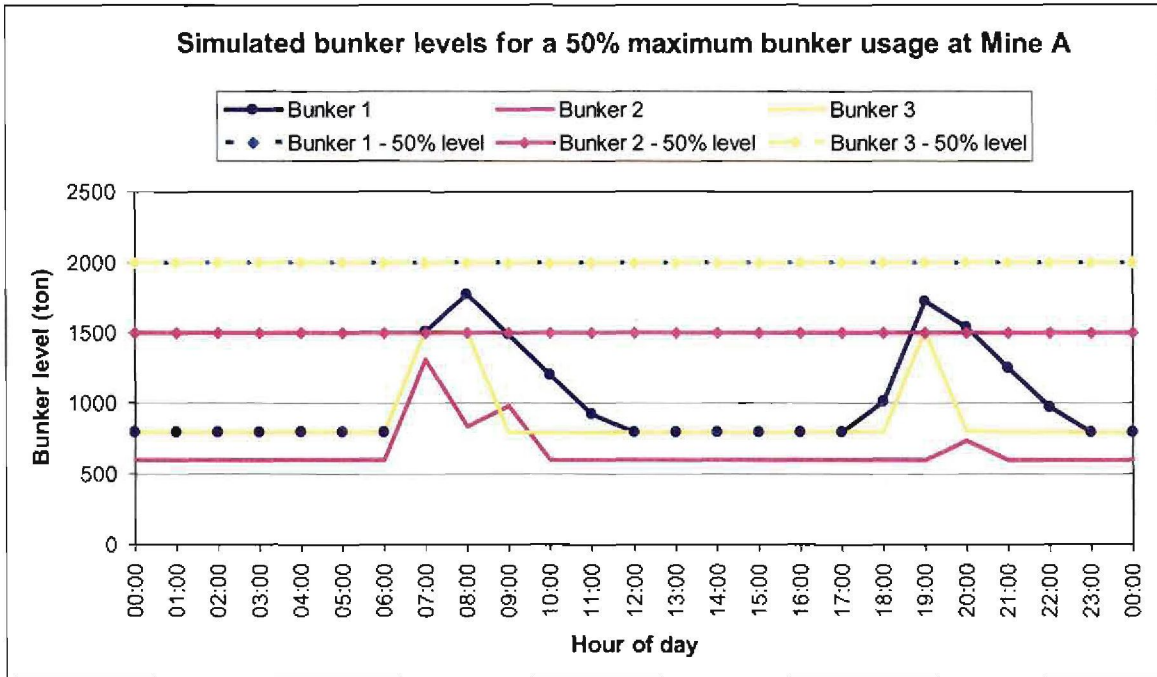


Figure 30 – Simulated bunker levels for a 50% maximum bunker level at Mine A

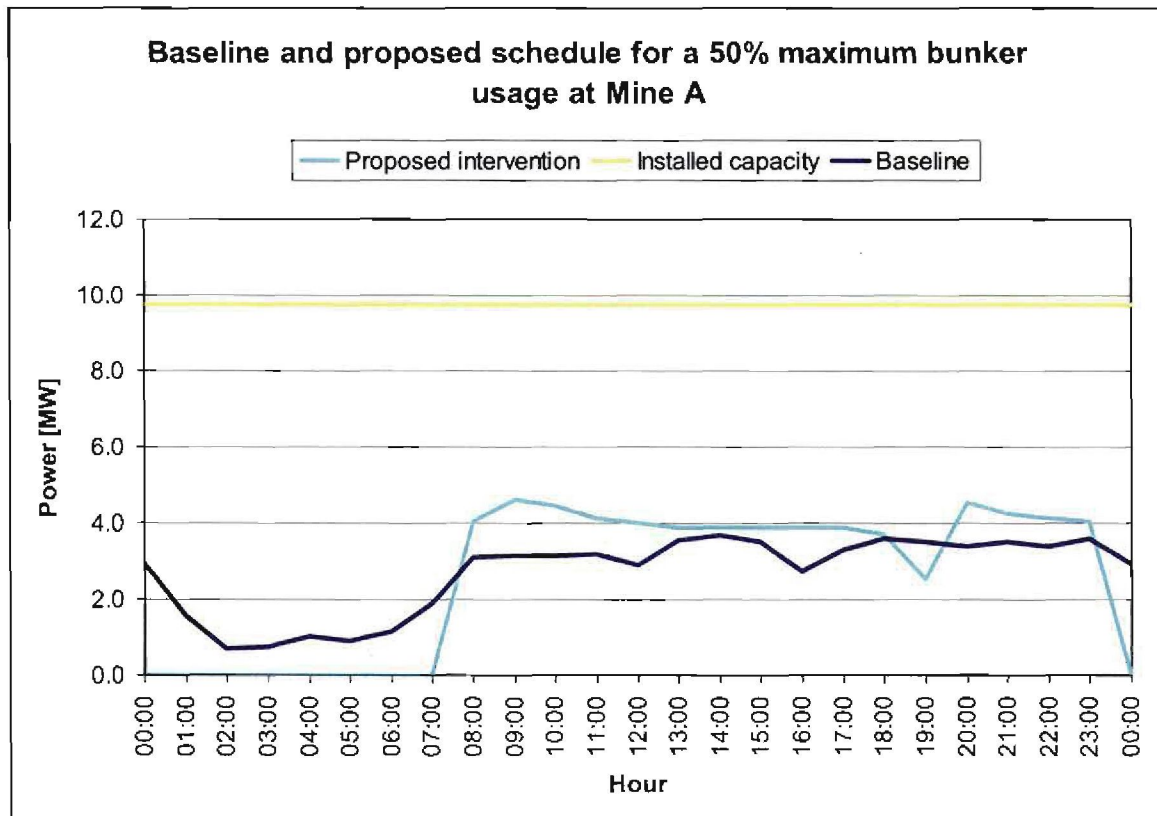


Figure 31 – Baseline and proposed intervention for a 50% maximum usage at Mine A

Only 30% of the available capacity of the bunkers is used for a 50% maximum bunker usage due to the 20% minimum bunker level that was used. It was clear from figure 30 that the maximum bunker level of 50% is never exceeded. A maximum bunker usage of 50% results in no load-shift during the morning peak but a 455 kW load-shift is achieved during the evening peak. No electrical cost savings will be achieved for such an intervention

It can further be observed from figure 30 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would thus occur if load shifting is performed on every weekday. A 50% maximum bunker usage could thus be applied for every weekday of the year and would achieve a daily load-shift of 455 kW during the evening peak.

4.2.3 60% maximum bunker usage

The maximum bunker capacity to be used for load-shifting at Mine A was increased to 60% to determine if it would be beneficial. The conveyor belt schedule for a 60% maximum bunker usage at Mine A is given in table 5. The bunker levels obtained for a 60% maximum bunker usage is shown in figure 32. The resultant electricity usage profile for this intervention is shown in figure 33.

Hour	Conveyor belt schedule for a 60% maximum bunker usage at Mine A (Minutes)			
	T1, T2, I1, I2, A1, A2, A3	A4	A5	A7
00:00	60	60	60	60
01:00	60	60	60	60
02:00	60	60	60	60
03:00	60	60	60	60
04:00	60	60	60	60
05:00	60	60	60	60
06:00	60	60	60	60
07:00	0	0	0	0
08:00	30	30	0	0
09:00	60	60	60	30
10:00	60	60	60	60
11:00	60	60	60	60
12:00	60	60	60	60
13:00	60	60	60	60
14:00	60	60	60	60
15:00	60	60	60	60
16:00	60	60	60	60
17:00	60	60	60	60
18:00	30	30	0	0
19:00	0	0	0	0
20:00	60	60	60	60
21:00	60	60	60	60
22:00	60	60	60	60
23:00	60	60	60	60

Table 5 – Conveyor belt schedule for a 60% maximum bunker usage at Mine A

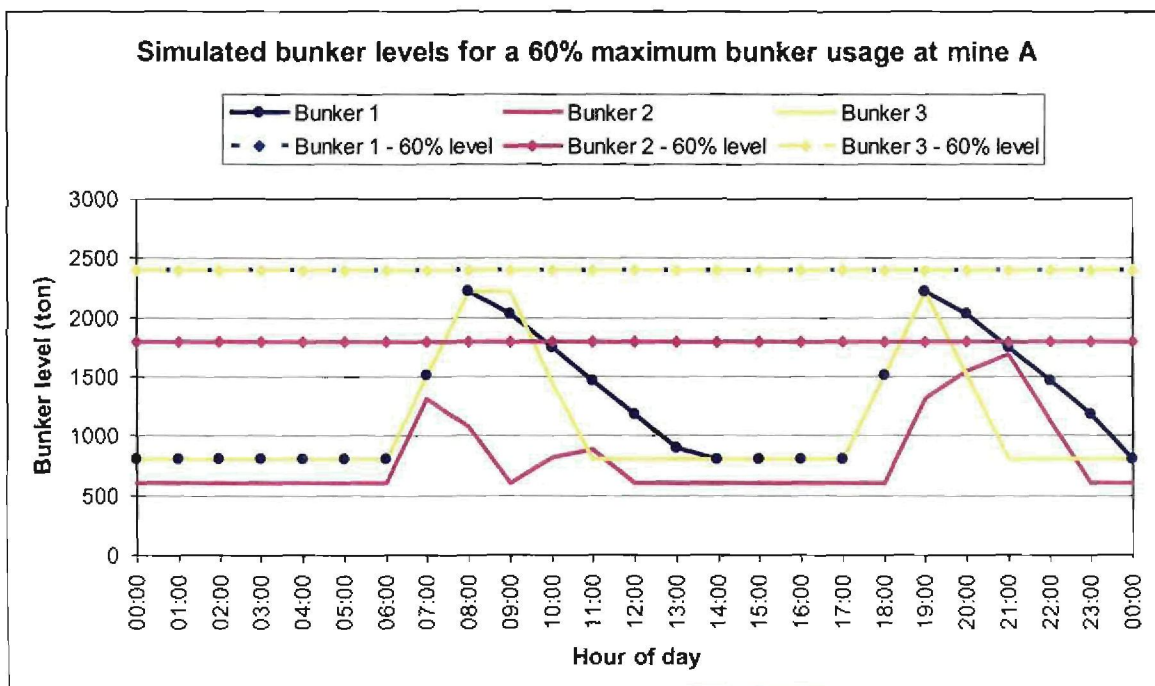


Figure 32 – Simulated bunker levels for a 60% maximum bunker usage at Mine A

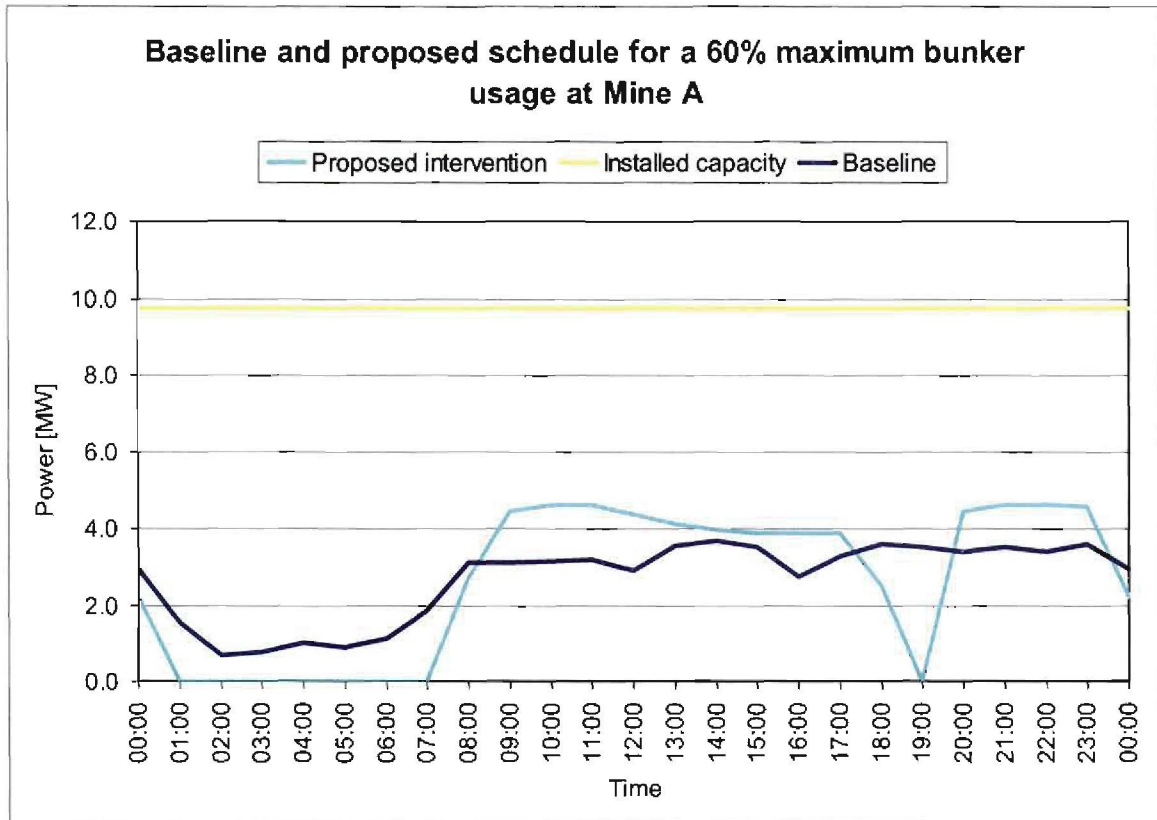


Figure 33 – Baseline and proposed schedule for a 60% maximum bunker usage at Mine A

A 60% maximum bunker usage results in a 310 kW load-shift during the morning peak and a 2,300 kW load-shift during the evening peak. The predicted electricity cost savings for such a load-shifting intervention is R 253,000 per year.

It can further be observed from figure 32 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would thus occur if load shifting is performed on every weekday. A 60% maximum bunker usage could thus be applied for every weekday of the year and would achieve a daily load-shift of 310 kW during the morning peak and a 2,300 kW load-shift during the evening peak.

4.2.4 70% Maximum bunker usage

The maximum bunker usage for Mine A was increased to 70% to determine the possible increase in electrical cost savings and load-shift. The conveyor belt schedule for a 70% maximum bunker usage at Mine A is given in table 6. The resultant bunker levels for a 70% maximum bunker usage are shown in figure 34. The predicted electricity profile for such an intervention can be seen in figure 35.

Hour	Conveyor belt schedule for a 70% maximum bunker usage at Mine A (Minutes)			
	T1, T2, I1, I2, A1, A2, A3	A4	A5	A7
00:00	60	60	60	60
01:00	60	60	60	60
02:00	60	60	60	60
03:00	60	60	60	60
04:00	60	60	60	60
05:00	60	60	60	60
06:00	60	60	60	60
07:00	0	0	0	0
08:00	0	0	0	0
09:00	60	60	30	30
10:00	60	60	60	60
11:00	60	60	60	60
12:00	60	60	60	60
13:00	60	60	60	60
14:00	60	60	60	60
15:00	60	60	60	60
16:00	60	60	60	60
17:00	60	60	60	60
18:00	30	30	0	0
19:00	0	0	0	0
20:00	60	60	60	60
21:00	60	60	60	60
22:00	60	60	60	60
23:00	60	60	60	60

Table 6 – Conveyor belt schedule for a 70% maximum bunker usage at Mine A

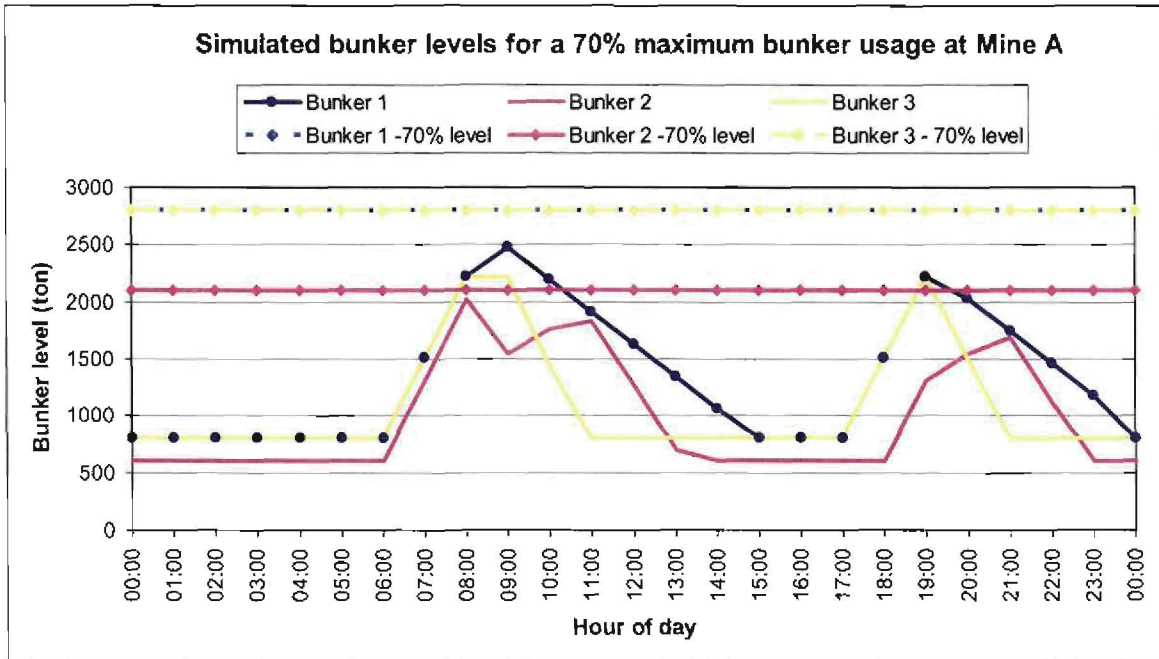


Figure 34 – Simulated bunker levels for a 70% maximum bunker usage at Mine A

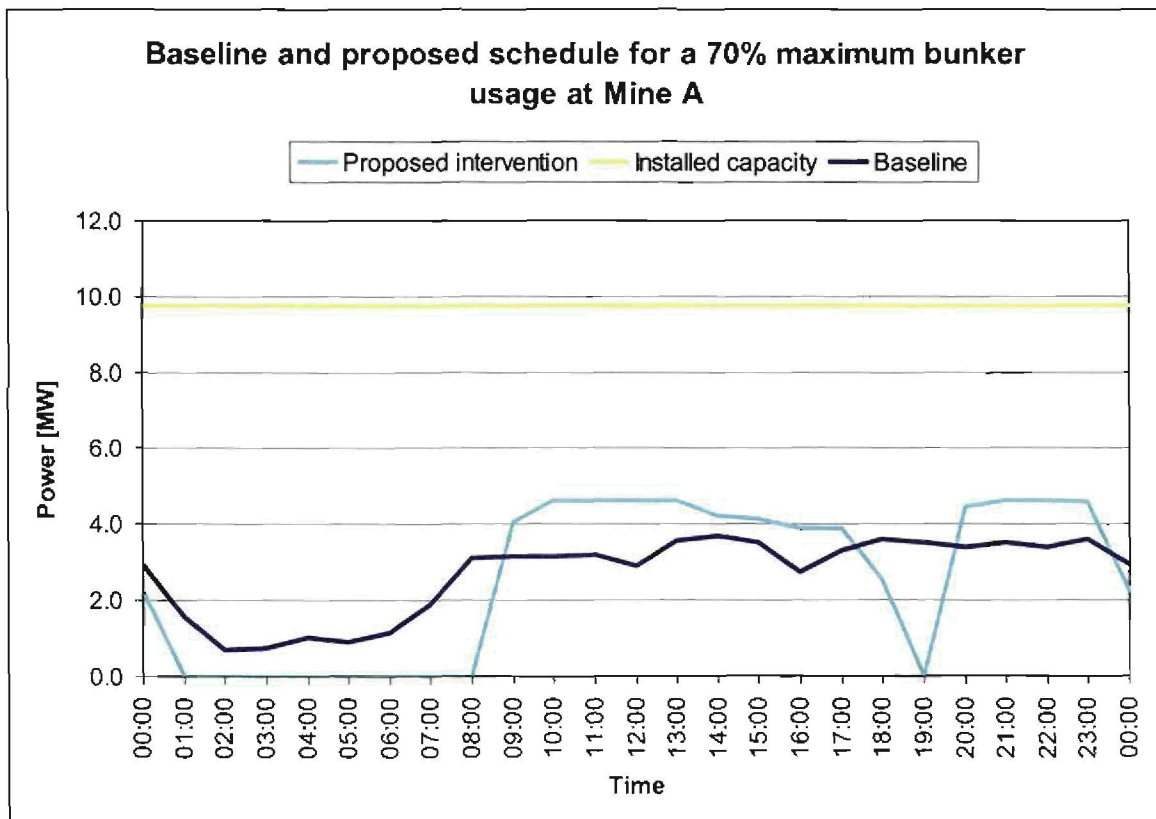


Figure 35 – Baseline and proposed schedule for a 70% maximum bunker usage at Mine A

A 70% maximum bunker usage results in a 1,300 kW load-shift during the morning peak and a 2,300 kW load-shift during the evening peak. The predicted electricity cost saving for such an intervention is R 386,000 per year.

It can further be observed from figure 34 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would thus occur if load shifting is performed on every weekday. A 70% maximum bunker usage could thus be applied for every weekday of the year and would achieve a daily load-shift of 1,300 kW during the morning peak and a 2,300 kW load-shift during the evening peak.

4.2.5 80% Maximum bunker usage

The maximum bunker level that may be used for load-shifting at Mine A was increased further to 80%. The conveyor belt schedule for an 80% maximum bunker usage at Mine A is given in table 7. The simulated bunker levels for such an intervention can be seen in figure 36. The predicted electricity profile for such an intervention can be seen in figure 37.

Hour	Conveyor belt schedule for an 80% maximum bunker usage at Mine A (Minutes)				
	T1, T2, I1, I2, A1, A2, A3	A4	A5	A7	
00:00	60	60	60	60	
01:00	60	60	60	60	
02:00	60	60	60	60	
03:00	60	60	60	60	
04:00	60	60	60	60	
05:00	60	60	60	60	
06:00	60	60	60	60	
07:00	0	0	0	0	
08:00	0	0	0	0	
09:00	30	30	0	0	
10:00	60	60	60	60	
11:00	60	60	60	0	
12:00	60	60	60	60	
13:00	60	60	60	60	
14:00	60	60	60	60	
15:00	60	60	60	60	
16:00	60	60	60	60	
17:00	60	60	60	60	
18:00	0	0	0	0	
19:00	0	0	0	0	
20:00	60	60	60	60	
21:00	60	60	60	60	
22:00	60	60	60	60	
23:00	60	60	60	60	

Table 7 – Conveyor belt schedule for an 80% maximum bunker usage at Mine A

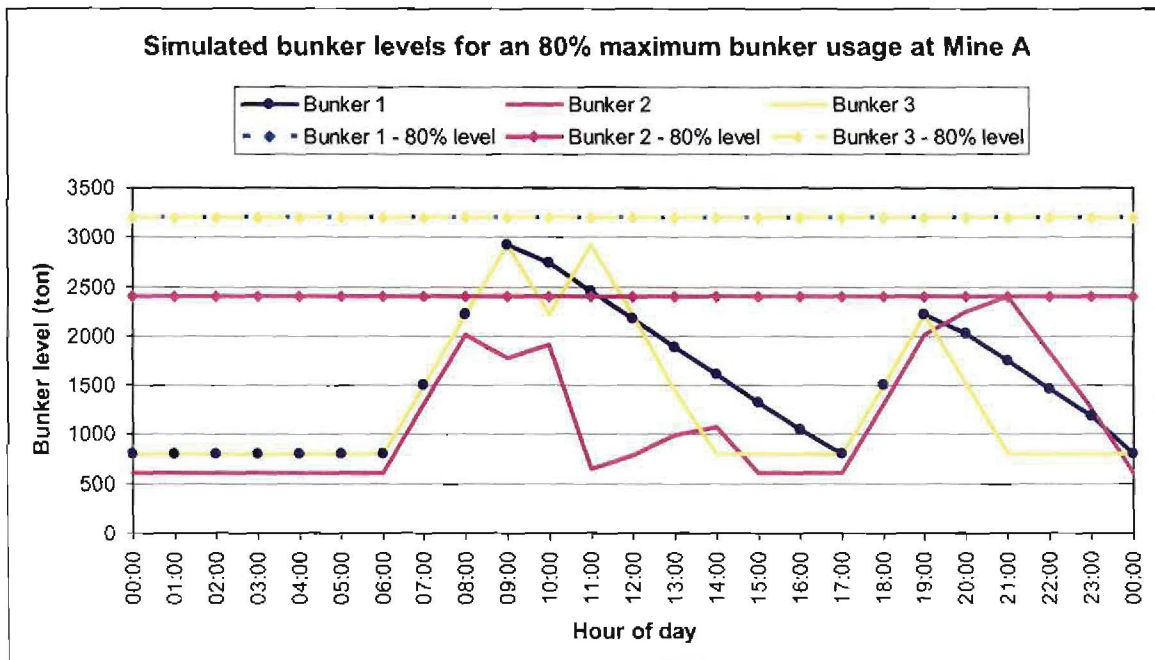


Figure 36 – Simulated bunker levels for an 80% maximum bunker usage

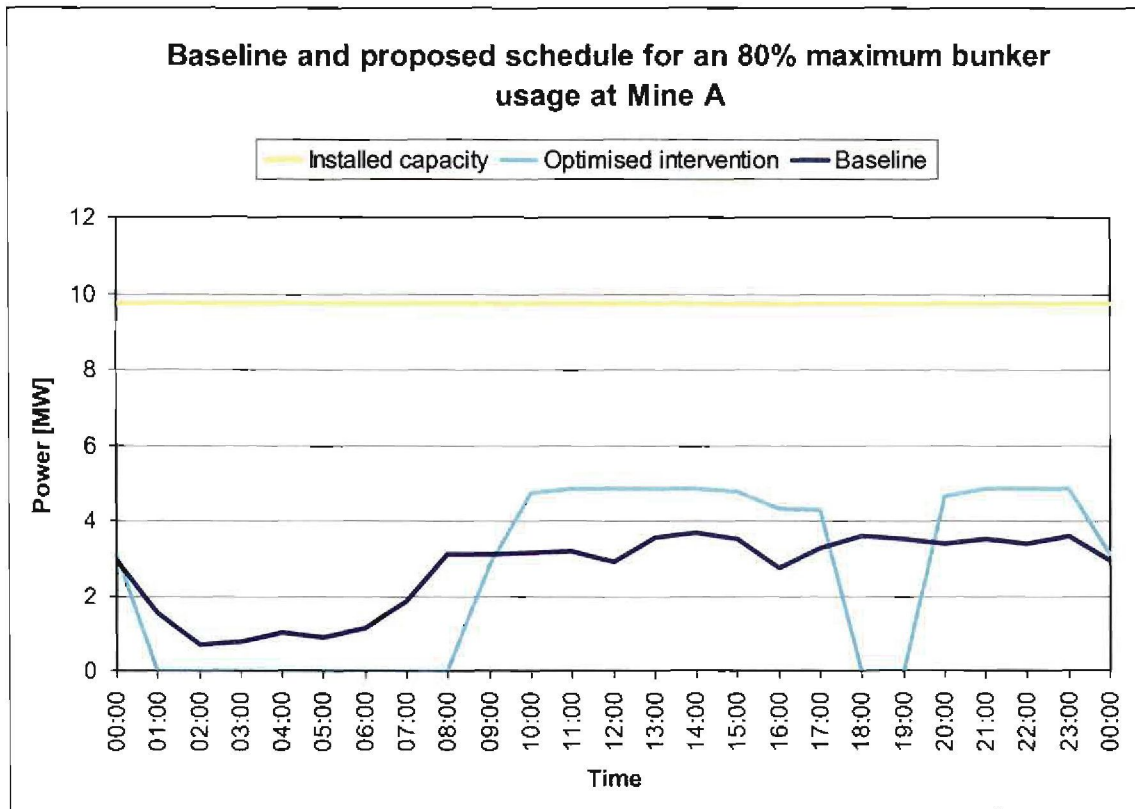


Figure 37 – Baseline and proposed schedule for an 80% maximum bunker usage at Mine A

An 80% maximum bunker usage results in a 1,700 kW load-shift during the morning peak and a 3,600 kW load-shift during the evening peak. The predicted electricity cost saving for such an intervention is R 529,000 per year.

It can further be observed from figure 36 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would occur if load shifting is performed on every weekday. An 80% maximum bunker usage could thus be applied for every weekday of the year and would again achieve an evening load-shift of 3,600 kW but with an increased morning load-shift of 1,700 kW during the morning peak.

4.2.6 Infrastructure upgrades required

The extra start-up requirements that are needed for the proposed intervention would place additional strain on the conveyor belts driven by DOL drives. It was proposed to replace the DOL drives with VSD drives. The following conveyor belts at Mine A have DOL drives installed:

- Incline belt 1
- Incline belt 2
- Conveyor belt T1
- Conveyor belt T2
- Conveyor belt A4
- Conveyor belt A5

The electrical motors that are currently used for the DOL drives operate at a voltage of 1,000V. The standard VSD drives that are installed on the other conveyor belts at this mine operate at a lower voltage of 380V. This implies that the 1,000V transformers and motors would have to be replaced with 380V transformers and motors. A motor replacement would further require the installation of a different gearbox.

An estimated price for changing the motors, gearboxes, transformers and drives on conveyor belts A4 and A5 is R 1,500,000 per conveyor belt. The cost for changing the DOL drives on the incline belts is estimated to be R 3,000,000 per conveyor. It was decided that the motors on conveyor belts T1 and T2 would not be changed to VSDs due to their small capacity. The estimated total cost for changing from DOL drives to VSDs at Mine A is R 9,000,000.

This results in a cost of R 2,500,000 per MW of load-shifted from the evening peak. This is a very expensive upgrade to make load-shifting possible and it is unlikely that Eskom would pay for such an expensive project. This was verified by a conversation with a director of an ESCO [49].

The mine did indicate that they are considering the replacement of the DOL drives with VSDs at their own cost. It would be very beneficial if VSDs are already installed before the implementation of load-shifting. The money made available from Eskom might be used to further improve the load-shifting capability of the mine by upgrading other equipment.

4.2.7 Conclusion

It is obvious that the maximum bunker usage would result in the highest electrical cost savings. The risk involved in maintaining such high bunker levels might however, outweigh the savings achieved.

A loss in production due to full bunkers would result in the loss of revenue for the mine. Figure 38 shows the relationship between the predicted electrical cost savings and the amount of electrical load that will be moved from the Eskom peak periods.

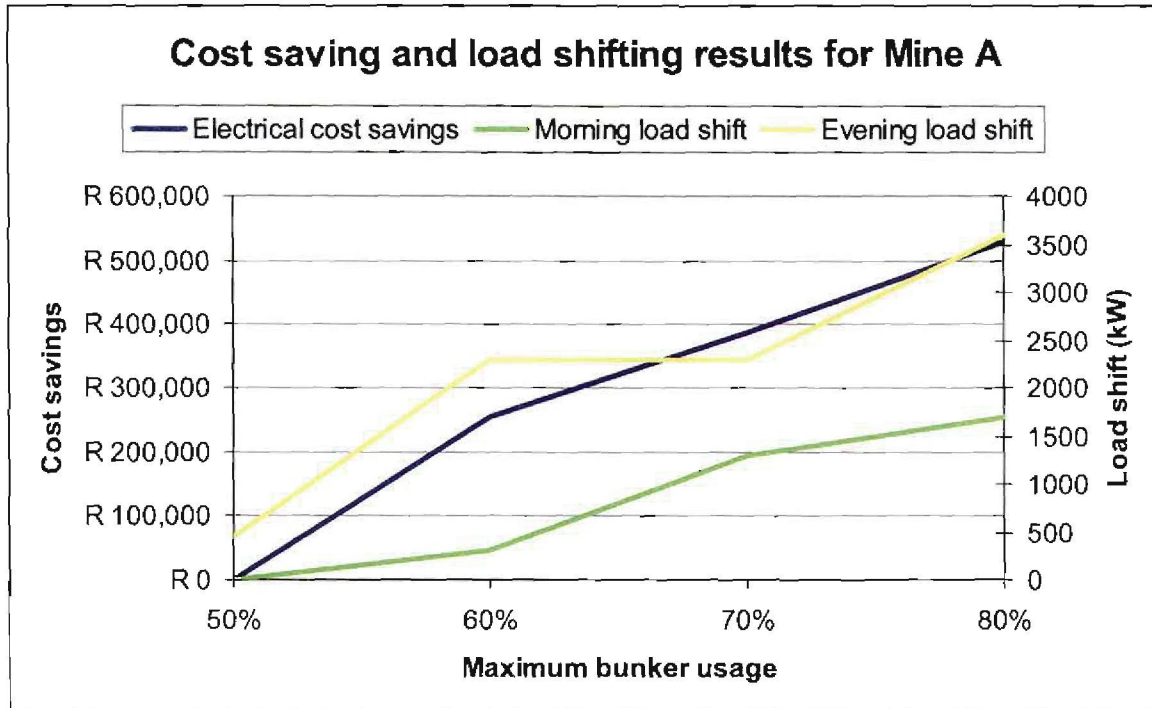


Figure 38 – Cost saving and load-shifting results for Mine A

A summary of the cost savings and load-shifting possible for the different bunker levels is given in Table 8.

Bunker level	Electrical cost savings per year	Morning load-shift (kW)	Evening load-shift (kW)
50%	R 0	0	455
60%	R 253,000	310	2,300
70%	R 386,000	1,300	2,300
80%	R 529,000	1,700	3,600

Table 8 – Load-shifting summary for Mine A

It is clear that there is a possibility to implement load-shifting at Mine A. It was realised that load-shifting might be implemented on conveyor systems despite the fact that conveyor belts play such an important role in production processes. The high cost for the installation of the VSDs might limit the scope to implement load-shifting at Mine A. The load-shifting capabilities of other mines will now be investigated.

4.3 Mine B

4.3.1 Background information

The conveyor belts with load-shifting potential for Mine B must also be identified by available storage capacity and process flow constraints. Mine B is divided into a southern and western side with separate conveyor systems. The different mining sections and conveyor trajectories for Mine B are shown in figure 39 and figure 40.

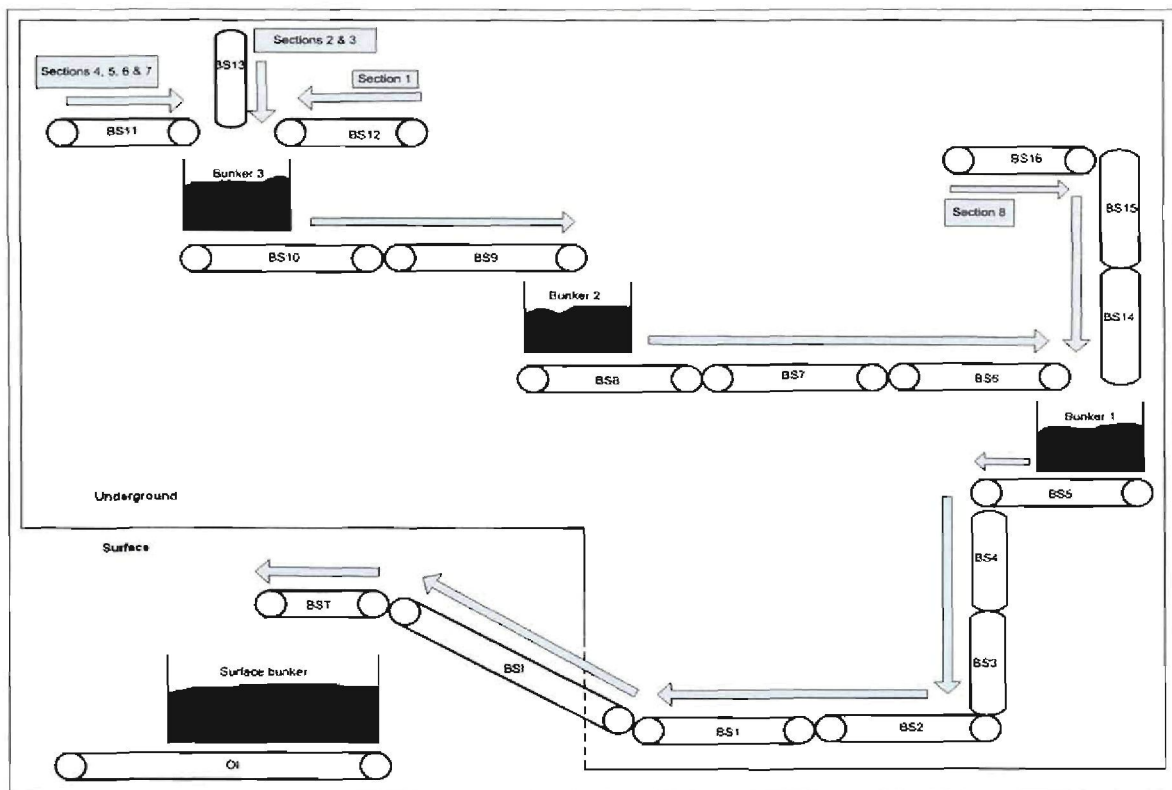


Figure 39 – Southern conveyor system layout at Mine B

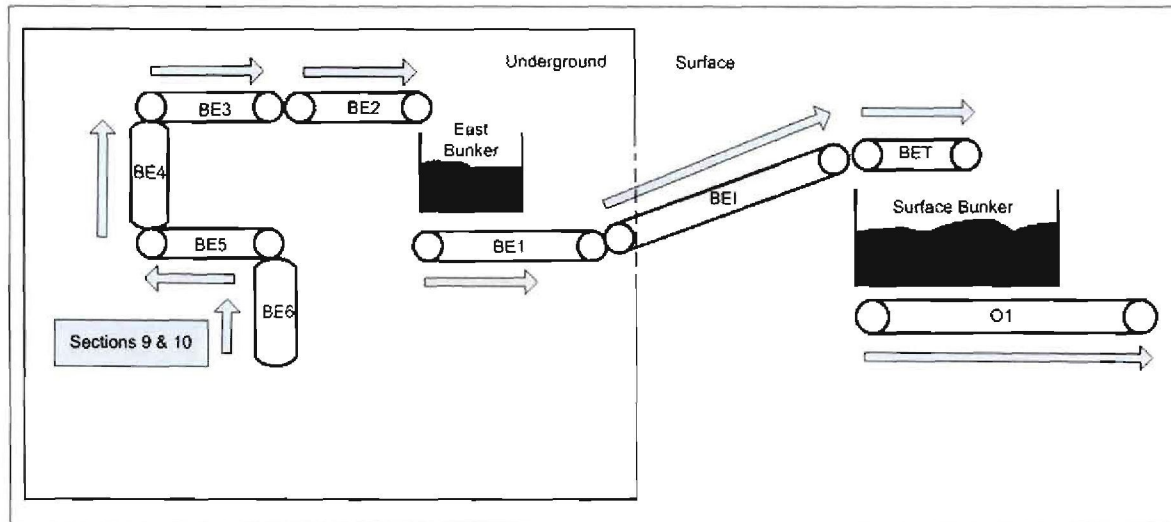


Figure 40 – Eastern conveyor system layout at Mine B

Storage capacities in the conveyor system were identified and are given in table 9. There is only one surface bunker at Mine B. All the coal from the southern and eastern conveyors is, therefore, transported to the same surface bunker. The conveyor belts that were identified to have load-shifting possibility are summarized in table 10.

Bunker name	Bunker capacity (ton)
Bunker 1	3,000
Bunker 2	1,800
Bunker 3	3,000
East bunker	660
Surface bunker	12,000

Table 9 – Bunker capacities at Mine B

There are 10 coal-producing sections at Mine B. Each section produces an average of 2,000 tons per shift. The same argument for the coal production per hour that was given for Mine A was used to determine the coal produced by the sections at Mine B.

Conveyor belt	Conveyor capacity (ton/hour)	Installed electrical capacity (kW)
BST	1,900	200
BSI	1,900	1,200
BS1	1,900	330
BS2	1,900	1,300
BS3	1,900	220
BS4	1,900	220
BS5	1,900	440
BS6	1,800	440
BS7	1,800	440
BS8	1,800	440
BS9	2,200	1,040
BS10	2,200	780
BET	1,800	200
BEI	1,800	1,200
BE1	1,800	1,040
Total		9,710

Table 10 – Mine B conveyor information on relevant conveyor belts

The coal produced by the sections was averaged out to hourly values to be used as input variables in the simulation model. The bunker capacities and the conveyor parameters were used in conjunction with the system layout to simulate the load-shifting effects.

The surface bunker at Mine B has a maximum capacity of 12 000 ton. The coal is conveyed from the surface bunkers using overland conveyors. Conveyor belt O1 is one of the overland conveyors that runs from Mine B and is not controlled by the mine.

The maximum transport rate for the overland conveyer belts is 2 200 ton/hour. The overland belts are not running 24 hours a day and are not controlled by the mine. The surface bunker at Mine B is hardly ever emptied during the week for the same reasons as that of Mine A. The surface bunker level at Mine B is therefore not a constraint for load-shifting.

The bunker levels were simulated on an hourly basis to make sure that they are kept between their maximum and minimum operating levels. Different maximum bunker usage scenarios were tested for load-shifting opportunities.

4.3.2 70% Maximum bunker usage

A 70% maximum bunker usage was found to be the lowest maximum bunker usage that would result in load-shifting. The conveyor belt schedule for a 70% maximum bunker usage is shown in table 11. The simulated bunker levels for such an intervention can be seen in figure 41. The electricity usage profile for a 70% maximum bunker usage can be seen in figure 42.

Hour	Conveyor belt schedule for a 70% maximum bunker usage at Mine B (Minutes)			
	BST, BSI, BS1, BS2, BS3, BS4, BS5	BS6, BS7, BS8	BS9, BS10	BEI, BET, BE1
00:00	60	60	60	60
01:00	60	60	60	60
02:00	60	60	60	60
03:00	60	60	60	60
04:00	60	60	60	60
05:00	60	60	60	60
06:00	60	60	60	60
07:00	60	60	60	60
08:00	0	0	60	60
09:00	0	0	0	60
10:00	60	60	60	60
11:00	60	30	30	60
12:00	60	60	60	60
13:00	60	60	60	60
14:00	60	60	60	60
15:00	60	60	60	60
16:00	60	60	60	60
17:00	60	60	60	60
18:00	0	0	60	60
19:00	0	0	0	60
20:00	60	60	60	60
21:00	60	60	60	60
22:00	60	54	60	60
23:00	60	0	0	60

Table 11 – Conveyor belt schedule for a 70% maximum bunker usage at Mine B

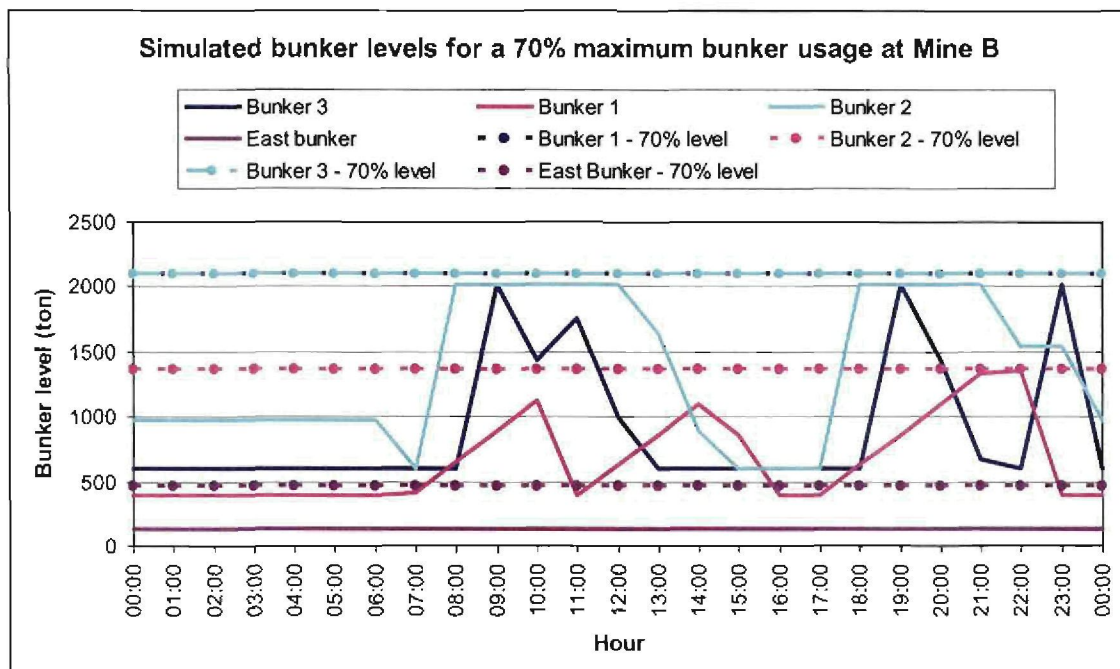


Figure 41 – Simulated bunker levels for a 70% maximum bunker usage at Mine B

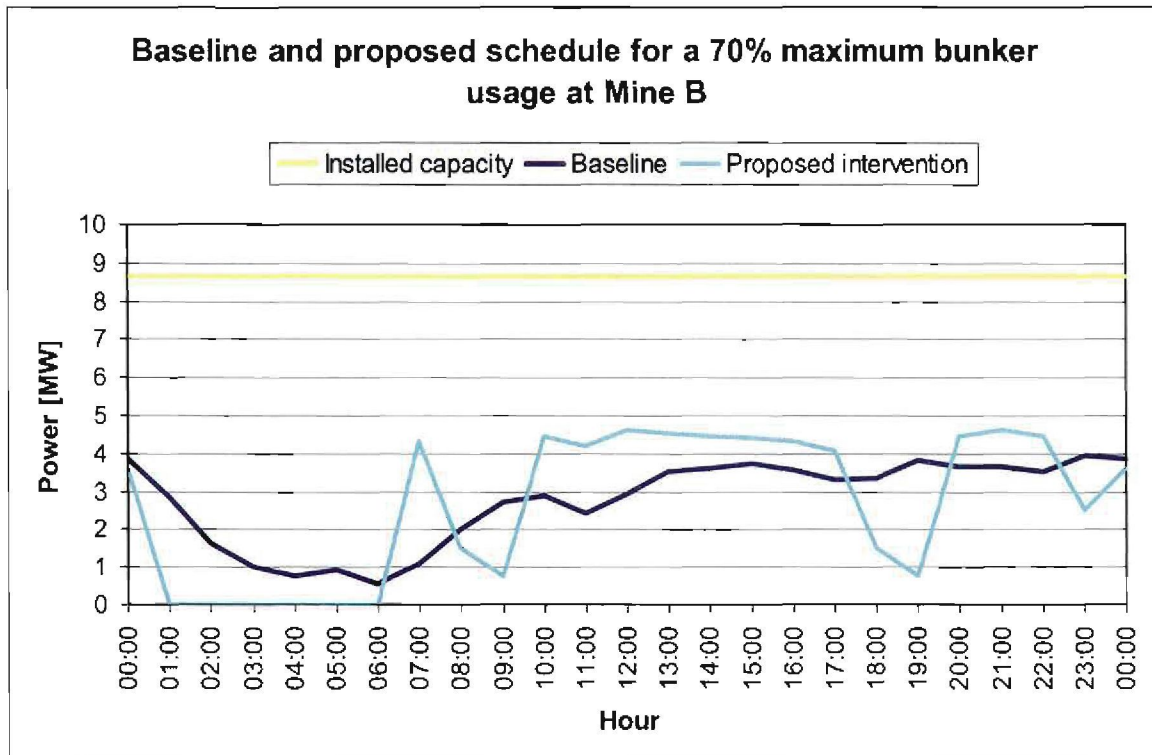


Figure 42 – Baseline and proposed schedule for a 70% maximum bunker usage at Mine B

It can be seen in figure 41 that the maximum bunker usage of 70% is never exceeded. A 70% maximum bunker usage results in no load-shift during the morning peak and a 2,600 kW load-shift during the evening peak. The predicted electricity cost saving for such an intervention is R 292,000 per year.

It can further be observed from figure 41 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would thus occur if load shifting is performed on every weekday. A 70% maximum bunker usage could thus be applied for every weekday of the year and would achieve a daily load-shift of 2,600 kW during the evening peak.

4.3.3 80% Maximum bunker usage

The maximum bunker usage at Mine B was increased to 80% to determine a possible increase in savings achieved. However, an 80% maximum bunker usage did not improve the load-shifting capabilities for Mine B.

4.3.4 Infrastructure upgrades required

The extra start-ups introduced by the load-shifting interventions will increase the wear on the conveyor belts. The installation of VSDs was thus also deemed necessary for Mine B.

The electrical motors used for the DOL drives at Mine B are all 1,000-volt motors. The replacement of the DOL drives with VSDs would then require the same cost per conveyor as for Mine A.

The following conveyor belts at Mine B make use of DOL drives:

- BST
- BSI
- BET
- BEI
- BS1
- BS3
- BS4
- BS5
- BS6
- BS7
- BS8

The cost to replace the DOL drives on the incline belts with VSD's was estimated to be R 3,000,000 per conveyor. The cost to replace the other DOL drives was estimated to be R 1,500,000 per conveyor. It was decided that it would not be viable to replace the DOL drives on conveyer belts BST and BET with VSDs due to their small electrical capacities.

The estimated total cost to replace the DOL drives at Mine B would therefore be R 16,500,000. This is very expensive for the amount of load-shifting that is possible at Mine B. The cost per MW for the replacement of the DOL drives for Mine B is approximately R 6,300,000 per MW. This cost is very high and it is very unlikely that Eskom will fund it. This was verified by a conversation with a director of an ESCO [49].

4.3.5 Conclusion

It was found that a 70% maximum bunker usage resulted in the best load-shifting capabilities for Mine B. Such an intervention resulted in a predicted cost saving of R 292,000 per year with a 2,600 kW load-shift. The cost to upgrade the DOL drives to VSDs was found to be very high and makes the feasibility of the project very low.

The project might become more feasible if the mine is willing to pay for some of the upgrades on the system. Another alternative would be to make use of other devices that may produce a softer start for the conveyor belts.

4.4 Mine C

4.4.1 Background information

The conveyor belts with load-shifting potential for Mine C were also identified by using the available storage capacity, and process flow constraints. The different mining sections and the conveyor layout for Mine C are indicated in figure 43.

Storage capacities in the system were identified and are given in table 12. The conveyor belts that were identified to have load-shifting capability are summarized in table 13.

Bunker name	Bunker capacity (ton)
Bunker 1	1,500
Bunker 2	1,500
Surface bunker	12,000

Table 12 – Bunker capacities at Mine C

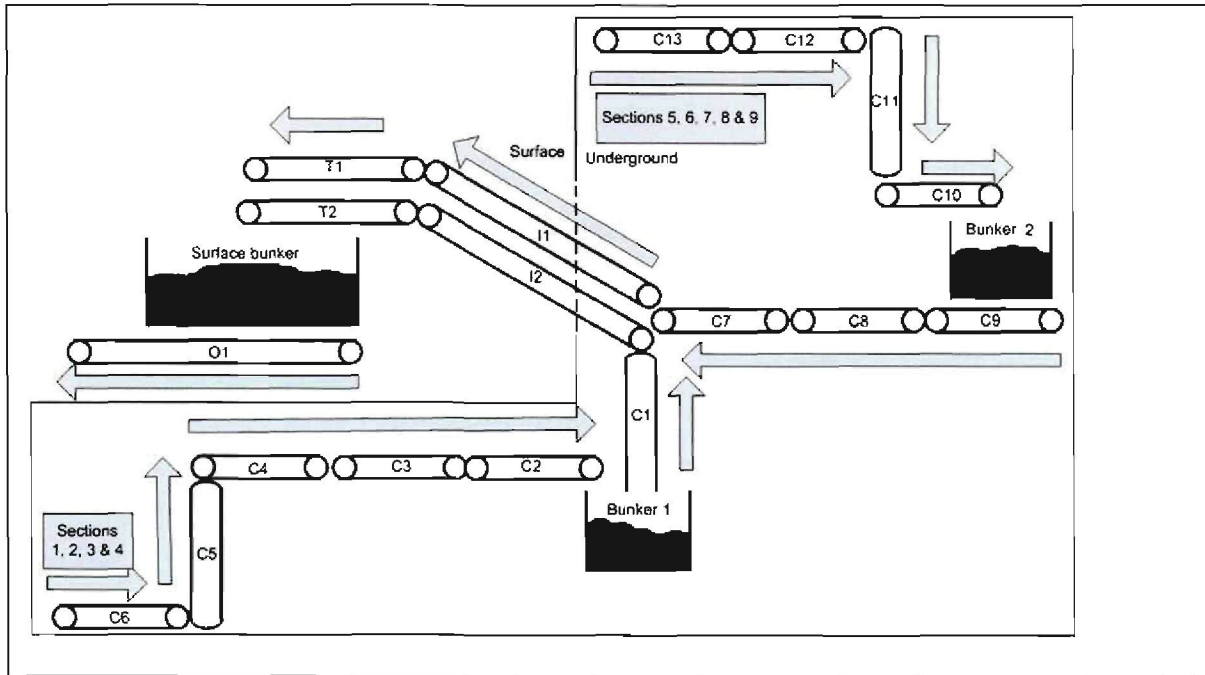


Figure 43 – Conveyor system layout at Mine C

Conveyor belt	Conveyor capacity (ton/hour)	Installed electrical capacity (kW)
T1	2,200	255
T2	2,200	255
I1	2,200	1,200
I2	2,200	1,200
C1	2,200	780
C7	2,200	1,040
C8	2,200	780
C9	2,200	1,040
Total		6,550

Table 13 – Mine C conveyor information on relevant conveyor belts

There are 9 coal-producing sections at Mine C. Each section produces an average of 2,000 tons of coal per shift. The same argument for the coal production per hour that was given for Mine A was used to determine the coal produced by the sections.

The coal produced by the sections was averaged out to hourly values to be used as inputs to the simulation model. The simulation model will make use of the production levels as inputs in conjunction with the bunker capacities, the conveyor parameters and the system layout to simulate the load-shifting effects.

The surface bunker at Mine C has a maximum capacity of 12,000 ton. The maximum transport rate from the overland conveyors that are used to transport the coal from Mine C is 2,200 ton/hour. Conveyor belt O1 is one of the overland conveyors that run from Mine C. The overland belts are not running 24 hours a day and are not controlled by the mine. The surface bunker at Mine C is hardly ever emptied during the week for the same reasons as that of Mine A. Therefore, the surface bunker level at Mine C is not a constraint for load-shifting.

The bunker levels were simulated on an hourly basis to make sure that they are kept between their maximum and minimum operating levels. The different running schedules were then compared to each other to find the optimum schedule for the conveyor system.

4.4.2 70% Maximum bunker usage

Mine C has very small bunker capacities available compared to Mine A and Mine B. There are no load-shifting capabilities for Mine C with a 70% maximum bunker usage.

4.4.3 80% Maximum bunker usage

The maximum bunker usage at Mine C was increased to 80% to determine the possibility of load-shifting at the mine. The proposed conveyor belt schedule for an 80% maximum bunker usage can be seen in table 14. The simulated bunker levels for an 80% maximum bunker usage, is shown in figure 44. The electricity profile that will be the result of such an intervention can be seen in figure 45.

Hour	Conveyor belt schedule for an 80% maximum bunker usage a Mine C (Minutes)		
	T1, T2, I1, I2,	C1	C7, C8, C9
00:00	60	60	60
01:00	60	60	60
02:00	60	60	60
03:00	60	60	60
04:00	60	60	60
05:00	60	60	60
06:00	60	60	60
07:00	60	60	60
08:00	60	30	60
09:00	0	0	0
10:00	60	60	60
11:00	60	60	60
12:00	60	60	60
13:00	60	60	60
14:00	60	60	60
15:00	60	60	60
16:00	60	60	60
17:00	60	60	60
18:00	60	30	60
19:00	0	0	0
20:00	60	60	60
21:00	60	60	60
22:00	60	60	60
23:00	60	60	60

Table 14 – Conveyor belt schedule for an 80% maximum bunker usage at Mine C

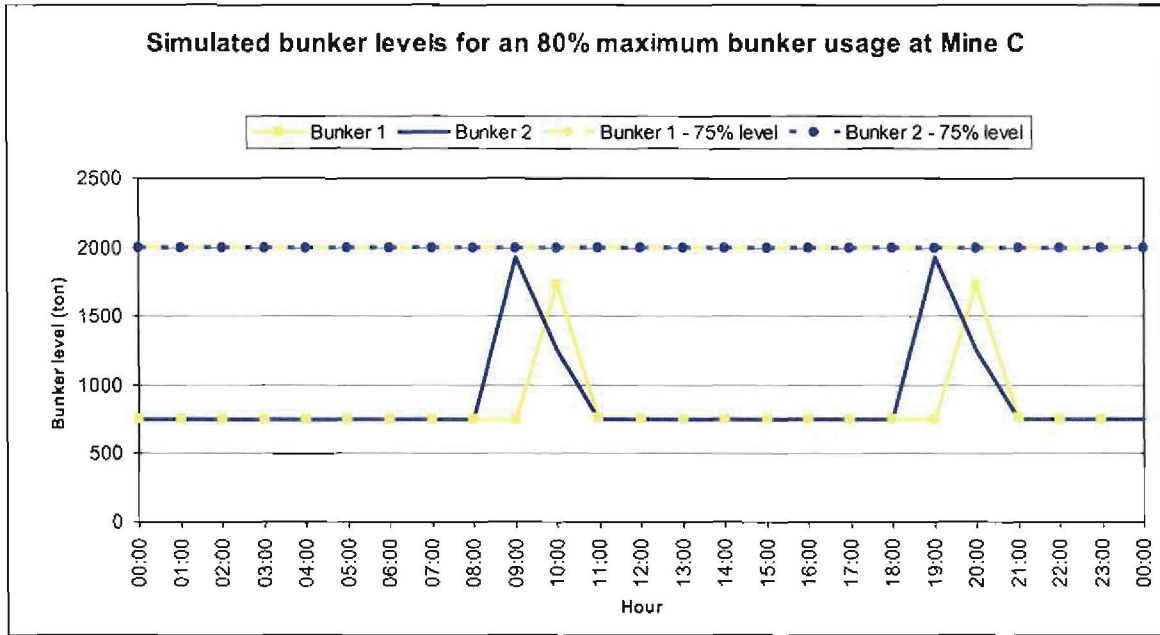


Figure 44 – Simulated bunker levels for an 80% maximum bunker usage at Mine C

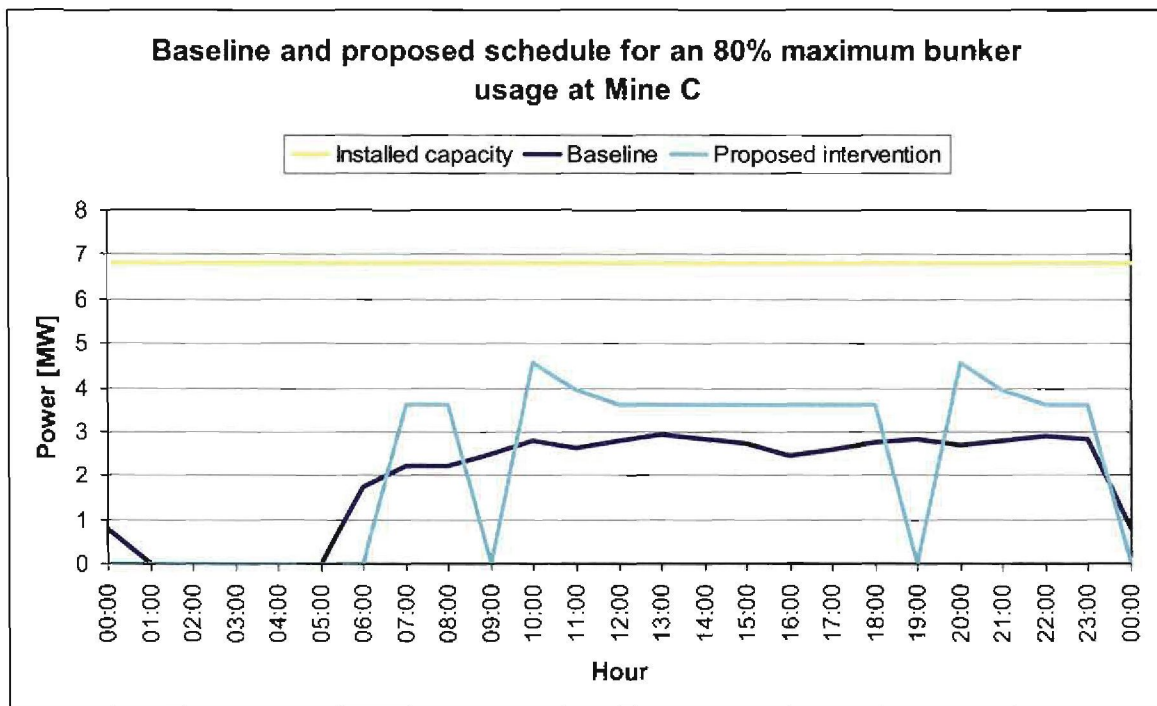


Figure 45 – Baseline and proposed schedule for an 80% maximum bunker usage at Mine C

It is evident in figure 44 that the maximum bunker usage level is never exceeded during the 80% maximum bunker usage simulation. An 80% maximum bunker usage results in an average load-shift of 300 kW during the morning peak and an average load-shift of 1,300 kW during the evening peak. The predicted electricity cost saving for such an intervention is R 150,000 per year.

It can further be observed from figure 44 that the bunker levels at the end of the day are the same as the levels at the start of the day. No material build-up would thus occur if load shifting is performed on every weekday. An 80% maximum bunker usage could thus be applied for every weekday of the year and would achieve a daily load-shift of 300 kW during the morning peak and a 1,300 kW load-shift during the evening peak.

4.4.4 Infrastructure upgrades required

The wear introduced by the extra start-ups would also be a problem for Mine C and consequently, soft starting techniques must thus also be used. The two incline belts are the only belts that would require the replacement of DOL drives with VSDs. The estimated cost of replacing these drives would be R 6,000,000 in total.

4.4.5 Conclusion

Mine C were seen to have limited load-shifting possibilities. This is due to the small bunkers that are available to be used for storage. An 80% maximum bunker usage would result in a load-shifting capability of 300 kW during the morning peak and a 1,300 kW load-shift during the evening peak. This resulted in an estimated cost saving of R 150,000 per year.

The cost for the infrastructure upgrades is lower than that of Mine A and Mine B. The cost per MW for this project would be R 4,600,000. This cost is very high for a load-shifting project. This was verified by a conversation with a director of an ESCO [49]. The project might become viable if the mine is willing to pay for some of the cost to upgrade the infrastructure. Another alternative would be to make use of less expensive equipment that will provide softer start-ups.

4.5 Mine D

The conveyor system layout for Mine D can be seen in figure 46. There is no surface bunker available at this mine. The coal that is conveyed from the underground bunker is not controlled by the mine, but by the plant. This leaves the underground bunker as the only bunker available to the mine for storage purposes.

It is clear from the conveyor system layout that load-shifting would not be possible from the mine's side. There might, however, be a load-shifting possibility from the plant's side.

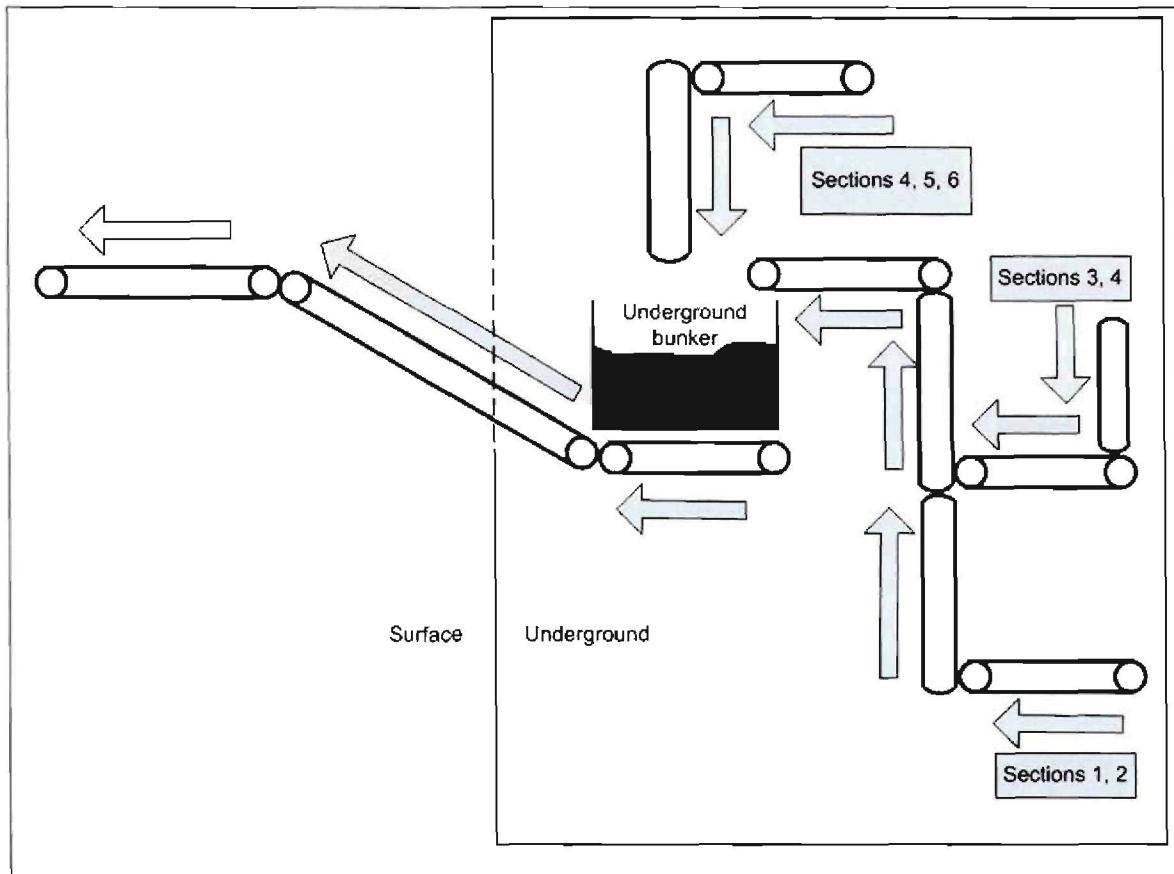


Figure 46 – Conveyor system layout at Mine D

4.6 Mine E

Mine E is similar to Mine D in the sense that there is only one bunker available as surge capacity for the mine. Mine E is another example where the conveyor system does not have any load-shifting capabilities. There might however be some load-shifting capabilities from the plants side.

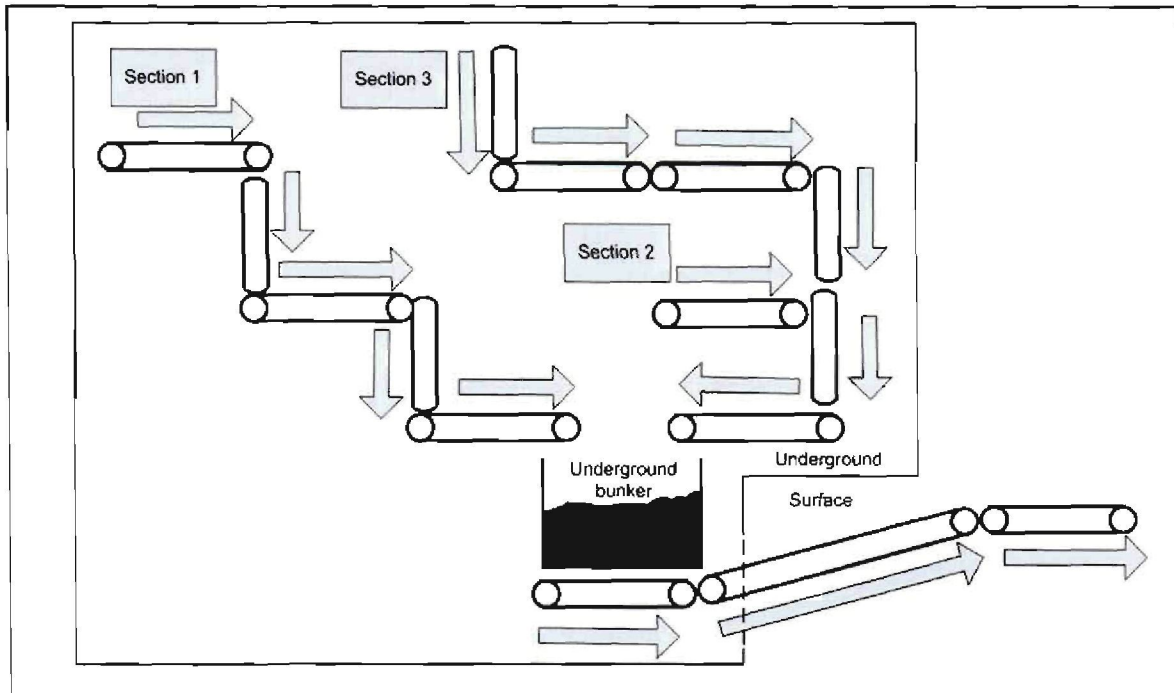


Figure 47 – Conveyor system layout at Mine E

4.7 Mine F

The conveyor layout at Mine F is similar to Mine D and Mine E in the sense that the mine does not have control over the belts that run from the bunker and stockpile. The conveyor layout of Mine F can be seen in figure 48.

It can be seen in figure 48 that there is now conveyor belts that will have load-shifting capabilities from the mine's side. There might be load-shifting potential from the plants side.

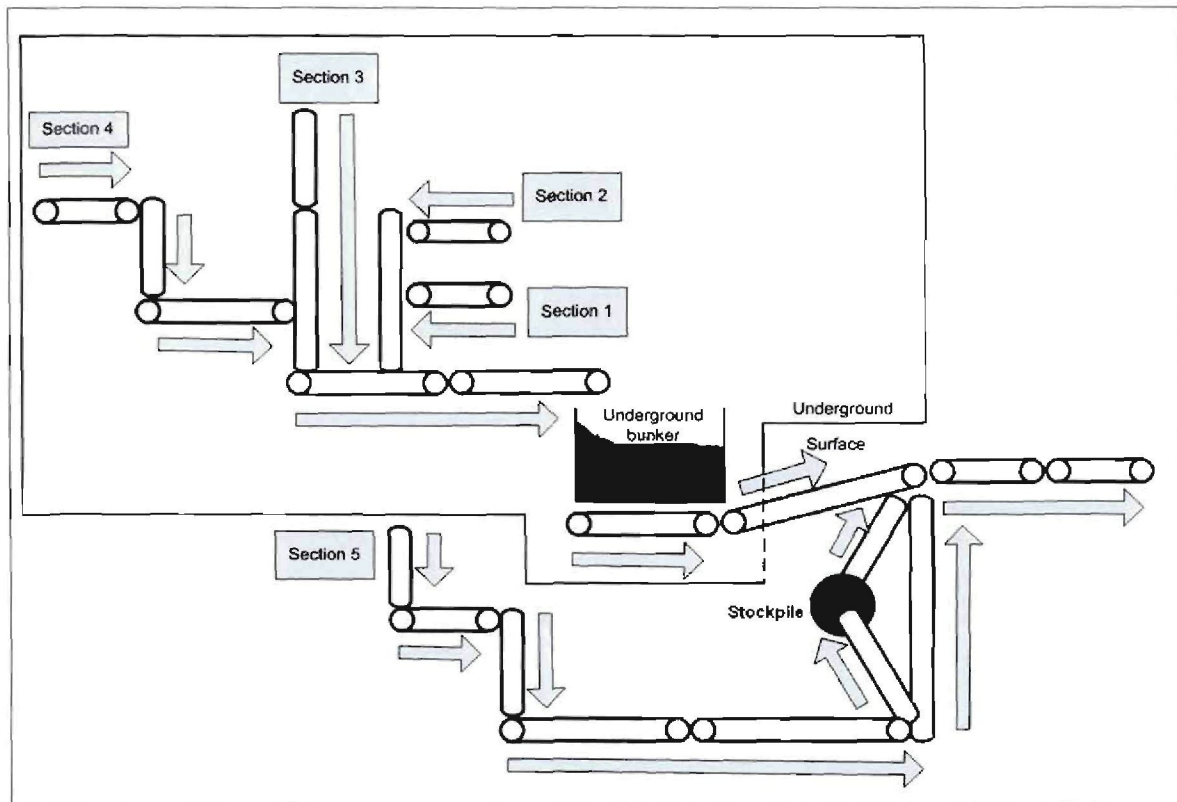


Figure 48 – Conveyor system layout at Mine F

4.8 Conclusion

It was seen that there are definite load-shifting capabilities on some of the conveyor systems studied. The sizes of the bunkers and the production rates were identified to be crucial factors for implementing load-shifting. Increasing bunker capacities might be an option to increase the load-shifting capabilities of the conveyor systems. The cost of building bunkers might however be very expensive and it would not be viable to increase the storage capacities just for load-shifting purposes.

The simulation model indicates the silo levels at the end of every hour. It was observed that the silo level at the end of the day is equal to the level at the start of the day. There would thus be no material build up if load-shifting is performed on consecutive days

Since the savings achieved from one day's simulation is generic for any weekday of the year it can be used to calculate the yearly electricity cost savings. The predicted yearly cost savings was calculated by extrapolating the simulation results obtained from the daily simulation. The load-shifting capabilities for the various mines are summarized in table 15. The savings listed in this table were calculated for a daily load shift from Monday to Friday.

Mine	Maximum bunker usage	Morning load-shifting (kW)	Evening load-shifting (kW)	Predicted yearly cost savings
Mine A	80%	1,700	3,600	R 529,000
Mine B	70%	0	2,600	R 292,000
Mine C	80%	300	1,300	R 150,000
Mine D	N/A	0	0	0
Mine E	N/A	0	0	0
Mine F	N/A	0	0	0
Total		2,000	7,500	R 971,000

Table 15 – Summary of load-shifting results on the conveyor systems

The simulation model can further be used to obtain a proposed schedule for the weekend. Only one production shift is active on Saturdays mornings. The conveyor belts would thus be switched off during the rest of Saturday and the whole of Sunday. The current electricity consumption on the conveyor belts would thus be close to zero on weekends. This implies that no extra saving will be achieved by implementing load-shift during weekends.

There are also only normal and off-peak hours during the weekend which would make load-shifting financially less attractive even if production occurred throughout Saturday. The savings that can be achieved during the weekends would be minimal compared to the savings achieved for Mondays to Fridays.

It is observed from table 15 that a 1,700 kW load-shift during the morning peak and a 3,600 kW load-shift during the evening peak can be achieved on Mine A for an 80% maximum bunker usage. Such an intervention would result in a cost saving of R 529,000 per annum.

It can further be seen from table 15 that a maximum bunker usage of 80% for Mine C results in a 300 kW load shift during the morning peak and a further 1,300 kW load shift during the evening peak. Such a load shift would realise an electricity cost saving of R 150,000 per annum. It is obvious that Mine A and Mine C would realise different savings for the same maximum bunker usage of 80%.

Another interesting observation is that a higher maximum bunker usage of Mine C compared to Mine B results in reduced load shift and reduced cost savings. These differences can be accounted for due to the fact that there are differences in conveyor system layouts, system constraints and production constraints.

Storage facilities that have enough surplus capacity for at least three hours of production is required to produce the best load shifting results on conveyor systems. The feed rate into and out of the storage facilities is also very important when determining the load shedding potential. This includes the transfer rate of the conveyor belts and the peripheral equipment such as feeders and transfer chutes.

The material flow from the bunker must also be high enough to reduce the bunker levels to acceptable levels after load shifting occurred. The bunkers must also be lowered to these acceptable times within a predetermined time.

Only three out of the six mines were identified to have load shifting potential. It was observed that the biggest constraint for load shifting at Mines D, E and F was the absence of storage facilities along the conveyor system. Storage facilities along the conveyor system were thus seen to be the most important system constraint.

A conveyor system that is designed to incorporate load shifting must thus have storage facilities that could provide ample storage during Eskom peak hours. The system must further be designed to have conveyor belts with high transport rates leading to and from the storage facilities. It must further be realised that the amount and sizes of the conveyor belts in the conveyor system would also influence the savings achieved.

Another important fact is that the maximum bunker usage levels proposed for Mine A and Mine C are very high. This leaves very little room for coal storage during unplanned breakdowns. These bunkers would fill to their maximum capacity in a very short time if a breakdown occurs within a short while after load-shifting.

The transfer rates from most bunkers are very high and it was seen in the simulations that the bunker levels stabilize to normal bunker levels quickly after the load-shifting interventions. The historical trends of breakdowns will indicate the likelihood of a breakdown.

The savings achieved through the interventions can then be compared to the possible loss of income due to the breakdowns. The mine must decide on the risk that they are willing to take for the interventions.

It should also be remembered that the duration of load-shifting is a maximum of 3 hours at a time. The chances are good that a major breakdown would have resulted in a production loss regardless of load-shifting.

Another concern regarding the implementation of load-shifting was the increased wear introduced due to the extra start-ups. This called for the replacement of DOL drives with VSDs. However, it was clear that the cost to install these VSDs were very high due to the extensive equipment changes that would have to be made to accommodate these drives.

A commitment from the mine to change from DOL drives to VSDs at their own cost would make the projects more feasible. There were some indications from the mine that they would consider replacing the DOL drives with VSDs due to the major benefits of VSDs. The money made available by Eskom for load-shifting can be used to upgrade other equipment to further improve the load-shifting capabilities.

CONCLUSION

This chapter gives an overview of the results that were obtained from this study. Suggestions for further improvements and DSM possibilities are also discussed in this chapter.

5 CONCLUSIONS

5.1 Summary

The ever increasing demand for energy was seen to have serious side effects on the environment. It was seen that the generation of electricity by making use of fossil fuels are one of these side effects.

The increasing demand for electricity called for the introduction of new measures to lower the demand for electricity. The peak demand problems were identified to contribute to the building and using of extra generating power. This places additional strain on the environment in terms of pollution and the depletion of resources.

The DSM program that was introduced in partnership with the DME, NERSA, and Eskom was identified to target the peak load problems. The cheaper cost of electricity during the non peak time periods of the Megaflex tariff structure, was used to realise electrical cost savings for the client. The funding made available by Eskom to implement DSM was considered in this study to identify equipment that would ensure sustainable load-shifting projects.

Conveyor belts that showed load-shifting potential at the coalmines considered for this study were seen to have installed electrical capacities in excess of 15,000 kW. This study identifies the opportunity to reduce the electrical load during peak times on conveyor systems.

The possibility of influencing production at the mines called for the need to evaluate the effects of load-shifting on production. The ideas behind DSM on pumping systems and cement plants were investigated to identify possible focus areas for DSM on conveyor systems. Existing research into the management of energy on conveyor belts were studied to identify ideas that was used by other people.

Conclusions

This research proved helpful in the study to identify possible constraints. The information gathered was used to develop a simulation model that was used to evaluate the DSM possibility on conveyor systems.

The simulation model was used to determine the possible effects on production by monitoring the bunker levels in the conveyor system. The belt schedules for the various mines were changed to obtain the best load-shifting results. The electricity cost savings from the proposed profiles were calculated for the various scenarios.

The results of the load-shifting interventions were discussed in chapter 4. The summary table that was given in chapter 4 is shown in table 16 for a quick reference to the savings that were proved to be possible.

Mine	Maximum bunker usage	Morning load-shifting (kW)	Evening load-shifting (kW)	Predicted yearly cost savings
Mine A	80%	1,700	3,600	R 529,000
Mine B	70%	0	2,600	R 292,000
Mine C	80%	300	1,300	R 150,000
Mine D	N/A	0	0	0
Mine E	N/A	0	0	0
Mine F	N/A	0	0	0
Total		2,000	7,500	R 971,000

Table 16 – Summary of load-shifting results on the conveyor systems

It is obvious from table 16 that load shifting can only be implemented on certain conveyor systems. It was observed in section 4.8 that the savings achievable by a mine was influenced by the size and position of the storage bunkers. The electrical capacities of the conveyor belts influenced the amount of savings that can be achieved as a result of the proposed load-shifting initiatives. These factors are thus crucial when determining the load-shifting potential at other mines or plants.

Conclusions

Eskom applied for an 18% increase in electricity prices for 2008 and 17% for 2009 at the National Energy Regulator of South Africa (NERSA). NERSA is in a process of evaluating this increase [50]. This would increase the electricity costs of the mines. The implementation of load-shifting on the mines would thus create even more savings. The predicted savings with such increases would result in the savings shown in table 17.

Mine	Predicted yearly cost savings (2007 pricing)	Escalated yearly cost savings for 2008 (18% increase)	Escalated yearly cost savings for 2009 (17% increase)
Mine A	R 529,000	R 625,000	R 731,000
Mine B	R 292,000	R 345,000	R 403,000
Mine C	R 150,000	R 177,000	R 207,000
Mine D	0	N/A	N/A
Mine E	0	N/A	N/A
Mine F	0	N/A	N/A
Total	R 971,000	R 1,147,000	R 1,341,000

Table 17 – Escalated savings for 18% increase in 2008 and 17% increase in 2009

The mining sections at the coalmines considered during this study are relocated to other areas in the mine when the quality of the coal is not up to standard or when the coal reserves are depleted at that location. The simulation model requires the location of a mining section to determine the coal load on a specific conveyor section. The load-shifting capability of a system can be changed by the relocation of a section. The long term planning of the mine would indicate the sustainability of the proposed load-shifting intervention.

The proposed belt schedules resulted in increased stopping and starting of conveyor belts. The mine personnel were concerned about the extra wear on the conveyor belts due to the increased start-ups of the belts. This called for the replacement of DOL drives with VSDs to provide soft starting capabilities for the conveyor belts.

Eskom would not fund a load-shifting project if the cost of the project is too high. This was verified by a conversation with a director of an ESCO [49]. The mine may however implement the proposed conveyor belt schedules to realise electricity cost savings.

The replacement of VSDs was found to be a very expensive option. There was some indication from the mine that they would be willing to replace the VSDs at their own cost due to the advantages of the VSDs. This option would create an opportunity to upgrade other equipment or install new equipment that would increase the load-shifting potential.

It has been proved that the electrical savings can be achieved on conveyor belts by altering the transfer rate of the conveyor belts [41]. The use of variable feeders that can vary the rate at which the coal is fed from the bunkers to the conveyor belts would increase the electrical savings on the conveyor belts. The increased savings that can be achieved by the VSDs would be an added advantage in addition to the improved controllability of the VSDs. This might persuade the mine to pay for the VSD upgrades. Eskom is also prepared to fund 50% of the costs for energy efficiency [24].

An alternative solution was investigated to provide better starting capabilities for the conveyor belts. The proposed solution is to replace the current fluid coupling devices with more effective couplings. The fluid couplings that are installed at the moment make use of fluid to provide a smoother start-up to the conveyor.

The couplings are used to connect the electrical motor to the gearbox. These fluid couplings have many disadvantages and do not provide the smooth starts that newer generation couplings has to offer. Other couplings, called Magnadrive couplings were investigated during this study that makes use of magnetism to transfer torque between the motor and the gearbox.

These couplings make use of Neodymium-Iron-Boron permanent magnets to transfer the torque from the motor to the gearbox via the magnetic fields. An Adjustable Speed Drive (ASD) Magnadrive can be used to control the torque applied to the conveyor drive drum.

This coupling device can therefore be used instead of VSDs to provide soft starts. The cost for a Magnadrive coupling could not have been established but the Magnadrive representatives said that it would be cheaper than the installation of VSDs. The amount by which the Magnadrive would be cheaper was thus not established. The basic operation of Magnadrive couplings is discussed for further reference in appendix B.

5.2 Suggestions for future work

Feeders are used to transfer the coal at a constant rate from the bunkers to the conveyor belts. The feeding rate of the feeders that are currently being used at the mines studied in this dissertation must be preset prior to operation. The feeding rate can thus not be changed real time to control the material transfer rate on the conveyor belts.

It was identified in other studies that there will be additional savings on the conveyor belts if the feed rate on the conveyors can be changed. [41] The implementation of variable feeding equipment can thus also be investigated to improve electrical savings.

The use of Magnadrive couplings can also be investigated in greater detail to determine the viability of using these couplings instead of VSDs. Other similar equipment that will enable conveyors to be started soft can also be investigated as alternatives to VSDs.

This study focussed on analysing the DSM opportunities on conveyor systems. The case studies that were considered for this dissertation were all coalmines where conveyor belts are used to transfer the coal from the mining sections to bunkers from where it is the plant's responsibility to transport the coal.

The coal must be conveyed beyond these bunkers to the beneficiation plants or storage facilities. The coal is often transferred over long distances using conveyor belts. These conveyor belts would also consume large amounts of electricity and might have load-shifting possibilities. Load-shifting on these conveyor belts can also be evaluated using the simulation model that was developed in this study.

Conveyor belts are also used in various applications in other mining and industrial processes. There might be load-shifting potential in these other conveyor applications.

6 REFERENCES

- [1] Mandil C., "30 Key Energy Trends in the IEA & Worldwide", International Energy Agency (IEA), 9 rue de la Fédération, 75739, Paris Cedex 15, 2005.
- [2] Mokoena S.S., "Electricity Supply Statistics for South Africa", National Energy Regulator, P.O. Box 40343, Arcadia, 0007, South Africa, 2004.
- [3] Horvei T., Padayachee V., "Security and adequacy of Supply in South Africa – a point of View on Associated Challenges and Some Solutions", AMEU Technical Convention, Gallagher Estate Midrand, Available at: <http://www.ameu.co.za>, 17 October 2006.
- [4] "Eskom - Annual report 2007", Eskom, P.O. Box 1091, Johannesburg, 2000, Available at: <http://www.eskom.co.za> 2007.
- [5] "Key world energy statistics 2007 edition", International Energy Agency (IEA), 9 rue de la Fédération, 75739, Paris Cedex 15, p6, 2007.
- [6] Weisser D., "A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies", International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria, 2007.
- [7] Winkler H., et al., "Energy Policies for Sustainable Development in South Africa: Options for the Future". Energy Research Centre, University of Cape Town, South Africa, 2006.
- [8] Matthews J., "Seven steps to curb global warming", Macquarie graduate school of management, Macquarie University, Sydney NSW 2109, Australia, 2007.
- [9] Richard A., et al., "Climate Change 2007: The physical basis - Intergovernmental Panel on Climate Change - Fourth Assessment Report, Summary for Policy Makers", 7bis, Avenue de la Paix, C.P.N° 2300, 1211 Geneva 2, Switzerland, 2007.

References

- [10] Asif M., Muneer T., "Energy supply, its demand and security issues for developed and emerging economies", School of Engineering, Napier University, 10 Colinton Road, Edinburgh, EH10 5DT, UK, 2005.
- [11] Gcabashe T.S., et al., "Eskom - Annual report 2006", Eskom, Capacity planning and management, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, 2006.
- [12] "Load Shedding", Website:
http://www.eskom.co.za/live/loadshed.php?Item_ID=3977, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, accessed on 26 June 2007.
- [13] Spencer A., et al., "Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations, U.S. – Canada Power Systems Outage Task Force, North American Electric Reliability Corporation (NERC), Princeton Forrestal Village, 116-390 Village Boulevard, Princeton, New Jersey 08540-5721, 2004.
- [14] Cauley G., et al., "August 14, 2003 Blackout", North American Electric Reliability Control (NERC), Princeton Forrestal Village, 116-390 Village Boulevard, Princeton, New Jersey 08540-5721, 2004.
- [15] Grebe E., et al., "Final Report of the Investigation Committee on the 28 September 2003 Blackout in Italy", Union for the Co-ordination of Transmission of Electricity, 15 Boulevard Saint-Michel, 1040 Brussels, Belgium, 2004.
- [16] LaCommare K.H., Eto J.H., "Cost of power interruptions to electricity consumers in the United States (US)", Ernest Orlando Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 90R4000, Berkeley, CA 94720-8136, USA, 2006.
- [17] Gcabashe T.S., et al., "Additional information to the Eskom Annual Report 2007 – Power shortages", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, 2007.

References

- [18] "Power Supply to Parts of Gauteng and Mpumalanga Affected Briefly", Media Release, Website:
http://www.eskom.co.za/live/content.php?Item_ID=3935, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, accessed on 26 June 2007.
- [19] "Media releases", Website, :
http://www.eskom.co.za/live/content.php?Category_ID=52, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, accessed on 14 November 2007.
- [20] "Strategically Important Developments – Eskom – PBMR - Transnet", Department of Public Enterprises, Private Bag X15, Hatfield, 0028, South Africa, 2007.
- [21] Wisner R., Bolinger, M., "Annual Report on US. Wind Power Installation, Cost and performance Trends: 2006", U.S. Department of energy, Energy Efficiency and renewable Energy, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401-3393, 2006.
- [22] "What is DSM?", Website: <http://www.eskomdsm.co.za/whatisdsm.php>, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, accessed on 25 January 2007.
- [23] Conradie D., "Eskom - Tariffs and charges 2007/8", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, 2007.
- [24] "Integrated National Electrification Program (INEP)", Website: http://www.dme.gov.za/energy/elect_inep.stm, The department of Minerals and Energy of the Republic of South Africa, Private Bag X59, Pretoria, 0001, South Africa, accessed on 22 January 2007.
- [25] Matjila C., "Regulatory policy on energy efficiency and demand side management for South African electricity industry", National Energy Regulator of South Africa, P.O. Box 40343, Arcadia, 0007, South Africa, 2004.

References

- [26] "Energy Efficiency and Demand Side Management in South Africa", Case Study: 2006 DSM case study, Eskom, P.O. Box 1091, Johannesburg, South Africa, 2000, Available at: <http://www.eskomdsm.co.za/>, 2006.
- [27] "The SA Demand Side Management Program – an Operational Guide for Energy Services Companies", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, DSM operational guide for ESCOs Resource CD, Available at <http://www.eskomdsm.co.za>.
- [28] "Eskom urges South Africans to conserve electricity", Website: http://www.eskom.co.za/live/content.php?Item_ID=1539, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, accessed on 24 March 2007.
- [29] Bolinger M., "Utility integrated resource planning: An emerging driver of new renewable generation in the western United States", REFOCUS, Elsevier Ltd, P O Box 150, Langford Lane, Oxford, OX5 1AS, Vol. 6, Issue 6, pp22 – 24, November/December 2005.
- [30] Nortje T., "South Africa's Demand Side Management program: a savings opportunity", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, 2005.
- [31] Creamer T., "Standards certainty crucial to South Africa saving 8 000 MW by 2025", Creamer media's Engineering news, PO Box 75316, Garden View, South Africa, Website: http://www.engineeringnews.co.za/article.php?a_id=115685, Accessed 12 November 2007.
- [32] "Analysis of current DSM effort & ESCO activity against electricity consumption patterns", Presentation, Available at: <http://www.eskomdsm.co.za/download.php>, Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, 2004.

References

- [33] "Eskom - Western Cape Newspaper Insert - An overview of the Western Cape Recovery Plan", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, Available at: www.eskom.co.za/content/newspaper%20insert-content~4.doc, 2006.
- [34] "Eskom Demand Side Management Program (DSM) - Mining Energy Savings to Reduce Operating Costs at Harmony's Elandsrand Mine", Eskom, P.O. Box 1091, Johannesburg, 2000, South Africa, Available at <http://www.eskomdsm.co.za/download.php>, Accessed on 23 March 2007.
- [35] Thein S., "Demand side management on an intricate multi-shaft pumping system from a single point of control", Thesis submitted to the Faculty of Engineering in fulfilment of the requirements for the degree Magister Ingenieria In Electrical Engineering At North West University, Potchefstroom Campus, Private Bag X6001, Potchefstroom, 2520, South Africa, 2007.
- [36] Jordaan J., "Real-time energy management in the cement industry", Thesis submitted in partial fulfilment of the requirements for the Degree Magister in Mechanical Engineering at the Northwest University, Private Bag X6001, Potchefstroom, 2520, South Africa, 2005.
- [37] "Goodyear announces energy – saving conveyor belt", Website: <http://www.goodyear.com/WorkArea/downloadasset.aspx?id=5442>, The Goodyear Tire & Rubber Company, 1144 East Market Street, Akron, Ohio 44316-0001, accessed on 25 April 2007.
- [38] "Conveyor belts: What can be done to save energy on conveyor belts", Website: http://www.energyideas.org/topics/default.cfm?s_qob=title&o=h,t,ts,ds&c=h,t,15,3001, EnergyIdeas Clearinghouse, PO Box 43165, Olympia WA 98504-3165 USA, accessed on 5 May 2007.

References

- [39] Dalglish A.Z., Grobler, L.J., "Measurement and verification of a motor sequencing controller on a conveyor belt", School of Mechanical and Material Engineering, Potchefstroom University for CHE, Private Bag X6001, Potchefstroom, 2522, South Africa, 2002.
- [40] Peltola M., ABB, Improving power factor with variable speed AC drives, Electrical Construction & Maintenance (EC&M), Prism Business Media, 9800 Metcalf Avenue, Overland Park, KS 66212, 2003.
- [41] Marx D.J.L., "Energy audit methodology for belt conveyors", submitted in partial fulfilment of the requirements for the degree Master of Engineering (Electrical-Engineering) in the Faculty of Engineering, Built Environment & Information Technology, University of Pretoria, 2005.
- [42] "Minera Los Pelambres, Chile - Turnkey joint venture with Krupp – Canada (2000)", Website:
http://www.conveyor-dynamics.com/projects/popup/fs_lospelambres.htm, Conveyor dynamics inc., 1111 West Holly Street, Suite A, Bellingham, WA 98225, USA, accessed on 12 May 2007.
- [43] "Minera Los Pelambres copper mine, Chile", Website:
http://www.mining-technology.com/projects/minera_los/, Mining-Technology.com, SPG Media Limited, Brunel House, 55-57 North Wharf Road, London W2 1LA, United Kingdom, accessed on 12 May 2006.
- [44] Sahoo R., Roach D., "Quantification of the lump coal breakage during handling operation at the Gladstone port", Faculty of Engineering and Physical systems, Central Queensland University, Rockhampton, Qld 4702, Australia, 2004.
- [45] Den Heijer W., "The measurement and verification guideline for Demand-Side Management Projects", Eskom, P.O. Box 1091, Johannesburg, 2000, 2005.

References

- [46] Kats G., et al., "International performance and measurement and verification protocol Concepts and Practices for Improved Indoor Environmental Quality Volume I", p22, USA Department of energy, Office of Scientific and Technical Information, P.O. Box 62, Oak ridge, TN 37831-0062, 2002.

- [47] "Joy Continuous Miners", Brochure, Joy Mining Machinery, Thorn Hill Industrial Park, 177 Thorn Road, Warrendale, PA 15086, United States, Available at: <http://www.joy.com>, 2005.

- [48] "Haulage Systems", Brochure, Joy Mining Machinery Thorn Hill Industrial Park, 177 Thorn Road, Warrendale, PA 15086, United States, Available at: <http://www.joy.com>, 2004.

- [49] Kleingeld M.K., Director, HVAC International Pty (Ltd), P.O. Box 20156, Faerie Glen, 0043, South Africa, Tel: 012 809 1076, Personnel communication, August 2007.

- [50] "Eskom's Application for Rule Changes in the Multi-Year Price Determination (MYPD) For 2008/9", Press statement, NERSA, P.O. Box 40343, Arcadia, 0007, South Africa, 2007.

APPENDIX A VARIABLE SPEED DRIVE

Appendix A will give an overview over the operation of a Variable Speed drive

APPENDIX A – VARIABLE SPEED DRIVE INFORMATION

7.1 Introduction

Breakdown torques of up to 2.8 times the rated torque is generated during the start-up of a conveyor belt [A.1]. These high torques produces strain on the system that increases the wear on the components. Variable speed drives can be used to overcome the high starting torques associated with Direct On Line drive systems. Variable speed drives are often referred to as variable frequency drives due to their operating principles.

Figure A1 shows a comparison between the torques that are produced by an induction motor that is not driven by a VSD and the torques produced when the motor is driven by a constant torque VSD. It can be seen that the variable frequency operation results in a constant torque load. The torque produced by the motor can be set to a certain level to achieve a desired constant torque output.

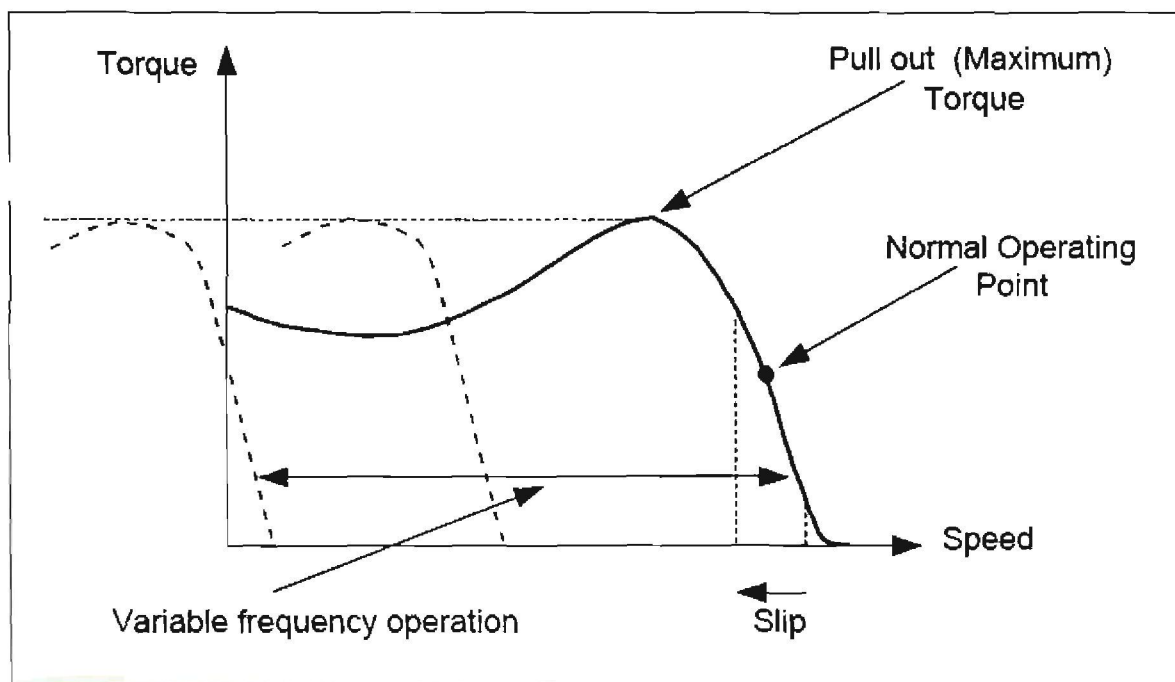


Figure A1 – Comparison between a constant torque VSD and normal torque characteristic [A.2]

It is evident from figure A1 that the VSD will improve the torque characteristics of the motor. VSDs can thus be used to limit the strain on equipment under starting conditions. The basic operation of a VSD will be discussed next.

7.2 Operation

The actual operation of a VSD is very complex. Appendix A is only intended to serve as a general overview of the operation of a VSD.

The rotational speed of an induction motor is determined by the frequency of the supply current and the amount of poles in the electrical motor. The rotational speed of an induction motor can be calculated by using the following equation [A.3]:

$$N = \frac{(1 - S)120 \times f}{P} \quad (A1)$$

where:

N = Rotational speed of the motor (rpm)

S = Slip

f = Frequency of the supply current (Hz)

P = Amount of poles in the motor.

The slip of an induction motor is defined as the following:

$$S = \frac{\text{synchrous_speed} - \text{actual_rotor_speed}}{\text{synchrous_speed}} \quad (A2)$$

The synchronous speed of an induction motor is the maximum rotational speed of the motor. The slip of an induction motor under no load is normally about 0.005. The full load slip of an induction motor is normally about 0.05 [A.3].

It can be seen from equation A1 that the speed of an induction motor can be controlled by changing the frequency of the current supplied to the motor or by changing the amount of poles in the electrical motor [A.3]. Figure A2 indicates a four pole induction motor [A.5]. A four pole motor operating at a frequency of 50 Hz would have maximum speed of 1 500 rpm.

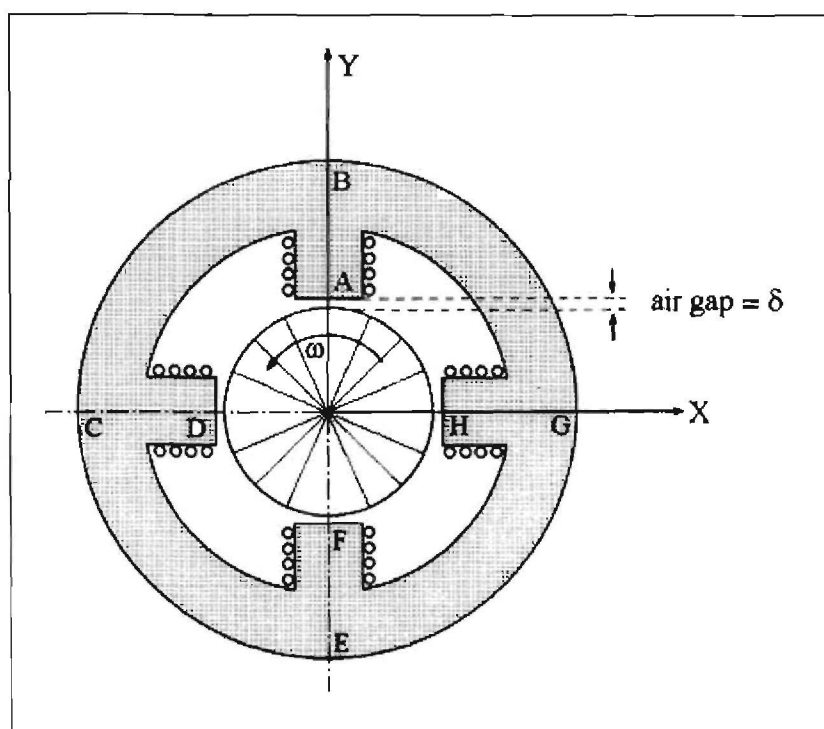


Figure A2 – Four pole induction motor [A.5]

The best option to control the speed of the motor without making use of mechanical equipment like gearboxes is to control the frequency of the current supplied to the motor. A simplified diagram of the operation of a VSD can be seen in figure A3. [A.2]

The alternating supply current is firstly rectified to a direct current. The direct current is then converted back to an alternating current by means of an inverter. The output frequency of the inverter can now be changed to determine the speed of the induction motor that is driven by the VSD. [A.2]

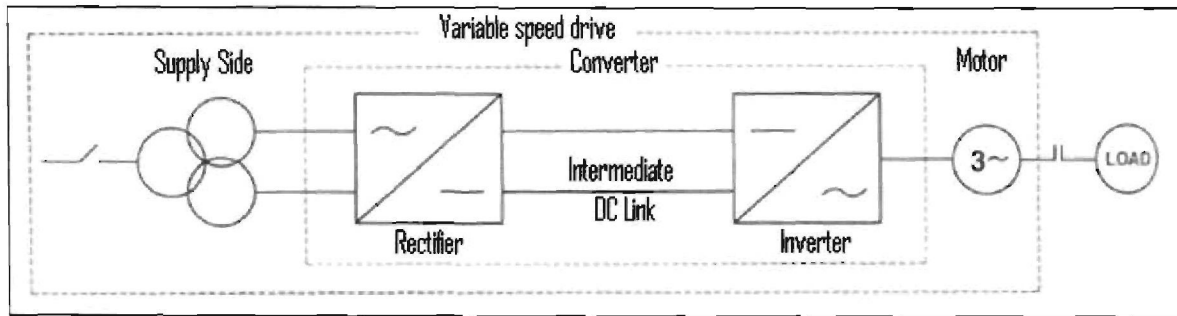


Figure A3 – Simplified operation of a Variable Speed Drive (VSD) [A.2]

The supply voltage to the motor must be changed along with a change in frequency to keep the magnetic flux from saturating the motor. By making use of Pulse Width Modulation (PWM), the supply voltage to the motor is changed. PWM is a process where Insulated Gate Bipolar Transistors (IGBTs) are used to reconstruct the alternating current. [A.2]

The IGBTs are switched on and off for variable periods to create square waveforms. The square waveforms are then filtered to create the sinusoidal wave form that is required for alternating current [A.2]. The waveform created by the IGBTs can be seen in figure A4

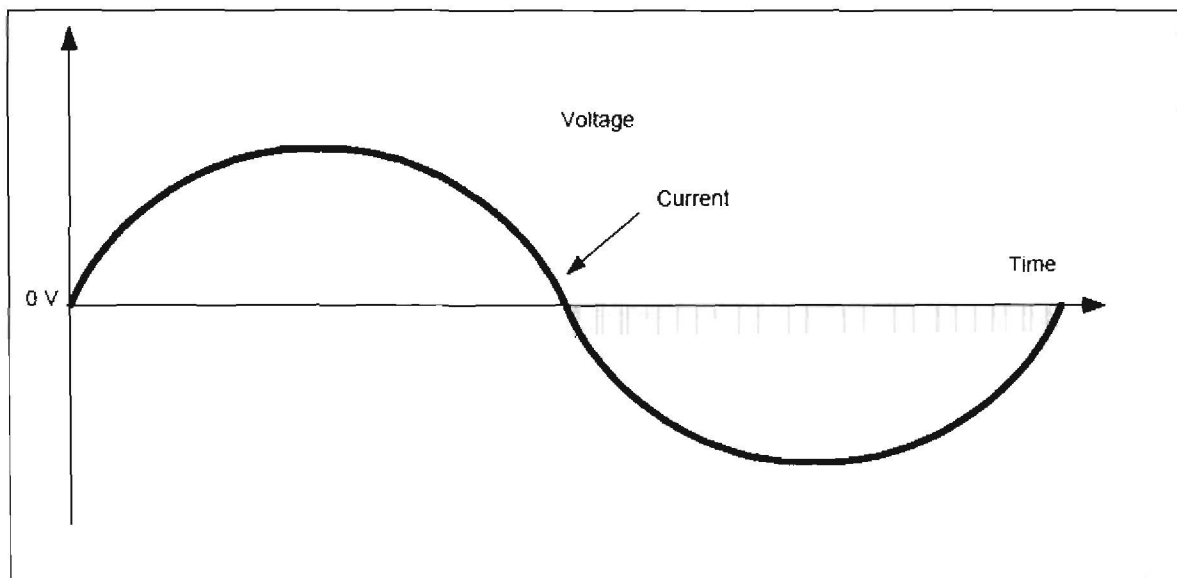


Figure A4 – PWM for VSD voltage control [A.2]

7.3 VSD applications

A major advantage of VSDs is the ability to control the speed of an induction motor. The good control offered by a VSD can be used to softly start big electrical equipment like conveyor belts, pumps, winders etc. VSDs are normally classified as being constant horsepower, constant torque or variable torque [A.4].

Constant horsepower loads are used in applications like winders. The diameter of the winding surface changes as the winder winds or unwinds. This change in diameter will change the speed of the object being winded. It may however be required for the speed to be kept constant. The speed of the driving motor must, therefore, be changed without changing the power. The torque, speed and power characteristics of constant power loads can be seen in figure A5. [A.4]

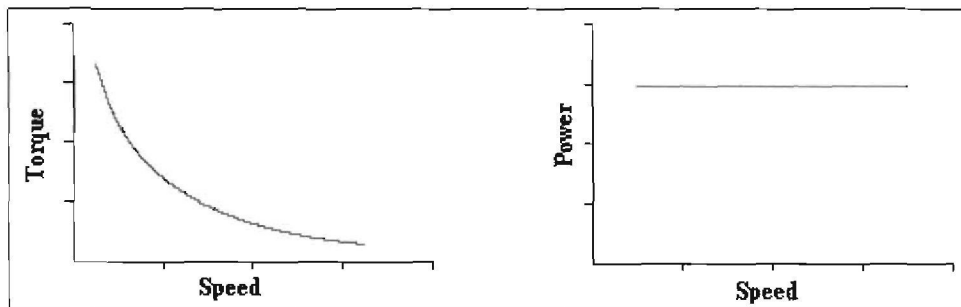


Figure A5 – Characteristics of a constant power VSD [A.4]

Constant torque VSDs are used when it is required to maintain a certain torque regardless of the speed that the motor is turning. Conveyor belts require constant torque VSDs to maintain the torque required to turn the drive drums of the conveyor belts regardless of the speed. The speed, power and torque characteristics of a conveyor belt are shown in figure A6. [A.4]

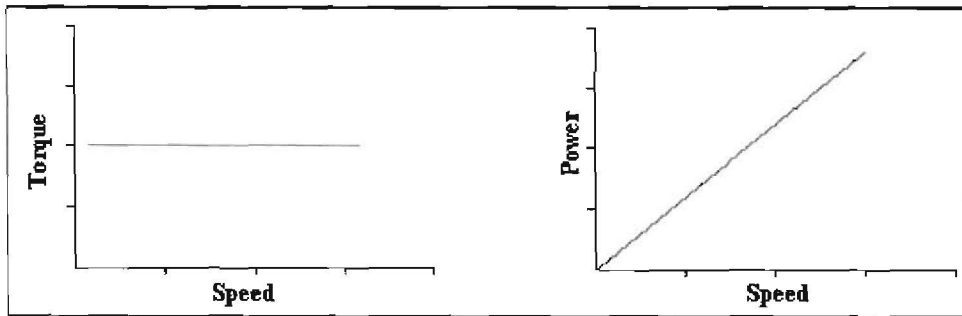


Figure A6 – Characteristics of a constant torque VSD [A.4]

Fans and pumps require variable torque VSDs to operate sufficiently. An increase in the rotational speed of the motor produces increased resistance from the air or water that needs to be displaced. The centrifugal forces are also increased with an increase in speed. The torque and the power applied by the motor must then be increased to obtain the higher speed required. The speed, power and torque characteristics of a variable torque VSD can be seen in figure A7. [A.4]

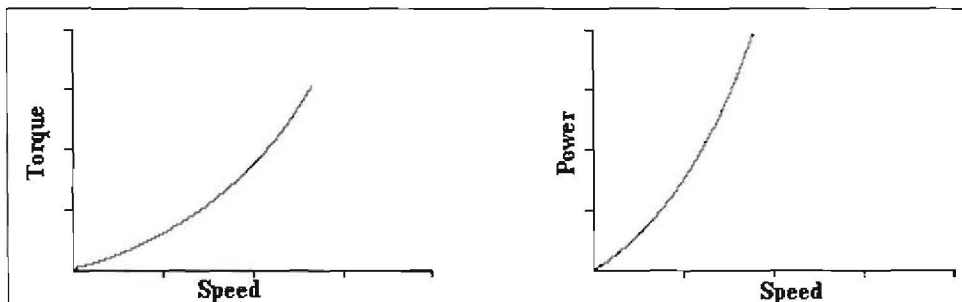


Figure A7 – Characteristics of a variable torque VSD [A.4]

7.4 Conclusion

The component wear on conveyor belts during start-up gave rise to the use of something to provide a soft start. VSDs were identified as an option to provide these soft start-ups. The operation of induction motors and VSDs explained why VSDs are helpful in controlling the speed of conveyor belts.

Constant torque VSDs were seen to be the best option for conveyor belt applications. The budget costs identified for replacement of DOL drives with VSDs were seen to be very high.

These high costs did not make it feasible to replace the DOL drives just for load-shifting purposes. Most of the costs incurred for the installation of the VSDs will have to be paid by the mine. The replacement of DOL drives with VSDs is currently taking place at some of the mines considered in the case studies.

The money made available by Eskom for the implementation of load-shifting can thus be used to pay for other infrastructure upgrades that would improve the sustainability of the project. An alternative to VSDs is Magnadrive couplings; an overview of these couplings is given in appendix B.

7.5 References

- [A.1] Marx D.J.L., "Energy audit methodology for belt conveyors", submitted in partial fulfilment of the requirements for the degree Master of Engineering (Electrical-Engineering) in the Faculty of Engineering, Built Environment & Information Technology, University of Pretoria, 2005.
- [A.2] "Micromaster – Applications Handbook", Siemens, Issue A1, Website: <http://www.siemens.fi>, accessed on 13 November 2007.
- [A.3] Sarma M., S., "Electrical Machines, Steady-State Theory and Dynamic Performance", 2nd edition, Northeastern University, PWS Publishing Company, 20 Park Plaza, Boston, MA 02116-4324, 1996.
- [A.4] Bathia A., "Variable Speed Drives in Electrical Energy Management", PDHcenter.com, Washington DC, Herndon, Virginia, USA, 2004.

- [A.5] Mukherjee A., Karmakar, R., Samantaray., A.K., Modeling of basic induction motors and source loading in rotor-motor systems with regenerative force field”, Department of Mechanical Engineering, Indian Institute of Technology, Kharagpur 721 302, India and High-Tech Consultants, Science and Technology Entrepreneurship, Park, IIT, Kharagpur 721 302, India, 1999.

**APPENDIX B
MAGNADRIVE INFORMATION**

Appendix B will give some Magnadrive brochures

APPENDIX B – MAGNADRIE INFORMATION

RELIABILITY THROUGH INNOVATION

Target Industries

MagnaDrive's technology is applicable to most companies. However, the following industries have demonstrated the most benefits by utilizing MagnaDrive products:

• Water / Wastewater	• Oil & Gas
• Power Generation	• HVAC
• Pulp & Paper	• Irrigation
• Mining & Cement	• Maritime
• Chemical Processing	

Target Applications

MagnaDrive products are used with a wide variety of rotating equipment in industry. The top five applications of MagnaDrive technology are as follows:

• Pumps	• Centrifuges	• Blowers
• Fans	• Bulk Handling	

U.S. Navy Program

The U.S. Navy has procured several hundred MagnaDrive units for a variety of critical pump applications. MagnaDrive's technology has passed the Navy's rigorous 9-G Shock Test and is currently placed on guided missile cruisers, destroyers and aircraft carriers, with plans to install MagnaDrive's products on pumps and other rotating equipment fleet wide, on all ship classes.

Existing applications include pumping equipment where reliability is critical to ship operations:

• Catapult Water	• JP5 Fueling
• Hydraulic Elevator	• Fire Water
• Chilled & Sea Water	

The Navy spends 29 sailor-days per year per pump repairing and replacing seals, couplings and bearings on existing equipment. These costly repairs are nearly eliminated with MagnaDrive Technology. The Navy calculates that using MagnaDrive Technology will reduce their annual staffing needs by over 1,700 sailors.



About MagnaDrive

Bellevue-based MagnaDrive Corporation was founded in 1999. The company's breakthrough magnetic technology provides a cost effective solution to increase reliability and lower maintenance expense while achieving energy savings and process control. The impact and potential of the technology was recognized by *Industry Week* magazine, which selected MagnaDrive as Technology of the Year in 2001. MagnaDrive was selected by *Inc.* magazine as one of 2004's 500 fastest growing private companies in the United States. Also for 2004, Deloitte & Touche named MagnaDrive one of the 100 fastest growing technology companies in North America.

IndustryWeek
Technology of the Year

Inc.
500

Deloitte
Technology Fast 100

FGC on guided-missile cruiser USS Anzio (CG 66) 11 ASD's at Ashland Water Treatment Plant in Oregon

MagnaDrive

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 Telephone 425-463-4700
 Fax 425-463-4747
 www.magnadrive.com

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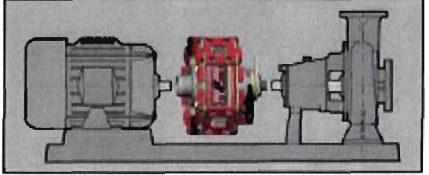
RELIABILITY THROUGH INNOVATION

MagnaDrive™

Breakthrough Technology

MagnaDrive replaces the physical connection between motors and loads with a gap of air. This air gap eliminates harmful vibration, wear and tear, enhances energy efficiency, increases motor life and protects equipment from overload damage.

MagnaDrive's patented technology transmits power across an air gap with motor and load completely disconnected. The result? Improved reliability, money saved on energy and maintenance every day, and a big change in the way factories and other industrial and commercial facilities operate.



Lowest Total Cost of Ownership

Maintenance, unscheduled downtime, and energy costs are three of the highest budget items in industry. Over a system's life, these costs are more than ten times greater than the purchase price of the equipment. Therefore, it is prudent to investigate the total cost of ownership rather than just initial price.

MagnaDrive's technology provides the lowest total cost of ownership in most applications due to significantly lower maintenance costs and increased reliability. Equipment life is extended due to reduced vibration. Variable speed applications have the added benefit of dramatically lower energy costs.

MagnaDrive

RELIABILITY THROUGH INNOVATION

MagnaGuard Standard Couplings (FGC & MGE)

Benefits:

- ✓ Lowest Total Cost of Ownership
- ✓ Low Maintenance
- ✓ Accepts Greater Misalignment
- ✓ Eliminates Vibration Transfer between Motor and Load
- ✓ Increases Seal and Bearing Life
- ✓ Simple Installation
- ✓ Efficient Torque Transfer
- ✓ Permits Shock Loading
- ✓ Meets ANSI B73 Standards (MGE only)
- ✓ Meets API 610 Standards (MGE only)

FGC & MGE – The New Standard for All Industrial Couplings



3 to 5,000 Hp - Up to 7,000 RPM

Ideal for Applications Subject to:

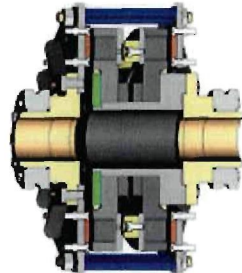
- Vibration
- Periodic Load Seizure
- Pulsating Loads
- Thermal Expansion
- Shock Loading
- Tight Space Constraints

MagnaGuard Delay Coupling (MGD)

Benefits:

- ✓ Cushioned Start & Stop
- ✓ Lowest Total Cost of Ownership
- ✓ Low Maintenance
- ✓ Accepts Greater Misalignment
- ✓ Eliminates Vibration Transfer between Motor and Load
- ✓ Increases Seal and Bearing Life
- ✓ Simple Installation
- ✓ Efficient Torque Transfer
- ✓ Permits Shock Loading

MGD – Advanced Cushioned Start & Stop



10 to 2,000 Hp - Up to 4,500 RPM

Ideal for Applications Subject to:

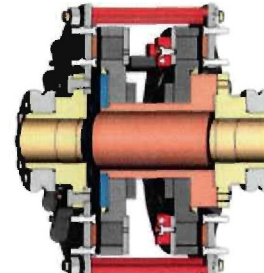
- Vibration
- Periodic Load Seizure
- Pulsating Loads
- Thermal Expansion
- Shock Loading
- Higher Starting Inertia/Torque

Torque Limiting Coupling (MGTL)

Benefits:

- ✓ Overload Torque Protection
- ✓ Self-resetting
- ✓ Cushioned Start & Stop
- ✓ Lowest Total Cost of Ownership
- ✓ Low Maintenance
- ✓ Accepts Greater Misalignment
- ✓ Eliminates Vibration Transfer between Motor and Load
- ✓ Increases Seal and Bearing Life
- ✓ Simple Installation
- ✓ Efficient Torque Transfer
- ✓ Permits Shock Loading

MGTL – Advanced Overload Protection



10 to 2,000 Hp - Up to 4,500 RPM

Ideal for Applications Subject to:

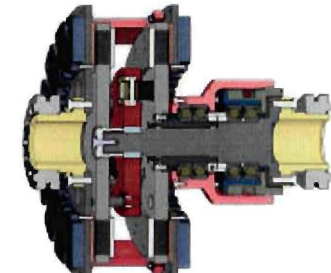
- Vibration
- More Frequent Load Seizures
- Pulsating Loads
- Thermal Expansion
- Shock Loading
- Higher Starting Inertia/Torque

Adjustable Speed Drive (ASD)

Benefits:

- ✓ Variable Speed Control
- ✓ Eliminates Inefficient Valves & Dampers
- ✓ Eliminates Electronic Harmonics
- ✓ Up to 66% Energy Savings
- ✓ Lowest Total Cost of Ownership
- ✓ Low Maintenance
- ✓ Accepts Greater Misalignment
- ✓ Eliminates Vibration Transfer between Motor and Load
- ✓ Increases Seal and Bearing Life
- ✓ Simple Installation
- ✓ Completely Disengaged Start-up
- ✓ Permits Shock Loading

ASD – Precise Process Control



10 to 2,500 Hp - Up to 4,000 RPM

Ideal for Applications Subject to:

- A Need for Process Control
- Vibration
- Periodic Load Seizure
- Pulsating Loads
- Thermal Expansion
- Shock Loading
- Higher Starting Inertia/Torque

MagnaDrive™

RELIABILITY
THROUGH
INNOVATION



10 — 4,000 Hp, Up to 3,600 rpm

MagnaDrive

*Adjustable Speed
Drives*

Benefits:

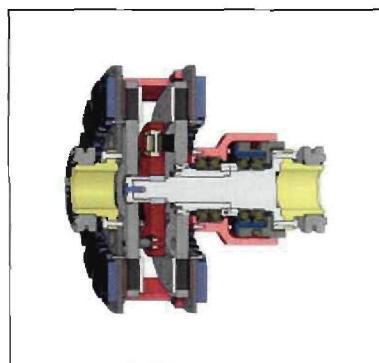
- Variable Speed Control
- Eliminates Valves & Dampers
- Eliminates Electronic Harmonics
- Significant Energy Savings
- Lowest Total Cost of Ownership
- Accepts Misalignment
- Eliminates Vibration Transfer
- Reduces Maintenance Costs
- Increases Seal & Bearing Life

Ideal for Applications Subject To:

- Vibration
- Periodic Load Seizure
- Pulsating Loads
- Thermal Expansion
- Shock Loading
- High Starting Inertia/Torque
- High Energy Costs
- Frequent VFD Failure

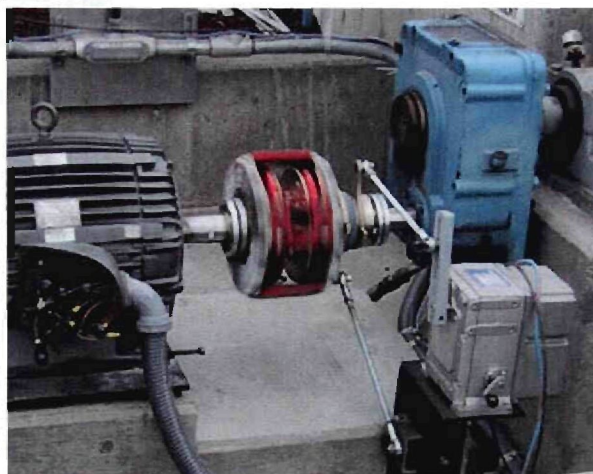
Principle of Operation

- The MagnaDrive ASD works by transmitting torque from the motor to the load across an air gap. There is no mechanical connection between the driving and driven side of the equipment. The torque is created by the interaction of powerful rare-earth magnets on one side of the drive with induced magnetic fields on the other side. By varying the air gap spacing, the amount of torque transmitted can be accurately controlled, thus permitting speed control.
- The MagnaDrive ASD consists of three sets of components.
 - A *magnet rotor assembly*, containing rare-earth magnets, is attached to the load
 - A *copper conductor* rotor assembly is attached to the motor.
 - *Actuation components* control the air gap spacing between the magnet rotors and the conductor rotors.
- Relative rotation of the copper conductor and magnet rotor assemblies induces a powerful magnetic coupling across the air gap



- Varying the air gap spacing between the magnet rotors and the conductor rotors results in adjustable output speed.
- The principle of magnetic induction requires relative motion between the magnets and the conductors. This means that the output speed is always less than the input speed. The difference in speed is known as slip. Typically, when the MagnaDrive ASD is operating at full rated motor speed, the slip is between 1% and 4%.

- The output torque of a MagnaDrive ASD is always equal to the input torque. The motor is only required to produce the amount of torque needed by the load.
- The ability of the ASD to transmit power or control speed is not affected by minor angular or offset alignment between the motor and load. Vibration due to misalignment is virtually eliminated. Transmission of vibration across the drive is also eliminated due to the air gap.
- Vibration is the largest cause of bearing and seal failures. MagnaDrive products reduce harmful vibration and minimize these problems.
- When installed in a system the MagnaDrive ASD can respond to a process signal. The pressure, flow, level, or other process control signal is received and scaled by a control system, then provided to the MagnaDrive ASD actuator. The actuator adjusts the air gap, which modulates the speed of the load to satisfy the control needs.



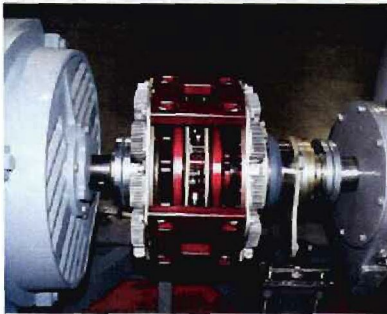
Benefits of the MagnaDrive ASD

- MagnaDrive Corporation replaces the physical connection between motors and loads with a gap of air. This air gap eliminates harmful vibration, wear and tear, enhances energy efficiency, increases motor life and protects equipment from overload damage. The result is:
 - Increased reliability
 - Money saved on energy and maintenance every day
 - A big improvement in the way factories and other industrial and commercial facilities operate
- The principal benefits offered by the MagnaDrive ASD are summarized in the following list. Any one of these benefits could justify installation of the MagnaDrive ASD.
 - Energy Savings
 - Increased Reliability
 - Reduced Maintenance Costs
 - Improved Process Control
 - No Harmonic Distortion
 - Ability to Operate in Harsh Environments
- MagnaDrive ASD's have been designed for users of Rotating Equipment who are dissatisfied with the high Total Cost of Ownership that comes with traditional adjustable speed products. MagnaDrive ASD's are a unique application of rare-earth magnetic technology that provides the Lowest Total Cost of Ownership for our customers by reducing the cost of maintenance, increasing process availability, and improving energy efficiency. In a departure from traditional adjustable speed technology, MagnaDrive Corporation has assembled a portfolio of torque transmission products that reduce vibration and harmonics, thereby increasing equipment life and improving energy efficiency.

Applications

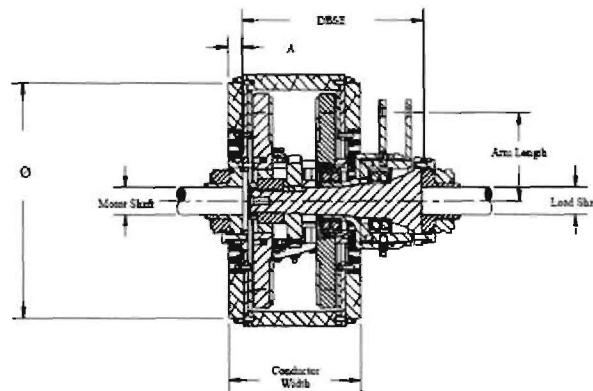
- MagnaDrive Corporation's technology is applicable to most companies. However, the following industries have demonstrated the most benefits by utilizing our magnetic technology:
 - *Water / Wastewater*
 - *Oil & Gas*
 - *Power Generation*
 - *Building System & HVAC*
 - *Pulp & Paper*
 - *Chemical Processing*
 - *Mining*
 - *Maritime*
 - *Cement*
 - *Irrigation*
- MagnaDrive Corporation products are used with a wide variety of rotating equipment in industry. The top applications of the MagnaDrive technology are as follows:
 - *Centrifugal Pumps*
 - *Centrifuges*
 - *Blowers*
 - *Fans*
 - *Bulk Handling*
 - *Dynamometers*

MagnaDrive Air-Cooled ASD's



MagnaDrive Air-Cooled Adjustable Speed Drives use the movement of air over the spinning conductors to dissipate the heat that is created as a result of "slip" between the magnet rotors and the conductors. This slip is directly related to the amount of torque transmitted by the ASD and is adjusted by varying the air gap between the rotors and conductors.

Typically, Air-Cooled ASD's are used in applications where the motor horsepower ranges between 10 and 500 Hp. When the motor horsepower is greater than 500 Hp or when the speed of the motor is low, there is a possibility that MagnaDrive Corporation will recommend a Water-Cooled drive.



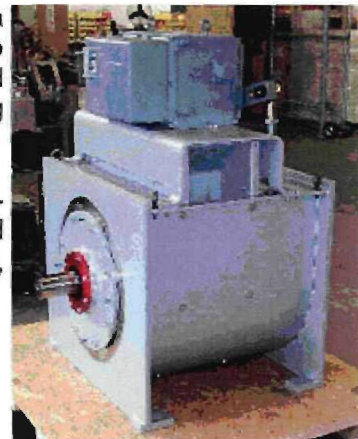
Size	Conductor Rotor Assembly							Magnet Rotor Assembly				Torque (ft-lb)		Actuation	
	DBSE (in)	Ø (in)	Width (in)	A (in)	Wt (lb)	Dist. to CG (in)	WR ² (lb ² *in ²)	Wt (lb)	Dist. to CG (in)	WR ² (lb ² *in ²)	Peak Linear	Per Slip rpm	Arm Length (in)	Linear Force (lb)	
6.5	8.60	8.0	6.11	.06	10	2.63	85	25	4.34	100	30	.108	5.0	20	
8.5	8.60	10.0	6.11	.06	16	2.50	200	35	4.70	250	60	.291	5.0	20	
10.5	12.10	13.5	8.98	1.0	50	3.36	875	85	5.45	500	90	0.52	6.0	60	
12.5	12.10	15.75	8.98	1.0	65	3.36	1650	95	5.90	900	210	1.65	6.0	80	
14.5	12.10	17.75	8.98	1.0	85	3.36	2750	120	6.54	2000	315	3.09	6.0	100	
16.5	12.96	20.0	9.54	1.0	105	3.30	4550	170	7.15	4000	450	5.18	6.0	130	
18.5	14.43	22.0	9.11	1.14	155	2.63	9700	197	7.60	4900	600	8.04	8.0	150	
20.5	14.43	24.0	9.11	1.14	173	2.71	13400	227	8.17	7620	780	11.80	8.0	180	
22.5	16.72	24.63	8.97	.69	165	2.74	12770	341	6.30	12175	1020	22.00	10.0	350	
24.5	18.95	28.63	9.32	.31	221	2.40	23000	503	7.11	23233	1240	40.46	11.0	500	
26.5	18.95	28.63	9.32	.31	221	2.40	23000	515	7.03	24576	1500	47.82	11.0	500	

Air-Cooled ASD Accessories

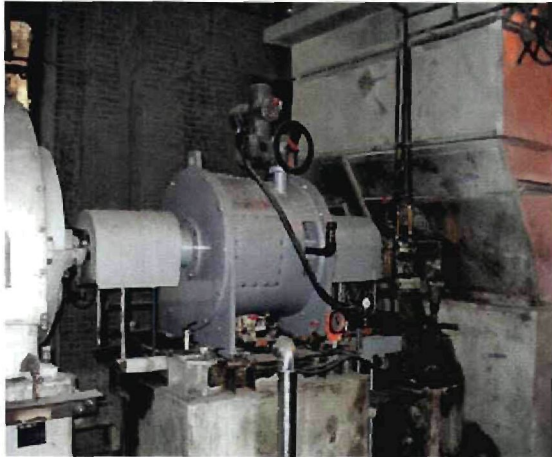


To meet our customers' varying application needs, MagnaDrive Corporation offers a wide selection of Air-Cooled Adjustable Speed Drive accessories.

- **Actuators** - We have selected a standard set of Electric Actuators to be used with our ASD's. These actuators are designed to accept an analog input signal from your control system and to position the ASD to give the right speed for your process.
- **Floating Shaft Kits** - This option is available for applications that require additional shaft support on the load side of the system. Thin shafts, split-case pumps, and high vibration applications will benefit from these kits.
- **Rigid Pedestal Mounts** - For larger ASD applications that require additional load shaft support, MagnaDrive Corporation offers the Rigid Pedestal Mount option.
- **Totally Enclosed Kits** - MagnaDrive Totally Enclosed Kits offer an additional level of value for our customers. By packaging the ASD and actuator in a single, pre-aligned, and easy to install unit, we provide a solution to high-speed and sleeve bearing applications.
- **Vertical Kits** - For vertical applications, a specially designed housing is provided for the ASD. An optional Thrust Pot is available and offers the ability to incorporate a non-reversing clutch and/or a shaft adjustment coupling option.
- **Machine Monitoring Instrumentation** - MagnaDrive Corporation will supply customer requested instrumentation including: Temperature Sensors, Speed Sensors, Position Indicators, and others.

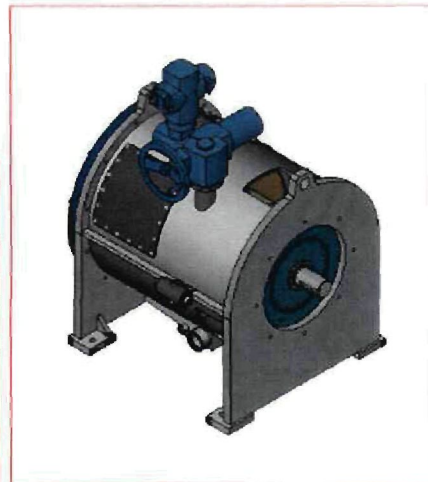
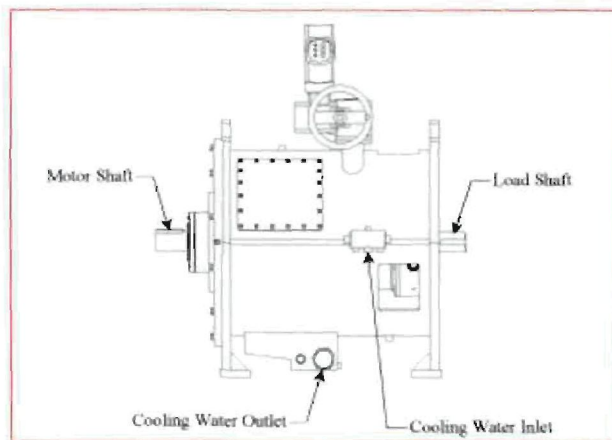


MagnaDrive Water-Cooled ASD's



- MagnaDrive Water-Cooled Adjustable Speed Drives use the rotation of the magnet rotors and conductors to centrifugally draw a steady stream of cooling water over the drive components providing conductive cooling to dissipate the heat created by the "slip" between the magnet rotors and the conductors.

- Typically, Water-Cooled ASD's are used in applications where the motor horsepower ranges above 500 Hp and in applications where the rotational speed of the magnet rotors and the conductors is low enough that air cooling of these components is insufficient. MagnaDrive Corporation has successfully installed its Water-Cooled Adjustable Speed Drives on Water Supply Pump Stations, Induced Draft Fans, Slurry Pumps, Water Treatment Aeration Fans, and Cooling Tower Fans as well as many other applications.

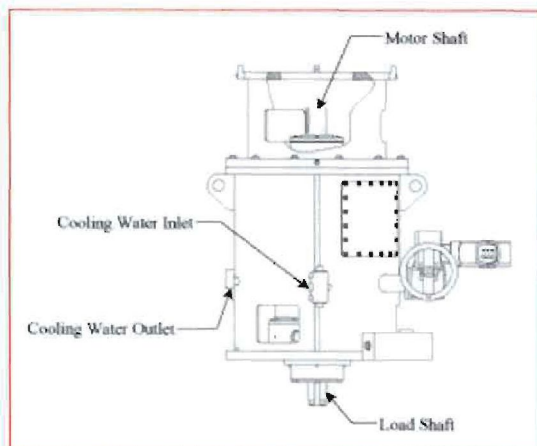


MagnaDrive Water-Cooled ASD's



- MagnaDrive Corporation offers a Standard Closed Loop Coolant Circulating System for use with it's Water-Cooled Drives. If this option is selected, MagnaDrive Corporation will provide a cooling system package design based on horsepower and speed of the application. Standard cooling system requirements include a minimum supply of clean water (25 gpm at 60 psi for 2500 Hp / 1800 rpm) and a maximum ambient cooling water temperature of 80° F. Additional features can be provided to meet customer specific requirements.
- MagnaDrive Corporation offers both Horizontal and Vertical Water-Cooled ASD configurations to meet your application needs.

- MagnaDrive Water-Cooled Adjustable Speed Drives are provided with an Oil Lubricated Gearbox and Output Shaft Assembly as standard equipment.
- For Vertical configurations, Oil Lubricated Thrust Bearings with an AFBMA 40,000 hour life and with 25,000 pounds of vertical down-thrust capacity are standard equipment.





MagnaDrive ASD Adjustable Speed Drive

**This Chart is presented for illustration purposes only
Please contact your MagnaDrive Distributor for ASD Sizing & Selection Assistance**

Centrifugal Applications (Centrifugal Pumps, Fans, Blowers) Only

Motor hp	Motor KW	Motor rpm	3600	1800	1200	900
10	7		6.5	6.5	8.5	10.5
15	11		6.5	8.5	10.5	12.5
20	15		6.5	8.5	10.5	12.5
25	19		8.5	10.5	12.5	12.5
30	22		8.5	10.5	12.5	14.5
40	30		8.5	12.5	12.5	14.5
50	37		8.5	12.5	14.5	16.5
60	45		10.5	12.5	14.5	16.5
75	56		10.5	14.5	16.5	18.5
100	75		12.5	14.5	18.5	20.5
125	93		12.5	16.5	18.5	22.5
150	112		14.5	18.5	20.5	24.5
200	149		14.5	18.5	22.5	26.5
250	187		16.5	20.5	24.5	31
300	224		16.5	22.5	26.5	31
350	261		18.5	24.5	31	31
400	298		18.5	24.5	31	31
450	336		20.5	26.5	31	31
500	373		20.5	26.5	31	33
600	448		-	31	31	33
700	522		-	31	31	33
800	597		-	31	33	33
1000	746		-	31	33	33
1500	1119		-	33	33	35
2500	1865		-	33	35	35
4000	2984		-	-	35	-

MagnaDrive Corporation offers a family of products to accomplish a broad range of operating objectives:

Speed Control, Torque Management, Cushioned Start, Reliability,
Vibration Control and Misalignment Tolerance.

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