CHAPTER 1

INTRODUCTION

1.1 Impact of the mining sector on South African electricity demand

Eskom is the main electricity provider in South Africa. In 2008, Eskom supplied approximately 95% of the electricity used in the country [1]. Eskom customers are categorised according to the application of electricity. Figure 1-1 is a pie chart illustrating the contribution of individual sectors to the total electrical energy consumption of 202,202 GWh [2].

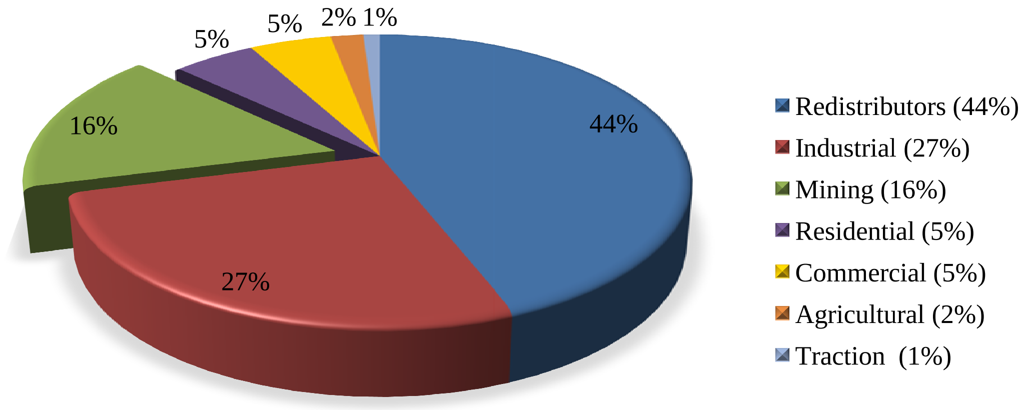

Figure 1-1: Electricity consumed per category of Eskom customers for 2009 (constructed from [2])

Redistributors are predominantly municipalities and Regional Electricity Distributors (REDS) where the distribution of electricity application is unknown. The other largest electricity consuming sectors in South Africa include the commercial, industrial, and mining sectors [2]. These sectors present excellent opportunities for Demand Side Management (DSM) projects [3]. Table 1-1 shows the average electricity consumption per Eskom customer in the mining and industrial sectors.

Table 1-1: Electricity consumption per customer for the major sectors for 2009

Sector	Total electricity consumption (GWh)	Number of Eskom customers	Average consumption per customer (GWh/customer)
Mining	32,177	1,144	28.13
Industrial	54,815	2,935	18.68

The total consumption of the mining sector is considerably less than that of the industrial sector. However, the average electricity consumption per customer in the mining sector presents the potential for more substantial electricity savings, generated by individual DSM projects.

1.2 Eskom DSM programme

1.2.1 Background

During periods of peak electricity consumption, the demand may approach significantly close to the available supply capacity. Eskom's supply reserve margins reduced from 8% in 2007 to 4% in 2008 [1], [2]. In 2009, South Africa experienced an economic recession resulting in a decrease in electricity consumption causing the reserve margin to increase to 14%. This margin was still lower than the internationally accepted range of 15% to 18% [3], [4].

When economic growth resumes, electricity demand will increase placing Eskom under more pressure to provide a reliable and sustainable supply of electricity [5], [6]. Eskom has received a $3.75 billion loan from The World Bank to invest in supply capacity expansion and the completion of the Medupi power station [7]. Capacity-increasing projects are however long-term projects, requiring up to eight years from conception to completion [8]. A short-term solution is required for the problem at hand.

1.2.2 DSM strategies

DSM is an attempt to manage consumer electricity demand and offers the following benefits:

- Short implementation time
- Small initial investment
- Short payback period
- Little environmental impact [9]

Successful DSM projects, which can be implemented within nine to twelve months, will provide short- to medium-term relief for Eskom [10]. This will allow Eskom time to complete capacity-increasing building projects.

Eskom subcontracts independent Energy Service Companies (ESCos) to implement DSM projects at mines. These projects undertake to achieve electrical load shifting, peak clipping or energy efficiency, particularly during the peak demand periods.

Load shifting is a means of shifting electricity demand from a peak time to an off-peak time, while still consuming the same amount of energy. Figure 1-2 illustrates the effect of load shifting on a 24-hour electricity usage profile. Weekday peak demand periods are indicated in this figure.

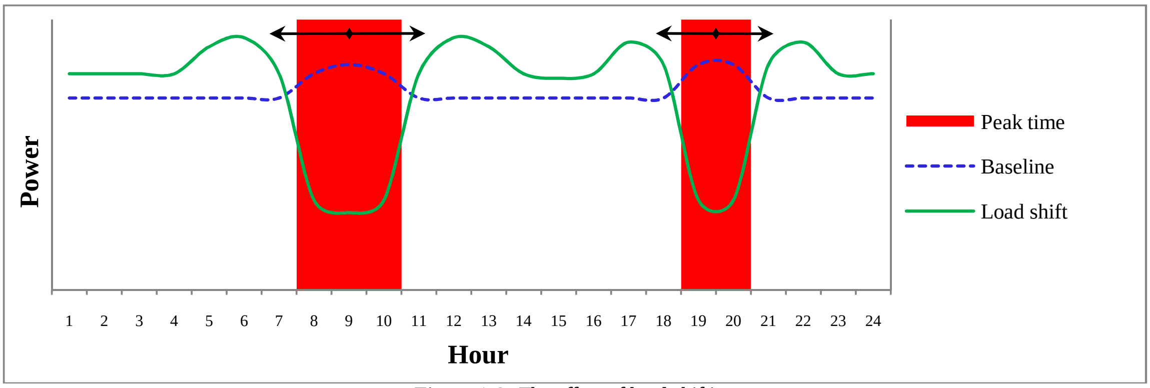

Figure 1-2: The effect of load shifting

Figure 1-3 shows the effect of peak clipping. Peak clipping reduces the amount of electricity used during peak periods. This is done by restricting electricity-intensive processes during the peak periods.

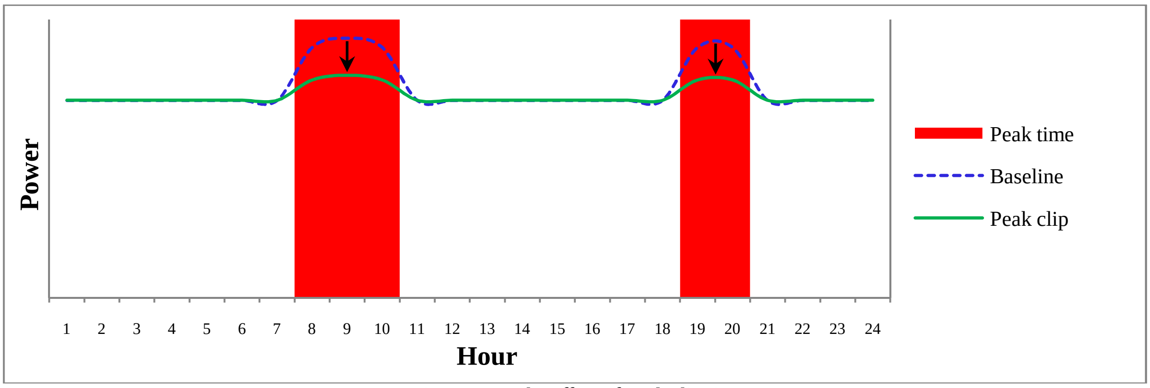

Figure 1-3: The effect of peak clipping

Energy efficiency reduces the total electricity consumption over a 24-hour period. Reducing unnecessary electricity consumption and using the most efficient equipment, result in energy efficiency as shown in Figure 1-4.

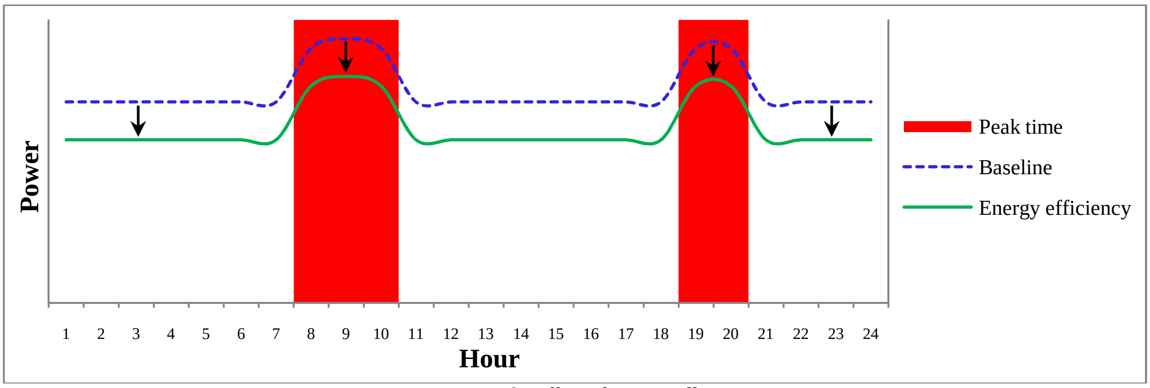

Figure 1-4: The effect of energy efficiency

The Eskom DSM programme focuses on the most feasible payback period for the investment made [11]. At present, the mining sector forms an important part of this DSM programme, with existing load shifting, peak clipping and energy efficiency projects [8].

1.2.3 Tariff structure

Eskom implements a tariff structure based on Time of Use (TOU), which has an increasing unit cost of electricity during peak-demand periods. Eskom's tariff structure is shown in Figure 1-5.

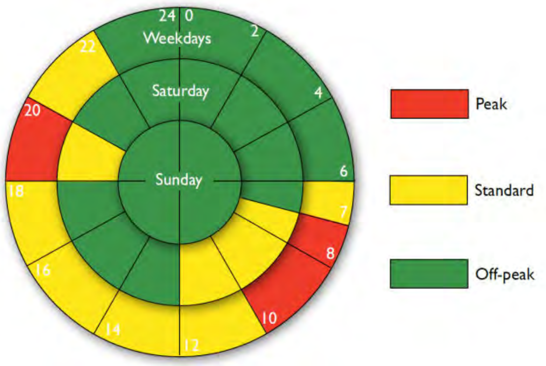

Figure 1-5: Eskom's TOU structure [12]

This structure is used for different TOU cost calculation for weekdays, Saturdays and Sundays. The TOU billing system indirectly acts as an incentive for mines to implement DSM projects. These projects strive to reduce electricity costs by minimising electricity consumption, specifically during Eskom peak periods.

1.3 Mine compressors as a significant electricity consumer

1.3.1 Typical mine electricity distribution

Natural methane gas is released as a result of underground mining. The risk of explosions, due to the ignition of methane gas, is considerably reduced when using pneumatic equipment. For this reason compressed-air systems, rather than electrical equipment, were originally installed at mines. As advances were made in the technology of electrical equipment for mining, electrical equipment became safer and more preferred than pneumatic equipment. However, compressed-air systems are currently used for a wide variety of applications and production purposes in the mining sector [13], [14], [15]. Because compressed air is also used for underground ventilation, it is an integral part of most mining operations.

Compressed air contributes 9% to the maximum demand in the mining and industrial sectors [8]. Electricity consumption data, obtained from AngloGold Ashanti South Africa, suggests that compressed air accounted for approximately 15% of the total electricity consumption of this mining group during the first quarter of 2010 [16]. Electricity, used by compressed-air systems, can however account for up to 20% of the electricity consumed on a typical gold mine [11].

1.3.2 Inefficient compressed-air systems

A typical compressed-air system, as used in the mining sector, is inefficient and expensive to operate [17]. Air leaks; increased airflow friction (due to the corrosion of steel pipes); inefficient pneumatic equipment; and a very long compressed-air network, result in the requirement for a large air supply [18]. Many opportunities present themselves for reducing the energy consumption of a compressed-air system by up to 50% [13], [14].

Compressed-air systems typically only effectively utilise 10% to 20% of the input energy [13], [18]. Figure 1-6 shows the cost distribution over the lifetime of a typical compressed-air system.

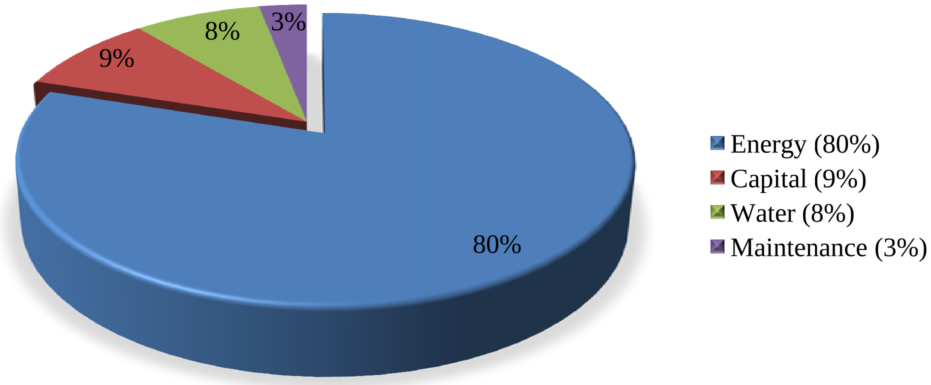

Figure 1-6: Cost components in a typical compressed-air system (adapted from [19])

Approximately 80% of the total costs incurred by the typical compressed-air system are attributed to the energy required to generate compressed air [19], [20]. The electricity cost for a compressor, running continually for one year, will exceed the capital spent on procurement of the compressor [2]. A significant reduction in energy consumption and operating cost of a compressed-air system can be achieved by supply-side optimisation [13], [14].

Incorrect or inaccurate compressor control is a contributor to inefficiency of the compressed-air system [15]. Peak pressure-demand periods, for example drilling shifts, which take place at scheduled times during the day, determine the maximum demand. Because of the high demand during a drilling shift, the compressed-air system operates at maximum load. No control is required and compressed air is supplied efficiently during these shifts. However, the operation becomes less efficient when compressed-air demand is less and the compressors continue to supply air at a constant high pressure [13].

1.4 Need for this study

The National Energy Regulator of South Africa (NERSA) approved Eskom's application for an average tariff increase of 24.8% for 2010/11, 25.8% for 2011/12 and 25.9% for 2012/13 [21], [22]. Electricity consumption and the rate of supply capacity increases are susceptible to influence from external factors. Irrespective of these fluctuations, the tariff increases result in an increased production cost in the mining sector.

After NERSA finalises the Power Conservation Programme (PCP) rules, mines might be allocated predefined energy consumption allowances each month based on previous consumption statistics. Energy consumption in excess of the allocated amount may result in PCP penalties [2], [10]. These penalties threaten to increase production costs even further, placing greater emphasis on the need for DSM projects. DSM savings reduce mining production costs, resulting in increased profit from mining activities.

Compressed-air system demand can be reduced by replacing old, less efficient pneumatic equipment and machinery with new, more efficient equipment. Replacement costs can be very expensive and this is not usually considered a viable option. Repairing and monitoring of system leaks are less expensive and will also contribute to a reduction in pressure demand. Reducing pressure demand alone will however be ineffective if the compressed-air supply cannot be properly controlled to match the reduced demand.

Both Eskom and the mine are beneficiaries of the proposed energy management solution. The benefits for each are listed below.

Mine:

- Facilitation of initiatives to reduce electricity consumption (required by PCP)
- Reduction in compressor operating cost and thus mining production cost
- Basis for implementation of projects to minimise compressed-air demand

Eskom:

- Contribution to achieving DSM targets
- Reduction in peak electricity demand
- Additional time to complete long-term capacity-increasing projects

1.5 Document overview

The aim of this research is the development of an energy management solution for mine compressor systems, with the focus on compressor control. The energy management solution consists of computer software capable of remote compressor control; and the hardware, which makes this control possible. This research document is organised in the following chapters:

Chapter 2: Overview of mine compressor systems

This literature study covers centrifugal compressor architecture, function and performance. General compressor control is discussed, followed by a comparison of existing energy management systems.

Chapter 3: Development of the energy management solution

Specifications are developed for the hardware required to achieve remote compressor control. The software development is based on these specifications. This allowed for easy integration of hardware and software to form a complete energy management solution.

Chapter 4: Verification of the energy management solution

The developed energy management solution was implemented on ten mine compressor systems. Two of these systems, one a basic and one an intricate compressor system, is presented as case studies. This is followed by a summary of the results obtained from all the implementations.

Chapter 5: Conclusion and recommendation

Conclusions are made based on the results presented in Chapter 4 and recommendations are made for future work.