The relationship between reoccurring plant failures and load shedding

SG Maringa
25402617

Mini-dissertation submitted in partial fulfilment of the requirements for the degree Master of Business Administration at the Potchefstroom Campus of the North-West University

Supervisor: Dr. HM Lotz
April 2017
ABSTRACT

In this mini dissertation, various components of research were explored to help in depicting a typical research problem. The research question was formulated to understand the reasons for reoccurring plant failures which, when not addressed, would lead to load shedding. The research tried to investigate whether there was a relationship/link between periods of plant failures and load shedding during the period 2007 up to 2014.

The research was conducted using both quantitative and qualitative data. The quantitative data was collected from Eskom WEB for the different power stations plant performances and a qualitative research questionnaire was design to gauge Eskom employees on their perceptions for reasons for reoccurring plant failures, different plant performances, check if they possess the required skills and knowledge to performance their jobs and whether management decision making and planning in the organisation were regarded to be sufficient to ensure a high performance culture.

Plausible recommendations were formulated from the resultant findings of the reoccurring plant failures with the aim to eliminate or at least reduce incidences of load shedding in the country.

The research is intended for both scholars of science subjects such as mathematics, physics, chemistry, statistics, biology and computer science, the Government, Eskom and the general public to aid in the understanding of reasons why reoccurring plant failures due to poorly maintained plants could lead to load shedding and what measures could be put in place to address or minimise occurrences of load shedding.

Various stages of research are discussed in detail within this research, crafting the history of Eskom, plant performance prior to load shedding occurrence and now.

Special care was taken to motivate the Government and Eskom to think beyond load shedding occurrences being caused just by the deficit in system capacity and to understand the significant impact of poor maintenance on load shedding.
The country lending sovereignty and growth is largely depended on a reliable energy sector which invariably prompts prospective researchers to learn systematic problem solving techniques for the country’s future growth and their learning growth prompting them to take up the challenging problems faced by Eskom and the country at large.

This research was chosen to inspire further research into the engineering and maintenance methods currently being applied so as to identify gaps and implement solutions that will improve Eskom electricity system reliability. This will ensure sustainable growth of the country which might even improve the negative GDP growth currently being experienced. The country is facing a possible downgrade, which looks more likely by the day, if nothing drastic is done to improve the growth of most sectors, of which the energy sector is the major player.
DECLARATION OF OWN WORK

I, Sifiso Maringa, declare that this report is my own, unaided work. It is submitted in partial fulfilment of the requirements of the Masters in Business Administration at North West University Business School. It has not been submitted before for any degree or examination at any other university or educational institution.

Signature

Date
ACKNOWLEDGEMENTS

I would like to acknowledge the following people for their contribution by providing information, time and support required to conduct this research:

- My Family especially my wife Makgwanya Maringa
- My Supervisor- Henry Lotz
- Eskom Management team
- Eskom Engineering team
- Eskom Occurrence Management team
- Colleagues both at the stations and around Generation
- Classmates
- Clarina Vorster cvlanguage.editing@gmail.com
- Outrospection Research Consultancy (Pty) Ltd for data analysis
- Prof Suria Ellis, Professional Science National, Associate Professor / Mede-professor (Statistical Consultation Services) North West University
# Table of Contents

ABSTRACT.......................................................................................................................... i  
DECLARATION OF OWN WORK.......................................................................................... iii  
ACKNOWLEDGEMENTS........................................................................................................ iv  
ABBREVIATION.................................................................................................................... vii  
LIST OF FIGURES................................................................................................................ ix  
LIST OF TABLES................................................................................................................... x  

CHAPTER 1: NATURE AND SCOPE OF THE STUDY .................................................................. 1  
  1.1 INTRODUCTION............................................................................................................. 1  
  1.2 PROBLEM STATEMENT.................................................................................................. 1  
  1.3 OBJECTIVES OF THE STUDY........................................................................................ 3  
    1.3.1 Primary objective...................................................................................................... 3  
    1.3.2 Secondary objectives .............................................................................................. 3  
    1.3.3 Benefits of the study............................................................................................... 3  
  1.4 SCOPE OF THE STUDY.................................................................................................. 4  
  1.5 RESEARCH METHODOLOGY........................................................................................ 4  
    1.5.1 Literature/theoretical study...................................................................................... 4  
    1.5.2 Empirical study........................................................................................................ 5  
  1.6 LIMITATIONS OF THE STUDY..................................................................................... 5  
  1.7 LAYOUT OF THE STUDY................................................................................................ 6  
  1.8 TERMINOLOGY............................................................................................................. 6  

CHAPTER 2: OVERVIEW OF THE ORGANISATION................................................................. 8  
  2.1 INTRODUCTION............................................................................................................. 8  
  2.2 OVERVIEW OF THE ORGANISATION.......................................................................... 19  
  2.3 CAUSAL FACTORS OF THE STUDY.............................................................................. 20  
  2.4 SUMMARY.................................................................................................................... 23  

CHAPTER 3: LITERATURE REVIEW........................................................................................ 24  
  3.1 INTRODUCTION............................................................................................................. 24  
  3.2 PLANT MAINTENANCE................................................................................................... 25  
    3.2.1 Planned maintenance............................................................................................... 26  
    3.2.2 Unplanned maintenance......................................................................................... 31
3.3  ACCIDENT/INCIDENT MANAGEMENT .......................................................... 33
  3.3.1  The difference between incident and accident .................................. 33
  3.3.2  Failure analysis techniques/methods ............................................... 34
3.4  QUALITY MANAGEMENT .......................................................................... 37
3.5  SUMMARY ................................................................................................. 41

CHAPTER 4: EMPIRICAL STUDY .................................................................. 42
  4.1  INTRODUCTION ...................................................................................... 42
  4.2  GATHERING OF DATA .......................................................................... 42
    4.2.1  Quantitative data presentation and analysis .................................... 43
    4.2.2  Qualitative data analysis ................................................................. 56
    Summary .................................................................................................. 56
    4.2.3  Section A: Demographical information ......................................... 57
    4.2.4  Section B: Skills and development .............................................. 64
    Skills and Development ......................................................................... 65
    4.2.5  Section C: Performance management .......................................... 66
    4.2.5  Section D: Plant performance ....................................................... 68
    4.2.6  Section E: Decision making and planning ..................................... 69
  4.3  INTER-CORRELATIONS BETWEEN THE DIFFERENT SECTIONS ......... 71
    4.3.1  Skills and development versus performance management ............ 71
    4.3.2  Plant Performance versus Decision Making ................................... 72
    4.3.3  Skills and Development versus Plant Performance ....................... 72
    4.3.4  Performance Management versus Decision Making and Planning .. 73

CHAPTER 5 .................................................................................................... 75
  5.1  INTRODUCTION ...................................................................................... 75
  5.2  CONCLUSION ......................................................................................... 75
  5.3  RECOMMENDATIONS ......................................................................... 79
  5.4  ACHIEVEMENTS OF THE OBJECTIVES OF THE STUDY .................... 81
  5.5  RECOMMENDATIONS FOR FUTURE RESEARCH .............................. 82
  5.6  SUMMARY ............................................................................................. 82

REFERENCES .............................................................................................. 83

ANNEXURES .............................................................................................. 89
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPA</td>
<td>Corrective Actions and Preventative Actions</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CM</td>
<td>Corrective Maintenance</td>
</tr>
<tr>
<td>CoPQ</td>
<td>Cost of Poor Quality</td>
</tr>
<tr>
<td>DSM</td>
<td>Demand Side Management</td>
</tr>
<tr>
<td>EAF</td>
<td>Energy Availability Factor</td>
</tr>
<tr>
<td>EXCO</td>
<td>Executive Committee</td>
</tr>
<tr>
<td>FMEA</td>
<td>Failure Mode Effect Analysis</td>
</tr>
<tr>
<td>FTA</td>
<td>Fault Tree Analysis</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>IPP</td>
<td>Independent Power Producer</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardization</td>
</tr>
<tr>
<td>KPA</td>
<td>Key performance Areas</td>
</tr>
<tr>
<td>KPI</td>
<td>Key performance Indicators</td>
</tr>
<tr>
<td>LCMP</td>
<td>Life Cycle Management Plan</td>
</tr>
<tr>
<td>MOI</td>
<td>Memorandum of Incorporation</td>
</tr>
<tr>
<td>MUT</td>
<td>Multiple Unit Trip</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatts</td>
</tr>
<tr>
<td>MYDP</td>
<td>Multi-Year Price Determination</td>
</tr>
<tr>
<td>NEDLAC</td>
<td>National Economic Development and Labour Council</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>NERSA</td>
<td>National Energy Regulator of South Africa</td>
</tr>
<tr>
<td>OCGT</td>
<td>Open Cycle Gas Turbine</td>
</tr>
<tr>
<td>OCLF</td>
<td>Other Capability Loss Factor</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OH&amp;S</td>
<td>Occupational Health and Safety</td>
</tr>
<tr>
<td>P/S</td>
<td>Power Station</td>
</tr>
<tr>
<td>PCLF</td>
<td>Planned Capability Loss Factor</td>
</tr>
<tr>
<td>PM</td>
<td>Planned Maintenance</td>
</tr>
<tr>
<td>PU</td>
<td>Production Unit</td>
</tr>
<tr>
<td>RCA</td>
<td>Root Cause Analysis</td>
</tr>
<tr>
<td>RCM</td>
<td>Reliability Centred Maintenance</td>
</tr>
<tr>
<td>SA</td>
<td>South Africa</td>
</tr>
<tr>
<td>SADC</td>
<td>Southern African Development Countries</td>
</tr>
<tr>
<td>SOC</td>
<td>State Owned Company</td>
</tr>
<tr>
<td>UAGS</td>
<td>Unplanned Automatic Grid Separation</td>
</tr>
<tr>
<td>UCLF</td>
<td>Unplanned Loss Capability Factor</td>
</tr>
<tr>
<td>YTD</td>
<td>Year to Date</td>
</tr>
<tr>
<td>ZLED</td>
<td>Zero Liquid Effluent Discharge</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1.1: Layout of the study .......................................................................................................................... 6

Figure 2.1: Eskom Reserve Margin trend since .................................................................................................10

Figure 2.2: Generation Energy Availability Factor ............................................................................................13

Figure 2.3: Plant breakdown trend from 2008 to 2015 ......................................................................................15

Figure 2.4: Eskom Coal Stockpile overview .....................................................................................................16

Figure 2.5: Eskom’s Organisational Structure .................................................................................................19

Figure 3.1: Maintenance strategies .................................................................................................................26

Figure 3.2: The bath tub curve concept ...........................................................................................................30

Figure 3.3: Number of failures reported from 1997 to 2003 in the turbo generators of a Mexican refinery ........................................................................................................................................32

Figure 3.4: Total quality management .............................................................................................................40

Figure 4.1: Generation Energy Availability Factor ............................................................................................44

Figure 4.2: Generation Unplanned Capability Loss Factor (UCLF)..................................................................45

Figure 4.3: Generation UAGS/7000 Hrs .........................................................................................................46

Figure 4.4: Planned Capability Loss Factor ......................................................................................................48

Figure 4.5: Top 3 plant failure areas that contributed to increased plant unreliability .....................................49

Figure 4.6: Plant Areas which failed the most and which stations contributed significantly ..........................50

Figure 4.7: Generation plant failures summary ...............................................................................................51

Figure 4.8: Energy Availability Factor from 2012-2016 ................................................................................55
LIST OF TABLES

Table 2.1: Current installed and commissioned base load stations of Eskom ........................................18

Table 3.1: Cost of nonconformance and maintenance strategy .................................................................39

Table 4.1: Gender of the respondents .........................................................................................................58

Table 4.2: Age group of the respondents ..................................................................................................58

Table 4.3: Ethnic group of the respondents ..............................................................................................59

Table 4.4: Academic qualifications of the respondents ..............................................................................60

Table 4.5: Respondents number of years working at Eskom .................................................................61

Table 4.6: Role of the respondents in the organization ..............................................................................62

Table 4.7: Department in which the responded work for .......................................................................63

Table 4.8: Reliability statistics for skills and development .........................................................................65

Table 4.9: Strength of the individual items under skills and development .............................................65

Table 4.10: Cronbach alpha coefficient for skills and development ......................................................66

Table 4.11: Strength of the individual item under performance management ........................................67

Table 4.12: Reliability statistics for plant performance ...........................................................................68

Table 4.13: Strength of the individual item under plant performance ....................................................68

Table 4.14: Reliability statistics for decision making and planning ........................................................70

Table 4.15: Strength of the individual item under Decision Making .....................................................70

Table 4.16: Skills and development versus Performance Management ................................................71

Table 4.17: Plant Performance versus Decision Making ..........................................................................72
Table 4. 18: Skills and Development versus Plant Performance ..........................................................72

Table 4. 19: Performance Management versus Decision Making and Planning ..........................73
CHAPTER 1: NATURE AND SCOPE OF THE STUDY

1.1 INTRODUCTION

Eskom is a South African state owned electricity power utility generating more than 95% of South African electricity. The company is 100% state owned and employs approximately 46 000 employees. Eskom (2014:25) performs different functions and operates a total of 27 power stations with an additional three newly built power stations currently under construction. These three new power stations are Ingula, Medupi and Kusile power stations. The current electricity capacity is approximately 42 000MW (Eskom, 2014:10 & 31) and will increase to more than 48 000MW when the new stations are completed and in operation.

Eskom generates, transmits and distributes its electricity to different industries, mining sectors, commercial sectors, agriculture sectors and most of South African residential areas as well as re-distributors. There is also some electricity being transported to the South African Developing Countries.

Eskom’s core purpose is to ‘provide a sustainable electricity solution to grow the economy and improve the quality of life of people in South Africa and the region’ (Eskom, 2014:8). It is a major driver of the South African economy, contributing about 3% of the country’s Gross Domestic Product (GDP), supplying approximately 95 % of South African electricity and 40% of the other Southern African Developing Countries (SADC) (Eskom, 2014:7). Currently, South Africa’s electricity demands have put lot of strain on Eskom as it is unable to supply the required demands. New avenues are being explored to supplement Eskom’s supply to ensure continuous supply with fewer interruptions to the country which is paramount to developing the country.

1.2 PROBLEM STATEMENT

The current biggest challenge for Eskom in ensuring adequate power supply to the country is sustained on a continuous basis whilst performing the necessary maintenance to ensure reliability of the system. With the current system demand, there is not adequate room to perform maintenance which has on numerous occasions
caused power shortages, forcing Eskom to implement load shedding to ensure system integrity. Currently, Eskom has operated just over a year without load shedding. This is mainly attributed to slow Gross Domestic Product (GDP) growth in the country and Eskom improving system stability through ensuring that minimum maintenance is still being carried out whilst supplying enough power not to go into load shedding mode. This has now become a balancing act which needs to be constantly managed until the three new power stations are online, in the hope that South Africa will not suddenly go into a positive growth that will surely put the country back into load shedding mode again.

The main contributors for the poor system availability have been highlighted as the following as per Eskom’s then Chief Executive in 2014, Mr. Tshediso Matona (Eskom presentation 2014: slide 5-6):

- Running the plant hard and delaying critical maintenance in Eskom past efforts to keep the lights on.
- Deterioration of maintenance quality.
- Sixty-four percent of Eskom’s current installed base load capacity plants are past their midlife, requiring longer outages and extended restoration time than planned.
- Declining coal quality impacts plant performance with the result of additional maintenance being required.
- Weather conditions, such as extreme heat or prolonged heavy rains.
- Disruptions of fuel supply to power stations.

The main purpose of this study was thus to investigate the contribution of reoccurring plant failure that occurred during the period 2004-2014 and linking those repeat incidents to load shedding incidents that occurred between 2007 and 2014. The study again sought to identify the main contributors to the recurring plant failures.

The study also sought to reveal the importance of ensuring proper and adequate skills development, performance management practices and that proper decision making and planning take place in relation to their contribution to recurring plant failures. Among the questions that were explored were: is the organisation properly structured to address
issues of poor plant performance, are decisions made at the correct levels and is the organisation equipped adequately to timeously respond to incidences of increased energy demand?

1.3 OBJECTIVES OF THE STUDY

1.3.1 Primary objective

The primary objective of the study was to investigate the relationship between reoccurring plant failures and load shedding and to make recommendations to reduce or even eliminate the occurrence of load shedding.

1.3.2 Secondary objectives

- To investigate the possibility of poor plant maintenance contribution to reoccurring plant failures.
- To investigate the importance of ensuring proper and adequate skills development and performance management practices and that proper decision making and planning take place in relation to their contribution to recurring plant failures.

1.3.3 Benefits of the study

The main benefits of the study were to achieve the following:

- To improve plant availability
- To reduce the need for load shedding
- To reduce the number of reoccurring plant failures in Eskom generation
- To improve national grid reverse margin for stable grid performance.
- To improve Eskom’s and South Africa’s image to draw back investors to the country
- To make it easy for Eskom to get the necessary funding to continue with the much needed electricity built programs
1.4 SCOPE OF THE STUDY

(Discipline, subject / geographical demarcation / industry / organisation)

This study was conducted in the energy sector industry, a state owned company (SOE), Eskom. The study focused on the Eskom Generation Division, Power Stations, which are the main electricity generation division. The technical disciplines which consist of engineers, technicians, artisans, incident investigation team members, some technical managers and Integrated Business Improvement practitioners, were approached for this study.

1.5 RESEARCH METHODOLOGY

1.5.1 Literature/theoretical study

Research methodology is a way in which the researcher systematically solves the research problem. It considers and explains the logic behind research methods and techniques used in the context of the research study (Kothari, 2009:8).

Kothari (2009:8) further explains that research methodology is aimed at “finding the reasons for undertaking a research study, how the research problem has been defined, in what way and why the hypothesis has been formulated, what data have been collected and what particular method has been adopted, why particular technique of analysing data has been used and a host of similar other questions are usually answered when we talk of research methodology concerning a research problem or study”. It is further supported by Kruger, et al. (2010:13), that research problems should consider the literature and identifying any gaps. These gaps indicate original areas of research (Fanie Kruger, 2010).

The sources that were consulted included but were not limited to:

- Eskom web.
- Municipality web for load shedding implemented, engineering journals and the internet.
Eskom data base. The study is executable as we have the actual power station incidents/plant failures from the investigations conducted between 2004 and 2014.

Text books.

Journals articles.

The key words that were used were load shedding, reoccurring plant failures, plant maintenance, plant availability, plant unavailability and incident management.

1.5.2 Empirical study

The empirical analysis carried out for this research was both qualitative (Eskom staff answering a structured questionnaire) and quantitatively (analysing Eskom plant performance data linking it to load shedding). The results were then analysed using statistical analysis measuring instruments and scoring the results to be able to make an interpretation of the results.

This quantitative data approach ensured that hard technical facts of plant performance were analysed and an objective conclusion reached. The qualitative data analysis helped to understand the human, process, structures and system challenges which, if addressed, might assist to eliminate or at least, reduce the frequency of load shedding by putting in measure to improve that plant reliability that would reduce recurring plant failures.

1.6 LIMITATIONS OF THE STUDY

The major limitation of the study was that it excluded Transmission and Distribution division contribution to reduced energy reserve margin. Investigations carried out by the above two divisions were not part of the research and thus their contribution was excluded. The limitation impact was minimised by looking at the contribution of generation incidences directly linked to power shortage and thus load shedding contribution discounting the other two division’s impact.
Due to the fact that the researcher works in Generation Division, the report mainly focused on Generation Division’s plant and people’s performance to understand their contribution to poor plant performance and their link to load shedding incidences. By virtue of the researcher working in Generation, information access was easier.

1.7 LAYOUT OF THE STUDY

The study followed specific steps to ensure that a desired outcome was reached and that all the research principles were covered. Figure 1 below illustrates the steps followed to conduct this particular research.

**Figure 1. 1: Layout of the study**

1.8 TERMINOLOGY

- **OCLF:** This indicator measures the production losses that are incurred by the Power Station due to other factors outside management control, mainly caused by external factors such as coal qualities supplied by the mines.
- **PCLF:** Measures the planned outages (production losses) that are utilised for the implementation of maintenance activities. The Power Stations PCLF target is 10% however it varies as per the Outage Philosophy. From the data review, it is evident
that the average PCLF for the six years is 10%, even though the target is not met yearly.

- **UCLF**: This is an indication of all unplanned production losses incurred by the Power Station due to several factors like plant breakdown, major incidents etc. The target for the Power Station for UCLF is 10%. If this indicator is high, it indicates poor performance.

- **EAF**: The overall Generation performance and availability is measured by the Energy availability factor which is the indicator that measures the combination of UCLF, PCLF and OCLF \( \text{EAF} = (100\% - \text{UCLF} + \text{PCLF} + \text{OCLF}) \). This indicates that the higher UCLF, PCLF and OCLF, the lower EAF. The target for the Generation is 80% (EAF), 10% (PCLF) and 10% (UCLF).

- **Load shedding**: The loss of power supply to part of a municipality or district due to Eskom not having enough energy reserve. This is done to protect the National Energy grid from total collapse.

- **Unipede**: This is the total unit of measure of the technical performance of the Generation plant. It measures the UCF, UCLF, EAF, OCLF and AUGS.

- **Blackout**: Total loss of the National Grid power supply. This means all the units supplying the grid have tripped or shutdown, effectively separating themselves from the grid, leading to total loss of power. This state can take a few days up to a week or more to restore since the grid will be starting from almost zero base.
CHAPTER 2: OVERVIEW OF THE ORGANISATION

2.1 INTRODUCTION

Eskom as a state owned company (SOC) is owned by the Government of South Africa. Eskom evolved over the years from Electricity Supply Commission (Escom) which was first established on 1 March in 1923 under the leadership of its first chairman, Doctor Hendrik Johannes van der Bijl. The primary goal behind the establishment of Escom was to supply government departments such as railways and harbours, local authorities and industry with cheap and abundant electricity.

Over the years, Eskom has been mandated by the South African Government to expand its energy supply to other industries such as the mines, the smelter and the municipalities. Eskom has always fallen under the Republic of South Africa and it has been incorporated in accordance with the Eskom Conversion Act, Act 13 of 2001 and continues to exist as a State-Owned Company (SOC) as defined in the Companies Act, Act 71 of 2008. As a SOC, Eskom’s purpose is to deliver on the strategic intent mandated by government and detailed in the Memorandum of Incorporation (MOI).

Mandate of Eskom

Although Eskom’s mandate has not changed over the years, it has expanded. The mandate is still to provide electricity in an efficient and sustainable manner, including its generation, transmission, distribution and sales. Eskom is and for the foreseeable future will remain a critical and strategic contributor to the South African Government’s goal of ensuring security of electricity supply in the country as well as economic growth and prosperity (Eskom, 2016:42).

Eskom vision statement as per Eskom Holding Corporate Plan (2016:29)

“Sustainable power for a better future”
Eskom mission statement as per Eskom Holding Corporate Plan (2016:29)

Eskom’s mission statement is, “to provide sustainable electricity solutions to grow the economy and improve the quality of life of the people in South Africa and in the region”.

Core values

Eskom has seven values which are:

1. Zero harm: Eskom will strive to ensure that zero harm befalls its employees, contractors, the public and the natural environment.
2. Integrity: Honesty of purpose, conduct and discipline in actions and respect for people.
4. Sinobuntu: Caring
5. Customer satisfaction: A commitment to meet and strive to exceed the needs of the receiver of product and service.

Key shifts in the Policy and Business Environment impacting Eskom

In keeping with the times, Eskom has evolved over the past 30 years due to government business and policy shifts from the late 1980s to presently which have shaped Eskom’s business environment. The downward trend impact was really felt in 2008, when South Africa experienced its first load shedding.

Eskom power status trend since 1999

- There has been a consistent decline in the energy reserve margin (see Figure 2.1 below).
- Eskom started to see an unprecedented increase in power usage of the generation fleet (measured by load factor).
- There has been an increase in unplanned outages of the generation fleet (UCLF).
Energy Availability Factor (EAF) started decreasing after it has been characteristically operating above 85% (see Figure 2.1 below).

**Figure 2.1: Eskom Reserve Margin trend since**

![Eskom Reserve Margin trend since](chart)

Source: Eskom (2011:34)

Eskom, as the major supplier of electricity in the country, always tries to match electricity demand with the electricity that it can supply to satisfy the South African economy. In the early 1980s, Eskom started predicting continued economic growth in the country and started placing contracts to build and augment current capacity with three new power stations consisting of six packs coal fired power stations. The stations are now known as Matimba (built in Lephalale), Kendal (built near Ogies in Mpumalanga) and Majuba (built near Volksrust at the edge of Newcastle).

The plan was to build all three power stations within a timeframe of three years apart. The construction of Majuba Power Station began in 1986. The anticipated growth did not materialise which necessitated Eskom to review the construction programmes of the three power stations within the three year space period to a longer timeframe. Kendal and Matimba power stations were built as initially planned.

Following studies of the options available, it was decided during 1988 to defer the Majuba project by three years. Contracts not yet placed or whose construction had not
yet started, would be deferred by the three year period and those whose construction had begun, split into a first phase of structural and major mechanical erection and the second phase erection and commissioning deferred by the same period.

Majuba Power Station, as the latest power station, was shelved from 1990 when it was discovered that the coal seams that was mined from the dedicated mine, namely Rand Mine, had a lot of dolomite. The process to separate the coal from the dolomite proved to be too expensive leading to a decision of closing down the mine. The decision to close the mine effectively shelved the construction of the power station. Since there was no urgency of increasing the electricity demand, Majuba construction was not necessary and Eskom thus did not know where and how they would obtain the coal to continue with the station commissioning.

There are major determinants in building a power station and if they are not satisfied, the need to build the power station is reviewed. For Majuba Power Station which holds true for all the coal fired power stations, the following considerations had to be reviewed:

- The economic life of Majuba with uncertain coal supply.
- Will all six units realise a full life expectancy of 50 years within the prevailing environment of uncertain coal supply?
- Material and equipment being sources, will they be able to give the expected power delivery as assumed during the studies of the construction of the station.
- What operating regime will be followed between Load Follow/Base Load operations?
- Is it possible to meet the set generation target of plant availability operating at 90% availability, 7% for planned maintenance and 3% for unforeseen plant breakdowns?
- Is there available water and if not, how will the turbine be cooled? Majuba went for three units using wet cooled condensers and the other three dry cooled condenser units due to the shortage of water in the area.
- All requirements for and legislation pertaining to a ZLED (Zero Liquid Effluent Discharge) site will be fully complied with.
- What maintenance strategy will be followed to ensure that the life expectancy of the power station is realised?
- How is the construction and commissioning of Majuba Power Station going to be financed and what will be the cost of building such a power station at the prevailing energy climate with the challenge of unavailable coal supply?

Majuba station management looked at alternative coal sources and eventually it was agreed that the station would go through different suppliers in order to not be tied down by a long-term coal contract to force coal mines to give them the best price for the coal on the spot market. Majuba Power Station’s commissioning plans furthermore took off whereby coal would be trucked by means of railway line especially built for and dedicated to the station.

The reserve margin was above 25% (Figure 2.2) prior 1999. In fact, when Majuba was eventually built and commissioned from 1996, there was already a surplus in energy demand. Majuba, situated in the South-eastern Highveld of Mpumalanga Province at an altitude of 1 709 meters (5 607 feet) above sea level, was Eskom’s newest power station. The power station consists of 3 x 657 MW direct dry cooled and 3 x 713 MW indirect wet cooled coal fired units, totalling 4 110 MW generating capacity. The first unit was declared commercial on the 1st of April 1996, with Unit 6 being commissioned presently.

The power supply then grew with the commissioning of Majuba and it reached 27% by 1999 (see figure 2.1 above). More electrification took place as it was part of government mandate which meant that the power demand started to pick up. More houses and industries were connected to the power grid and no more power stations were built since 1999. The energy demand kept on picking up which led to Eskom approaching the Government in 2001, showing a projection that if no more power stations were to be built, the energy would be dropping to the 15% energy reserve by 2007.

By 2003, the energy reserve was already at 15.9 and still dropping (see figure 2.1 above). By 2014, the energy reserve reached 8.2% which was way below the industry standard (Figure 1.2). This led to the Government looking for quick solutions and in a huff and puff mode, the three power stations, namely Komati, Camden and Grootvlei
which at the point in time, were mothballed, had to be brought back to stream. At the same time, Gas Turbines (Gourikwa and Ankerlig) were commissioned to boost the energy during peak time. All the above actions reactions, were meant to halt the decreasing energy supply whilst Eskom was mandated again to start building the bigger coal fired power stations (Kusile and Medupi) and 1 Pump Storage power stations (Ingula) (Eskom 2007: 4). Since 2003, the energy reserve has never been above the 15% mark.

Even now, with the construction and commissioning of Kusile, Medupi and Ingula, Eskom is still struggling to ensure safe and reliable energy supply. The energy availability factor is still way below the 80% availability and was 76% in 2015 (Figure 2.2). This means that the system is not healthy for it to be able to sustain instances of loss of big machines without the risk of plunging the country into another load shedding situation as those which were seen in 2007 and early 2014.

Figure 2.2: Generation Energy Availability Factor

Source: Eskom (2015:36)
In 2001, the focus was on ensuring that there was a match between electricity demand increase and the coal stockpiles reserves which were then far below the Eskom station plan for the period leading to dangerously low stockpiles which would have plunged the country into total darkness for an extended period whilst coal supply was being restored. As mentioned by Eskom, “The direct correlation between the declining reserve margin and increased load factor underlines the drive since 2001 to maximise use of existing generation capacity – which in turn put pressure on plant performance levels and primary energy usage (i.e. coal)” (Eskom 2015:58.).

Figure 2.1 above depicts a declining reserve margin over the years from 27.1% in 1999 to 5% in January 2008 and to 10% December 2014 that reduced energy reserve margin making it difficult for quick response to energy shortage.

The main contribution, as per Eskom’s Chief Executive in 2014, Mr. Tshediso Matona (Eskom, 2014: slide 5-6), in the deteriorated power supply was attributed to the following:

- Running our plant hard and delaying critical maintenance in our past efforts to keep the lights on.
- Deterioration of maintenance quality.
- Sixty-four percent of Eskom’s current installed base load capacity plants are past their midlife, requiring longer outages and extended restoration time than planned.
- Declining coal quality impacts plant performance with the result of additional maintenance being required.
- Weather conditions, such as extreme heat or prolonged heavy rains.
- Disruptions of fuel supply to power stations.

The plant breakdowns increased from around 2000MW in 2008 to above 5500MW in 2014 (see Figure 2.3 below).
Coal stockpile levels and coal quality

In 2007-08 financial years, the coal stockpile across the generation fleet dropped from 25 days to 15 days by the end of the financial year. This was the first time in Eskom history that the coal stockpiles went to slow. (Figure 2.4). From the early 1990s to 2000, the system coal stockpile levels were above 60 days. This reduced to just over 40 days between 2000 and 2005. From 2006 to 2007 the levels dropped from 35 days to 28 days and from June to December 2007 they further dropped from 20 days to 15 days. The levels then dropped dramatically to an unsustainable 11 system days towards the end of 2007 leading to the first nationwide load shedding incident. The direct causes for the decreasing coal level trends were as follows:

- Increased production at certain coal-fired power stations
- Lower than expected coal volumes at collieries directly supplying stations
- Lower than expected coal quality resulting in thermal inefficiency and accelerated wear on the boilers
- Challenges around coal transportation logistics
Challenges with coal

Higher than average rainfall patterns occurred from October 2007 to February 2008, with the South African Weather Services confirming that, in some areas, this was the highest rainfall in decades. In previous years when high rainfall occurred, the level of stockpiles was much healthier allowing access to dryer coal underneath the wet coal. In addition, excess capacity allowed output reductions due to wet coal handling problems and combustion problems to be compensated by plants that were available in reserve.

Eskom reaction to load shedding

Load shedding was implemented from November 2nd 2007 to December 8th 2007 as result of the above reasons. Plants have were then operated to their maximum capabilities since the first load shedding incident reared its head in 2007 to curb further incidents of load shedding. Coal supply problems have been addressed on all sites by ensuring that mines stick to their delivery promise through the imposing of heavy penalties and monitoring their performance on a daily basis. Coal stockpiles have been increased back to the 60 days limit with the lowest stock level allowed being 45 days at
any given moment. Tetris maintenance planning too was introduced which drastically improved plant system reliability.

The Tetris maintenance tool is life and therefore looks at the current energy power supply versus energy demand versus maintenance requirements of the different power units to determine how many power units can be taken out of service to conduct the necessary maintenance. Even with the Tetris maintenance planning too, most plants are continued being operated above the planned maintenance schedules at times to satisfy demand. This will be the situation of the balancing the supply and demand until the two big power stations are on line around 2020-2021 (Medupi and Kusile). Ingula power station is current full on line which has somewhat helped to stabilise the grid system.

_Eskom Current Power Mix_

Eskom’s current base installed plant has been in operation since 1966 and is mostly reaching its end of life (see Table 2.1 below). Grootvlei, Komati and Camden were retired during the period when Eskom had excess capacity and due to the increased electricity demand and the low reserve margin, all three stations were brought back to service. The business case of Eskom was not supporting the de-mothballing of the three stations due to the exorbitant cost of bringing them to service and the life remaining of operating them but due to the fact that it would take at least ten years to commission a new power station. The quickest stations to bridge the gap was the two mothballed power stations and the building and commissioning of new gas turbines which were all situated in in and around Cape Town, to reduce gas transport cost.
Table 2.1: Current installed and commissioned base load stations of Eskom

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Nominal capacity MW</th>
<th>Year fully commissioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired stations (14)</td>
<td></td>
<td>36 551</td>
<td></td>
</tr>
<tr>
<td>Arnot</td>
<td>Middelburg, Mpumalanga</td>
<td>2 232</td>
<td>1975</td>
</tr>
<tr>
<td>Duvha</td>
<td>Emalahleni</td>
<td>3 450</td>
<td>1984</td>
</tr>
<tr>
<td>Grootvlei</td>
<td>Balfour</td>
<td>1 120</td>
<td>1969, mothballed in 1990, recommissioned in 2009</td>
</tr>
<tr>
<td>Hendrina</td>
<td>Emalahleni</td>
<td>1 793</td>
<td>1976</td>
</tr>
<tr>
<td>Kendal</td>
<td>Emalahleni</td>
<td>3 840</td>
<td>1993</td>
</tr>
<tr>
<td>Komati</td>
<td>Middelburg, Mpumalanga</td>
<td>904</td>
<td>1966, mothballed in 1990, recommissioned in 2009</td>
</tr>
<tr>
<td>Kusile</td>
<td>Witbank, Mpumalanga</td>
<td>0</td>
<td>1st unit is being commissioned</td>
</tr>
<tr>
<td>Kriel</td>
<td>Bethal</td>
<td>2 850</td>
<td>1979</td>
</tr>
<tr>
<td>Lethabo</td>
<td>Viljoensdrift</td>
<td>3 558</td>
<td>1990</td>
</tr>
<tr>
<td>Majuba</td>
<td>Volksrust</td>
<td>3 843</td>
<td>1996</td>
</tr>
<tr>
<td>Power Station</td>
<td>Location</td>
<td>Capacity</td>
<td>Commissioned</td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
<td>----------</td>
<td>--------------</td>
</tr>
<tr>
<td>Matimba</td>
<td>Lephalale</td>
<td>3 690</td>
<td>1993</td>
</tr>
<tr>
<td>Matla</td>
<td>Bethal</td>
<td>3 450</td>
<td>1983</td>
</tr>
<tr>
<td>Medupi</td>
<td>Lephalale</td>
<td>800</td>
<td>2nd Unit being commissioned</td>
</tr>
<tr>
<td>Tutuka</td>
<td>Standerton</td>
<td>3 510</td>
<td>1990</td>
</tr>
</tbody>
</table>

Source: Eskom Standard Presentation (2015:14)

2.2 OVERVIEW OF THE ORGANISATION

Eskom’s structure supports the organisational strategy and mandate. The structure clarifies the role and main mandate of each entity within Eskom and the elements have been brought together into the structure, where there are line functions ‘operating the business’, service functions to ‘service the operations’ and strategic staff functions to ‘develop the enterprise’ as depicted in Figure 2.5 below.

**Figure 2.5: Eskom's Organisational Structure**

Source: Eskom Holding Corporate Plan (2016/2017:36)

The governance in this structure is a combination of a more targeted Executive Committee (EXCO) and a broader Management Committee, which include line leaders.
and functional leaders. The structure is based on closer links between the business and the executives. It has clear roles and responsibilities for each layer of leadership, with EXCO providing overall guidance while the Management Committee team collectively supports EXCO in running the business.

Eskom’s structures have been designed around the following governance principles (Eskom Holdings Corporate Plan 2015/16–2019/20 Revision 3):

- Transparency
- Decision-making at appropriate levels
- Strengthened individual accountability
- Improved committee structures and simplified processes to deliver results
- Clearly defined roles and responsibilities (e.g. line/corporate, operating units/functions)
- Elevated participant capabilities and behaviour

Generation Division’s core business is the electricity generation process. The process of energy generation is based on the principle of energy conversion whereby energy is converted from one form to the other. The energy conversion begins with chemical energy (coal) which is converted to heat energy (steam boiler) which is then converted to mechanical energy (turbine blades) and finally to electrical energy (Eskom, 2013:6).

Power stations are designed for a 50 year lifespan and have in modern days being successfully extended to 60 years with proper maintenance plans and sound operational principles. South Africa’s economic growth, future infrastructure development and other long-term plans by the Government depend on electricity reliability and availability.

2.3 CAUSAL FACTORS OF THE STUDY

In January 2008, Eskom introduced load shedding – planned rolling blackouts based on a rotating schedule, in periods where short supply threatened the integrity of the grid. Demand-side management focused on encouraging consumers to conserve power during peak periods in order to reduce the incidence of load shedding. Eskom took
steps to maintain some of its plants, increase coal stock piles and improve plant performance which had led to them suspending load shedding from May 2008 onwards.

Eskom is contractually obliged to fund the capital for six cost plus mines to stay in business and to contribute 60% to the New Largo Colliery (Kusile Power Station tied colliery) establishment and stay in business capital. Failure to capitalise the mines will result in reduced coal production from these collieries and higher cost incurred in purchasing the coal from other third party suppliers (Eskom, 2015/16–2019/20: Revision 3:61).

Eskom is continuously experiencing difficulty in concluding medium-term and long-term contracts due to mining houses pricing exceeding the NERSA predetermined unit cost of coal. Mining houses are also demanding export parity prices. The coal market is unregulated posing a huge challenge for Eskom.

Immediately after the declaration of the national emergency by Government on the 25th of January 2008, a National Response Plan was launched focusing on demand-side initiatives, sectorial interventions (government buildings and freight rail) and supply-side initiatives. Eskom launched an internal recovery programme in line with this plan but also included initiatives to deal with identified weaknesses. This plan was focused on the security of the supply situation (Eskom, 2015/16–2019/20: Revision 3:61).

A social dialogue was also convened in May 2008 to discuss the cost of supply precipitated by the requested tariff increase. This was done through the National Economic Development and Labour Council (NEDLAC). Some consensus was reached on the need for a higher level of price increases but for it to be smoothed over several years. NERSA also publicly stated its view on a possible five-year price path. Since then, Government has indicated its commitment to some level of financial support for Eskom as well as some level of guarantees for Eskom debt (Eskom, 2015/16–2019/20: Revision 3:61).
Eskom’s new build programme

In 2005, Eskom embarked on a capital expansion programme in order to support South Africa’s economic growth and increased energy requirements. Eskom is constructing new power stations that will provide an additional 11 096 MW of generation capacity which is in addition to the 6 137 MW of capacity that has been added to the system from 2005 to September 2013 (Eskom, 2015/16–2019/20: Revision 3:61).

Key projects currently in construction include Medupi, Kusile, Ingula, Sere, Majuba Rail and Power Delivery projects. These projects are at different stages of implementation. Eskom is also currently expanding its transmission grid throughout the country. The transmission projects secure the uplink of industry and households to electricity. The most extensive project is the upgrading of the grid to N-1 status.

Expanding generating capacity will see an estimated expenditure of R340 billion (excluding capitalised interest) by 2019/20, with over 17 000 megawatts of additional capacity due to be online by 2022.

Although significant progress has been made with the New Build Programme, there have been delays and other challenges to the completion timelines of the programme due to the following:

- Labour unrest
- Safety incident
- Under-performance by key contractors
- Critical technical challenges, for example, the welding on the boilers and the control and instrumentation systems for the units

MYPD3 Determination and the resulting shift in Eskom’s operating environment

In February 2013, NERSA determined an 8% tariff increase from the applied tariff increase of 16%. The impact of the NERSA determination required significant changes to the business. Eskom as a wholly state-owned company necessarily pursues a comprehensive mandate. It therefore serves not only to power South Africa’s economy but also contributes to the wider development of the country at large. While Eskom’s
mandate and strategic objectives remain unchanged, the strategy to deliver on its mandate was further compromised by the determination. In 2013, Eskom developed a response strategy to its various challenges including the NERSA determination. The aim of the strategy was to ensure Eskom’s sustainability in a changing environment and was built on the Integrated Delivery Plan and outlined more specifically the key trade-offs and risks that Eskom faced immediately and in the more medium- to long-term, as well as the implications for Eskom’s business model (Eskom, 2015/16–2019/20:Revision 3:62).

2.4 SUMMARY

Eskom power supply has been less than desirable since late 2007, culminating with the worst performance in early 2008. The term blackout was used for the first time in Eskom history during that period. Since then, the system has somewhat stabilised. There has been a lot of speculation as to why, but one of the contributions is that, during the bad period of 2008, Eskom reached an agreement with bigger consumers like the smelters and the mines to shed 10% of the energy consumption. That agreement is still in place and it has since been hurting the bigger suppliers. There is a concern that, if the bigger suppliers insist to increase their consumption to 100%, Eskom might go back to blackout scenarios again.
CHAPTER 3: LITERATURE REVIEW

3.1 INTRODUCTION

Electricity crisis is something which has long been coming in South Africa. Nick Smith, on his narration of Road to a Blackout, wrote that “It was here, in 2000 and again in 2001, that key government officials and regulators met top Eskom executives to chart the way forward for SA’s electricity industry”.

It was a road into unknown territory, embarked on with the best of intentions, but with the most disastrous of outcomes. This misconception about power prices led to inappropriate investments in electricity-intensive industries, while at the same time there was enormous political pressure to provide power cheaply and widely to a country emerging from a past where basic services were the preserve of the minority (Smith, 2008:1).

In the third week of January 2008, more than 20% of South Africa’s electricity-generating capacity was out of commission. By the fourth week, a quarter of Eskom’s capacity was unavailable. Huge blackouts occurred throughout the country (Degut et al., 2013:1).

In December 2014, Eskom’s then CEO, Tshediso Matona, had to make a public announcement on the reason behind Eskom’s failure to supply electricity to the country on a continuous basis, leading to frequent load shedding in some areas. During that time, there were concerns that the electricity system would collapse, leading to the country experiencing a blackout state.

In the 2005, according to a World Bank Enterprise survey, one-third of Indian business managers named poor electricity supply as their biggest barrier to growth. According to these managers, blackouts were far more important than other barriers that economists frequently studied, including taxes, corruption, credit, regulation and low human capital (Alcott, 2014:2).
3.2 PLANT MAINTENANCE

Maintenance strategies are typically developed per facility or machine to be maintained. The methodology mostly used for this purpose is that of Reliability Centred Maintenance, combined with statistical failure analysis to understand the failure modes involved well enough to be able to develop strategies that will lead to a high positive impact on the profit of the company.

Devising optimal maintenance strategy for maintaining a plant can be a complex task. “An effectiveness maintenance strategy can be known only if one is able to identify and evaluate a given maintenance strategy (Pintelon et al., 2006:8). Pintelon et al. also concluded that for long-term effectiveness of a company, maintenance should be managed properly for long term contribution of enhancing the competitive advantage of a company. The study clearly showed that companies that seek a balance of excellence in all of their functions perform better (Pintelon, 2006:19). Velmurugan (2015:1628) explains maintenance strategy as a road map for maintenance which includes alternatives, provides direction, flexible enough to adjust with the changing environment.

Reliability Centred Method (RCM) to be effective, it is based on proactively performing Preventative Maintenance (PM) program. When PM’s are performed correctly, plant availability could be improved by only one or two percent points which has huge payoff in the multimillion-dollar range for a company like Eskom. Failure is detrimental to the objective of the organisation. Okoh (2013:494) states that the integrity of the barriers cannot be maintained without adequate level of maintenance. Maintenance is therefore a key activity to reduce the risk of major accidents.

Each time failure occurs, money is lost, either due to the cost of repairing the failure, production loss incurred or both the cost and production. The process of these failures has to be managed properly. The most important aspects of such managed process are derived from maintenance strategy setting, deciding what maintenance to do, when and how often (Prajapati, 2012:385). This is what Reliability Centred maintenance is all about - providing maintenance strategies with a road map to find the most suitable maintenance strategy for equipment.
The challenge is to optimise the balance between them for maximum profitability. In general, corrective maintenance is the least cost effective option when maintenance requirements are high. Various maintenance strategies are indicated in Figure 3.1 and they are subsequently discussed.

**Figure 3.1: Maintenance strategies**

![Maintenance strategies diagram]


### 3.2.1 Planned maintenance

Planned maintenance is the type of maintenance that can be deferred and/or properly planned. There are a few categories of planned maintenance, namely:

- time based, age based, and condition based, which means that the system has to be taken out of operation; and
- Opportunistic maintenance means that a unit will perform preventive maintenance only when its maintenance opportunity reaches some certain value Hou and Jiang (2013:283).
Typical maintenance strategies followed by bigger industries such as power generations and aviation are dependent on the cost of breakdown to production and the cost of premature repairs.

3.2.1.1 Corrective maintenance

There are two types of corrective maintenance. This is the type of maintenance that is done after the plant equipment has already failed and it is done to bring it back to its original state.

- Run to failure

Corrective maintenance is basically the "run it till it breaks" maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended, either to prevent failure or to ensure that the designed life of the equipment is reached (Shafiee et al., 2015:387; Ioannis & Nikitas, 2013: 25).

- Opportunity maintenance

Maintenance carried out when there is forced shutdown on other parts of the plant, e.g. boiler tube leaks. This is typical the case where the continuous operation of the plant is critical and/or the loss incurred during plant downtime is severe. The task are scheduled for execution but only carried out when the opportunity arises (Shafiee et al., 2015:387). As indicated by Ab-Samat & Kamaruddin (2014:116) opportunity maintenance can reduce the number of breakdowns and machine stoppages especially in the continuous operations.

3.2.1.2 Preventative maintenance

Preventative maintenance is pro-active maintenance whereby plant equipment is repaired and serviced before failures occur. The frequency of maintenance activities is pre-determined by schedules based on the level of repair analysis (Neelamkavil, 2010:46. Preventive maintenance aims to eliminate unnecessary inspection and maintenance tasks, to implement additional maintenance tasks when and where needed and to focus efforts on the most critical items. The higher the failure rate
consequences, the greater the level of preventive maintenance that is justified. This ultimately implies a trade-off between the cost of performing preventive maintenance and the cost to run the equipment to failure.

Inspection assumes a crucial role in preventive maintenance strategies. Components are essentially inspected for corrosion and other damage at planned intervals, in order to identify corrective action before failures actually occur. Preventive maintenance performed at regular intervals usually results in reduced failure rates. As significant costs are involved in performing preventive maintenance, especially in terms of scheduled downtime, good planning is vital.

There are two (2) types of preventative maintenance which are either condition based or time based.

- **Condition based**

Condition Based Maintenance (CBM) is defined by Prajapati (2012:388) as “a set of maintenance processes and capabilities derived from real-time assessment of equipment system condition obtained from embedded sensors and/or external test and measurements using portable equipment. The goal of CBM is to perform maintenance only upon evidence of need.” This further implies that CBM is based on the actual condition of a component for maintenance to be performed (Gerdes, 2016:399). Maintenance is not performed according to fixed preventive schedules but rather when certain changes in characteristics are noted. Therefore, condition monitoring forms a critical part of condition based maintenance. A typical example of a condition monitoring strategy in the motor industry is changing the oil at a specific interval to prolong engine life. This change is done irrespective of whether the oil change is really needed or not.

Condition based maintenance entails changing the oil based on changes in its properties, such as the build-up of wear debris. When a car is used exclusively for long distance highway travel and driven in a very responsible manner, oil analysis may indicate a longer critical service interval. Some of the resources required to perform condition based maintenance will be available from the reduction in breakdown maintenance and the increased utilisation that result from pro-active planning and
scheduling. Good record keeping is very important to identify repetitive problems and the problem areas with the highest potential impact.

Using preventative/predictive maintenance means using a system that gives early warning of impending plant failures if maintenance is not carried out timely. Early detection of initial equipment failure is an important factor in preventing serious damage to a system. According to Ben-Daya, et al., (2009:99) an effective maintenance organization has 80 % or more preventive maintenance, which leaves 20 % or less for corrective maintenance. A different distribution signals a lack of control of the manufacturing equipment. However, Nyman and Levitt (2010: xviii) affirm that planning should be the core of the maintenance efforts since it provides delivery of all the other proactive maintenance in the organisation. They further state that combining both preventative and predictive maintenance can produce quantum benefits that accrue on the organisation bottom line.

Consistently monitoring the plant performance and performing the necessary maintenance on a timely basis using the condition base tool, can reduce the number of unexpected failures. The reduction in unexpected and serious damages to the system increases the system’s operating life and the system reliability (IAEA, 2007: 17). Figure 3.2 illustrates the life cycle of a machine from early life until when the machine is retired. During the commissioning phase of the equipment, the failure rate is high until the machine is optimised. Then the equipment will operate trouble free with minimum maintenance being carried for most of its life until towards the end of life. The probability of failure increases again towards the end of life, which necessitates an increase in maintenance frequency.

According to Hameed et al. (2010:88), the process is simple as there is the initial phase, called the burn in period, the stable phase, called the useful life period and the end phase, called the wear out period. They also state that reliability of any design is the most important feature and this can be ensured by overwhelming the previous weaknesses and faults occurred in the design and then formulating novel strategies and techniques to minimise these shortcomings. By doing so, the reliability and robustness of that design can be enhanced. Therefore, using condition monitoring to track the
condition of equipment during its life period, the failures may be detected in advance and unexpected failures can be prevented. Figure 3.2 below is further supported by Bloom (2006:162), who says that 89% of all components fail randomly and the other 11% can be predicted. Therefore, maintenance strategy has to be more condition based and less time based. By applying condition monitoring, the life expectancy of an equipment can be increased which in turn increases reliability. The bathtub curve (Figure 3.2) has therefore been formulated to increase the reliability of any equipment by being able to predict its failure rate.

**Figure 3.2: The bath tub curve concept**

![Bathtub Curve](image)

Source: Chet Heibel (2012:09)

### 3.2.1.3 Improvement

Maintenance improvement is when failures are eliminated before they occur. The best way to improve the equipment performance is firstly knowing how the equipment should perform and secondly putting measurements in place to measure for any deterioration. This is best stated by Frederickson & Larsson (2012:36). The main objective is to modify the particular system or components to minimise load losses and safety related aspects.
• **Failure prognosis**

The function of failure prognostic system as stated by Shuping et al. (2009:2) compares and analyses the prediction value and real-time value of a system operation. It further states that the system based failure prognosis on similarity modelling can widely apply to all kinds of rotation equipment and non-rotation equipment and cover the key equipment and typical failures of the power plant.

Of note as in a typical power station, the following key rotational equipment for analysis are the Induced Draught fans, Force Draught fans, Generator, Main and Auxiliary turbines, Pulverised fuel coal milling plant, etc. which are costly to repair and when not in service, lead to system load losses. In the milling plant, the design is such that the manufacturers of pulverised fuel systems shall follow the requirements states in the National Fire Protection Association (NFPA 85_Boilers 20078:159) where applicable to ensure that the risks from coal dust explosions are eliminated or properly controlled.

Most of the failures in the power station are mainly caused by operation problems (frequent stop and starting of the equipment), performance degradation (age related), bearing fault (inferior material used), mechanical damage (poor lubrication) and wear, heating problems (mainly due to poor alignment and restricted flow problem) and burn problems due to electrical faults or fire occurring in the vicinity of the equipment (NFPA 85_Boilers 20078:250).

**3.2.2 Unplanned maintenance**

This refers to emergency breakdown requiring immediate action to be taken. It is a corrective maintenance (retro-active strategy) whereby action is only taken when a system or component failure has occurred. The task of the maintenance team in this scenario is usually to effect repairs as soon as possible. Costs associated with corrective maintenance include repair costs (replacement components, labour and consumables), lost production and lost sales. To minimise the effects of lost production and speed up repairs, actions such as increasing the size of maintenance teams, the use of back-up systems and implementation of emergency procedures can be
considered. Unfortunately, such measures are relatively costly and/or only effective in the short-term.

The maintenance strategies utilised depend on the technology used in the organisation. The conveyor chute design formed the integral part of this study.

A recent study carried out on the implication and typical examples of plant failures on the Electrical Generator was caused by delayed outages (Reyes et al., 2016:401). They have found that the rotor winding is the component that has the highest number of failures in a refinery which operates in a similar environment as the Eskom Generators. The report states the main cause of the failures to be the presence of contamination such as dust, oil and precipitation. From their study, they have found that, for a period in-between 1987 to 2003, a total of 15 failures were reported in five of the turbo generators of a Mexican refinery. Twelve of them occurred in their rotors (see Figure 3.3 below).

**Figure 3.3: Number of failures reported from 1997 to 2003 in the turbo generators of a Mexican refinery**

![Number of failures reported from 1997 to 2003 in the turbo generators of a Mexican refinery](image)

Source: Reyes (2016:401)
3.3 ACCIDENT/INCIDENT MANAGEMENT

Incident management is a high risk incident defined by Patient Safety and Quality Unit (2011:6) as any event that would have resulted in a significant incident should it have eventuated (a significant near miss), which are (i) Incidents that could attract significant media attention; or (ii) Possible significant incidents; (that is, significant incident status is unclear until further review is conducted).

3.3.1 The difference between incident and accident

Accidents are unexpected events or occurrences that result in unwanted or undesirable outcomes. The unwanted outcomes can include harm or loss to personnel, property, production, or nearly anything that has some inherent value. These losses increase an organisation’s operating cost through higher production costs, decreased efficiency and the long-term effects of decreased employee morale and unfavourable public opinion (United States Department of Energy Handbook (DOE) 2012:21). Furthermore, according to the National Safety Council, accidents result in an undesired event that leads to personal injury or property damage (Cogen, 2013:9).

Incidents are defined by Lukic (2010:428) as a result of a combination of failures, rather than a single event which tends to be preceded by near missed and other small scale events, which, if not detected earlier, results in larger events (major incidents). Furthermore, according to the National Safety Council, it is any unplanned, undesired event that adversely affects completion of a task (Cogen, 2013:9). Based on the above definitions, plant failures and load shedding are therefore classified as incidents. Load shedding is an incident on the power grid which results in a partial loss of the power system.

Major incidents, according to the Patient Safety and Quality Unit (2011:6) are classified as when three or more staff requires time off following an adverse event or a hospitalisation of two or more workers/visitors following an adverse event or a reoccurring plant failures or repeated unplanned plant maintenance of the same equipment or component.
Reliability is the measure of the number of times that the technical system or machine experiences problems. It provides an indication of the continuity of the production process. While high availabilities are important to ensure sufficient operating capacity, a low level reliability will lead a high proportion of nuisance stoppages, with corresponding loss due to plant stoppages.

According to Newfoundland and Labrador (2006:7), accident/incident investigations are an important part of the OH&S program. They include a process of fact finding to identify the root (basic) cause of accidents/incidents as a means of preventing further occurrences. Ergonomic considerations should always be part of accident/incident investigations. Including investigations in the OH&S program strengthens the internal responsibility system and is essential to building a positive health and safety culture in the workplace.

Newfoundland and Labrador (2006:8) further state that an accident/incident investigation is a well-planned analysis of an event that identifies the root cause and recommends corrective action to prevent the event from happening again. Despite what many people think, workplace accidents/incidents don’t just happen. They are the result of a series of events that usually stem from an ineffective OH&S program (Newfoundland & Labrador, 2006: 8). This emphasise the importance of organisational learning from incident events and even near misses in order to prevent human or capital cost to the organisation caused by poor management, hence continuous organisational learning is encouraged.

### 3.3.2 Failure analysis techniques/methods

Failures happen in different plant system/components of the plant. It is the role of the engineering person to understand the failure mode and ensure that they are predictable and preventable. There are several techniques that are utilised to understand the behaviour as well as to plan the suitable maintenance strategies. Kumar et al.(2007:526-529) explain three different methodologies, namely Root Cause Analysis (RCA), Failure Mode Effect Analysis (FMEA) which are commonly used in industries and Fault tree analysis (FTA) (Sharma & Sharma, 2010:67). The failure analysis is described in detail below:
3.3.2.1  **Fault tree analysis**

It is a top-down approach to the identification of process hazards. It is considered one of the best means for systematically identifying and graphically displaying the many ways that something can go wrong. The first step is to define the undesired event. Then look backwards from the event to answer the question “How could this have happened?” This gives you the primary causes. The next step is to ask the question again to identify the contributing causes, and so on. Once all possible faults and causes are listed, eliminate the causes through deduction or investigation and determine their (root) causes.

3.3.2.2  **Root cause analysis**

Kumar *et al.* (2007:526-529) define RCA “as a failure analysis tool that provides in-depth analysis of system reliability aspect by classification of causes which helps to build a knowledge base for conducting FMEA”. RCA is aimed at preventing future reoccurrences by determining the root cause of the problem, classification of causes and establishing a knowledge base on how to deal with problem. This approach helps in improving reliability, availability, quality and profitability (Sharma & Sharma, 2010:67). According to Ashok *et al.* (2013:170-171), RCA is a structured approach used in many industries to identify the root cause of the incident (safety, production, environment, etc.) and problem solving on quality and productivity improvement.

**FMEA**

The FMEA tool is used to analyse the potential failure modes of the system/component. In addition, Ahsen (2008:466-467) describes FMEA as a tool that companies use for risk management due to its nature of component analysis. Inoue and Yamada (2010:371) explain FMEA as an approach that the organisation can use to proactively identify and eliminate potential problems even during the early development of the product. Some of the benefits of FMEA include improved plant/system/component reliability, safety, knowledge management and improvement in quality standards (Inoue & Yamada, 2010:371). Das *et al.* (2014:601-603) include the component/equipment criticality as part of the analysis which is then referred to as Failure Mode Effect
Criticality Analysis (FMECA). The criticality criteria according to Das et al. (2014:601-606) are divided into five categories, namely:

- traditional criteria- frequency of failure, severity and degree of detection,
- human factors – skills level of both operators and maintenance personnel,
- downtime reduction factors – maintainability and spares availability,
- operating environmental condition - temperatures, humidity, dust, pressure etc. and
- Economic factors - economic loss of failure.

Components/equipment criticality forms an integral part of risk management whereby potential failures are identified, evaluated and eliminated in order to improve plant reliability and safety (Lui et al., 2015:763).

The investigation process will improve overall safety performance and it includes:

**Root cause** which is a number one step in a sequence of events that, if removed, the accident would not have occurred (Cogen, 2013:24).

**Contributing causes** which are the other concerns that must also be addressed (Cogen, 2013:24).

According to Gyger (2012:8), to have an effective corrective actions and preventive actions process, the following steps should be executed:

- Identification: The problem should be articulately defined
- Impact / risk assessment: Clear initial assessment of the impact and the magnitude of the problem.
- Immediate action: What needs to be done to protect the customer from the problem when it does occur again?
- Root cause investigation: identify the root cause of the problem by using a systematic approach. The root cause when clearly identify, will help to put measures in place to eliminate the problem from occurring again.
• Conclusion and quality decision: final thorough conclusion on the impact and magnitude of the problem and/or decision for or against using of the product, etc.
• Action plan: define corrective and preventive actions.
• Implementation and follow-up: implement corrective and preventive actions and verify their effectiveness.

A high number or repeated number of failures in any organisation has disadvantages such as increased down time, unsatisfied customers, increase operational and maintenance cost, reduced production capacity etc. During capacity planning, certain assumptions need to be made with regard to plant failures, based on the previous plant history.

3.4 QUALITY MANAGEMENT

Throughout the years there have been different views and definitions of quality.

According to Narayan (2012:184), a quality service of the product is one that:

• meets or exceeds the customer’s stated or implied expectations and/or predetermined performance standards;
• does this consistently, over a long period;
• has a sense of value to justify its price;
• anticipates constantly evolving expectations;
• performs predictably, i.e. no surprises; and
• Ultimately “wows” the customer who comes back for more.

There are commonalities in the definitions above by Narayan (2012:184) and from Elassy (2015:251-252) who define quality by five approaches which include conformance to standards, fitness for purpose, meeting customers’ needs and effectiveness in achieving long-term goals.

Quality is further defined by Kim et al. (2012:10 in five different classifications, namely:

• transcendent, which is a subjective measure based on individual knowledge and experience, product based on its prescribed features and performance;
- user based which is the extent to which the client’s needs and wants are satisfied by the service or the product;
- manufacturing which mainly relates to the product conformance with the manufacturing standards; and
- Value based which is determined by the client on whether the value has been achieved or not.

Kim et al. (2012:11 further explain the different dimensions of quality as performance, reliability, serviceability, performance, durability, conformance etc. It is critical in any organisation that quality of maintenance be of required standard based on the dimensions mentioned above. This is mainly due to the fact that in most organisations including Eskom Power station; maintenance spending constitutes a large portion of operational cost. Quality of maintenance plays an important role in the organisation's competitiveness with regard to cost, quality and delivery. Therefore poor quality maintenance can be costly. Salonen & Deleryd et al. (2011:65) describe this concept as cost of poor quality (CoPQ) which requires maintenance to be more proactive and improving on planning activities.

Conformance is one of the quality dimensions. Salonen & Deleryd et al. (2011:68) developed a model in which CoPQ is linked to both preventative and corrective maintenance, as indicated in Table 3.1 below
Table 3.1: Cost of nonconformance and maintenance strategy

<table>
<thead>
<tr>
<th>Cost of Conformance</th>
<th>Corrective maintenance</th>
<th>Preventive maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indispensable corrective maintenance:</td>
<td>Valid preventive maintenance:</td>
<td></td>
</tr>
<tr>
<td>Corrective Maintenance due to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Failures with random distribution and no measurable deterioration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Failures which are not financially justified to prevent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-accepted corrective maintenance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrective Maintenance due to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lack of preventive maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Poorly performed preventive maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Poor equipment reliability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Salonen & Deleryd et al. (2011:68)

This emphasises the importance of selecting the correct maintenance strategies as discussed in section 3.2.2, in this report.

Knezevic (2012:216) defines the quality of maintenance as a probability that the maintenance task or activity could be completed without fault resulting from the maintenance process. It should also be noted that maintenance activities are performed under different environmental conditions such as climate condition, availability of space etc. which can also affect the quality of the maintenance task if not properly assessed.

According to Maletič et al. (2014:442) “Effective maintenance extends equipment life, improves equipment availability and retains equipment in proper condition”.

Weckenmann et al. (2015:283) illustrate the overview of concept in quality management and how it had evolved over years, from quality inspection to current total quality management in Figure 3.4 below.
Total quality management requires a strategic leadership approach for long-term sustainability of the organisation. Leadership plays important roles in creating a culture whereby employees are encouraged to take ownership and responsibility for improved quality in the organisation. This includes management commitment by providing necessary resources such as finances, materials, people and time to ensure that quality initiatives are implemented. ISO 9001:2000, clause 5 explains that management commitment should:

- communicate the importance of meeting customers’ as well as statutory and regulatory requirements to the organisation;
- establish quality policy;
- ensure that quality objectives are met;
- conduct management reviews; and
- Ensure that the resources are available.

According to Buckley (2009:43) he states that for organisation to achieve improved quality of maintenance and other activities/functions in the organisation, the leaders in
those organisation’s should have questioning attitudes that will cause their employees to invariable have improved their focus, make them more collaborative towards one another and make them feel more empowered to help the organisation achieve its goal. The leadership roles in quality are further emphasised by Rashid (2012:312) as ensuring that the quality policy is in place, development and deployment of quality goals as well as continuously ensuring that quality initiatives are in place. It is further noted that “Establishing a quality based-culture can improve operational performance, customer satisfaction, financial performance etc.” Truong et al. (2016:445).

3.5 SUMMARY

The age of the plant and the maintenance carried to ensure proper functioning of the plant, play an important role to ensure continued effective operation of the plant. As the plant ages, the maintenance needs to become more intensive to ensure that the plant still operates optimally.

The importance of carrying out maintenance when it is due cannot be emphasised enough. The Original Equipment Manufacturer (OEM) normally specifies the type of maintenance to be carried out as well as the frequency of the maintenance. If the recommendations from the OEM are adhered to, the equipment normally operates trouble free for the period specified by the manufacture. If the recommendations from the OEM cannot be adhered to for whatever reason, trouble is eminent for the peace of equipment which thus results in breakdowns.
CHAPTER 4: EMPIRICAL STUDY

4.1 INTRODUCTION

To understand the reasons behind the unreliable performance of the Eskom Generating plant, the historical background needs to be understood first, the drop in performance needs to be trended and the reason why it happened needs to be understood. It is thus importance that data needs to be collated, trended and analysed. For this reason, plant failures and reasons were analysed both qualitatively and quantitatively.

The primary focus of the study was to eliminate or reduce the frequency of load shedding in the country. It thus follows that the effectiveness and efficiency of plant maintenance employed by Eskom must be assessed and the correction of plant failures when they do occur must be understood and improved on, to improve the supply and reliability of the Eskom grid system. These will then result in the reduction or total elimination of occurrences and reoccurrences of load shedding.

For this purpose, the discussion is therefore informed by the research objectives to the recurring plant failures leading to load shedding in the country. These research has been designed to ascertain the reasons for the recurring plant failures and using the empirical analysis carried out both qualitatively (Eskom staff answering a formulated questionnaire) and quantitatively (analysing Eskom plant performance data) to make a deduction that the plant failures do actually lead to load shedding incidents. The results are then analysed using statistical analysis measuring instruments and scoring the results to be able to make an interpretation of the results.

4.2 GATHERING OF DATA

To investigate the problems leading to the reoccurring plant failures is not going to be an easy task. Eskom is a big organisation and there are many facets that could have failed leading to load shedding.

The most noted definition of data analysis is that of Creswell (2009:184), who defined data analysis as “an ongoing process involving continual reflection about the data, asking analytic questions and writing memos throughout the study”. For the above
reason, it should be noted that analysis carried out in this research is both qualitative and quantitative, since it is an ongoing process and not a static one to be followed by future research, for their further analysis on a similar project where they will be using research design and data collection processes.

Quantitative data analysis was done too using Eskom data to trend the performance of the Eskom generating plant in order to understand where and when the deterioration occurred from previously good performing Eskom plant and the current poor plant performance which has frequently led to incidents of load shedding.

A questionnaire was designed to collect the qualitative data and distributed to Eskom staff both via emails and hand delivered for those in close proximity. Questionnaires were only given to those individuals who were deemed to have intimate knowledge of the Eskom Generation business to give a fair assumption of its operation, both plant wise and people wise. Of the 150 distributed, 135 were received back, giving a 90% response. Time was said to be the main reason why some individuals did not complete and return their questionnaires. The statistical analysis was done by a company called Outrospection Research Consultancy (Pty) Ltd.

4.2.1 Quantitative data presentation and analysis

4.2.1.1 Plant availability

Plant availability is measured by overall energy availability factor (EAF). Looking at Figure 4.1, for the energy availability during the first half of 2016, it can be seen that the peaking stations are fairly constant in delivering reliable energy (above 95%), Nuclear is operating on a flat level, except for the period where they have to do refuelling of the units (one unit is taken down every 18 months for refuelling). The most challenging stations are the coal fired stations, whose energy availability dropped from 75% to about 65%.

The Unplanned Grid separation target was 3%. This means that incidents where machines are separated from the grid should be minute and predictable. From Figure 4.1 below, it can be seen that those incidents have been on the rise from 3% to almost
double. Generation has been battling to get a grip on the incidents which enviably led to incidents of load shedding at the beginning of 2015. With the unplanned separation of machines, a substitute was needed and in this case, there were three options, namely (1) use expensive gas turbine, which of course Eskom did; (2) try to return the tripped machine, which in most cases took longer and (3) load shed customers with the first ones, the voluntary customers and then the civilians.

Figure 4.1: Generation Energy Availability Factor

Source: Eskom, 2016:8
Figure 4.2: Generation Unplanned Capability Loss Factor (UCLF)

Figure 4.2 above shows the detoriating Unplanned Capability Loss Factor (UCLF). In 2008, the UCLF was a 5% on average for the year and then it dropped to 4% in 2009. In 2010, the UCLF started increasing on a year to year basis without reducing until it reached 16% in 2015.

**Load shedding Incident 1**

During 2007/8 period, even though the UCLF for the year was at 5%, there was a brief period where it increased dramatically due to a combination of power generators failing and poor coal availability (Figure 4.2 above and Eskom, 2016, 59).

**Load shedding Incident 2**

In 2014, the coal availability and quality improved in most power stations but the system unreliability was still high as was observed with the loss of 2 big machines at Kendal...
and Duvha. Duvha 3 is still out of service due to the boiler explosion and Majuba Coal Silo collapsing which caused three machines to be out of service. The above events destroyed the power system reserve to the brink of a National blackout.

Since the implementation of the Tetris planning tool in the 3rd quartile of 2015, it can be seen that the UCLF has been improving significantly to the point where planned maintenance is being done and the system reliability is improving such that load shedding is a distant memory.

**Figure 4.3: Generation UAGS/7000 Hrs**

From Figure 4.1 to Figure 4.3, it can be seen that, even with the implementation of the Tetris maintenance tool, the system outlook remains tight and the probability of load shedding remains high for the near future until the three new power stations are fully commissioned. Quality maintenance execution and effectiveness of maintenance
strategies play a crucial role in ensuring that the probability of load shedding and the risk of a total national black-out are averted.

There are several factors that impacted on balancing electricity demand and supply. These are:

- Eskom’s commitment to “Keep the Lights on” by delaying critical plant maintenance and refurbishment has resulted in the declining performance of Eskom’s ageing power stations and the increase in unplanned.
- Delaying maintenance and urgent repairs is increasing breakdowns and the associated maintenance cost. Urgent repairs tend to compromise quality of maintenance.
- Due to some of the generating units being taken off-load for maintenance during periods of constrained capacity, increased usage of the open-cycle gas turbine (OCGT) stations is necessitated for Eskom to meet demand.
- The delay in delivering on the newly built programme has created additional pressure on the current ageing fleet of power stations to perform at a time when most are due for maintenance.
- Inadequate availability and quality of local coal. The South African coal sector requires substantial investment and recapitalisation to meet both domestic and export requirements, as the current mining capacity will not meet the growing demand.

**Generation Plant Performance for 2015 Analysis Compared to the Same Period In 2014.**

The generation plant availability deteriorated compared to the same period the previous year, from 75.13% to a dismal 73.73% for the same period the previous year (see Figure 4.1 above). This performance was way below the target of 80% availability for EAF.

The planned capability loss factor (PCLF) YTD was 13.33% which was an increase for the same period the previous year which was 8.96% (see Figure 4.4 below).
The unplanned capability loss factor (UCLF) YTD was 12.51% in 2014 and increased to 15.728% in 2015, therefore trending in the wrong direction. The reliability indicator - Unplanned Automatic Grid Separations (UAGS /7000) - year to date for 2015 was 5.43, which was marginally lower for the same period in 2014 which was 5.71.

4.2.1.1 Plant failures categories

A drop in UCFL is indicative of a poor generating fleet. This was attributed to deteriorating plant health of an ageing power station fleet. The factors that contributed to the high UCLF percentage were amongst others, partial load losses, increase boiler tube failures and major/significant load losses (Eskom, 2013:29; Eskom, 2014:49) mainly as a result of different plant failures.

Figure 4.5 below shows the main contributing plant failure from 2004 to 2014. The graph shows that the main plant areas which are failing leading to load losses and plant shutdowns are Multiple Unit Trips (MUT) at the same time, followed by the loss of turbines machines which invariably caused the generators to stop producing power,
(separating from the grid) and then fire incidents. These failures have a direct link to poor plant maintenance and few are caused by design deficiencies. From the investigation conducted, poor plant maintenance and plant checking were found to have the most contribution during incident investigations (Generation Analysis, 2015:05).

**Figure 4. 5: Top 3 plant failure areas that contributed to increased plant unreliability**

Source: (Generation Analysis, 2015:05)

Coal fired power plants have been designed with a 50 years life span. System reliability is greatly improved with the implementation of a condition monitoring system. As it has been explained by Figure 3.2 (the bath tab curve), the longer equipment operates the more maintenance it will require. Most of Eskom’s power plants are beyond midlife and approaching end of life, which means more maintenance is required. Figure 4.5 above, shows the failure rate per power station. It can be seen that the older the power station, the higher the failure rate. Hendrina power station is 40 years old. It is the second oldest power station that has been operating continuously since it was commissioned, with the oldest being Arnot power station. The oldest power stations built are Camden, Grootvlei and Komati but all three were mothballed for almost 20 years, which effectively make them 30 years old. Majuba shows the second highest failure rate in comparison, but that can be easily explained as Majuba, when commissioned, was operated as a two shifting
machine, which increased its failure rate tremendously. The frequent stop and start is better explained on the (Okoh, 2013:494) as one of the main causes of operating machines’ failure rates.

Figure 4. 6: Plant Areas which failed the most and which stations contributed significantly

Source: Generation Analysis, 2015:07.

Looking at Figure 4.6 above, an interesting trend is depicted. Duvha, Tutuka, Grootvlei and Matla have the highest number of Multiple Unit Trips (MUT). This is owing to the high failure rate during refurbishments of Duvha, Tutuka and Matla and the return to service of Grootvlei. This is in line with the high expected failure rate expected during the commissioning phase of new equipment (Okoh, 2013:494). Figure 4.7 below shows that the MUT are the leading causes of plant failures, followed by the Turbine failures.
Load shedding implications (Analysis)

Load shedding has become the order of the day in South Africa. Is this due to poor maintenance as the population is meant to believe or is it due to incorrectly identified actions? The incorrectly identified actions could be emanating from poorly conducted significant incidences which then lead to reoccurrences of the same type of incidences which could have been prevented in the first place, has proper investigation been conducted.

In the context of an already constrained and vulnerable power system, the reason for implementing the 2014 load shedding was primarily due to the combination of the inability to source sufficient diesel for the open cycle gas turbines (OCGTs), the high increase in unplanned breakdowns at Eskom’s power stations and the depleted water reserves to run pumped storage schemes.

Load shedding had to be undertaken in early November 2014 after the Majuba power station lost capacity to generate power when one of its coal storage silos collapsed. On
4 November 2014, there was a 4 000 MW shortfall in electricity demand vs supply. Eskom has 45 583 MW of generating capacity but could only supply 24 000 MW due to “planned and unplanned” maintenance. Apart from the Majuba disaster, Duvha power station Unit 3 is currently also still out of commission due to an incident that occurred in March 2014.

**OCGT operations and liquid fuel availability**

Open cycle gas turbines are designed to ideally run for a maximum of three hours a day during peak periods. However, due to the constrained system, Eskom operates these stations for long periods throughout the day, which resulted in the consumption of approximately 140 million litres of diesel in November 2014 (Eskom 2015:62). The cost and supply of liquid fuel are two areas that require strategic focus.

**Impact of load shedding on the Economy**

Security of supply remains a key priority area for Eskom. However, until new capacity is commissioned, the challenges associated with load shedding remain real. Eskom is cognizant of the impact of load shedding on its business reputation, credibility and overall public confidence. The impact of load shedding on the South African economy remains unquantified and will need to be assessed independently.

Eskom adopted a generation sustainability to try and improve system efficiency and at the same time increased maintenance budget spent for generation. The strategy incorporates an 80:10:10 operational plan, which is aimed at improving the generation plan performance over a five-year period to a sustained availability of 80% by 2018. The plan focused on plant, people and processes. There has been an additional funding required due to the reliance on open cycle gas turbines (OCGTs) which has been used for emergency generation due to the unavailability of the bae load units. This has come at an exorbitant cost to Eskom. R9.546 billion was spent on OCGT’s for the 2014/2015 fiscal year (Eskom 2015:29).
Eskom key sustainable challenge

Eskom’s revenue shortfall (as a result of NERSA’s decision to grant only an 8% tariff increase instead of the requested 16% by Eskom) not only impacted on Eskom’s financial sustainability and an already constrained and vulnerable power system, but also on its ability to operate in compliance with the numerous laws and regulations governing the company, including conditions relating to tariffs, expansion activities, environmental compliance and regulatory and licence conditions. These emerged as specific and key sustainability challenges.

The impact of MYPD3

The impact of the NERSA MYPD3 determination has resulted in significant financial constraints for Eskom. This places pressure on Eskom’s future liquidity and ongoing concern status as Eskom has insufficient funds to meet its financial and operational obligations.

The risk of further downgrades in Eskom’s credit ratings remains, which will result in diminished access to funding, higher finance costs and can also impact current debt agreements.

Eskom Turnaround strategy

Eskom developed a Turnaround Strategy to try and arrest the unstable grid incidences which led to the establishment of the Governmental task team War Room. This was an interdisciplinary team which comprised of both government leadership and Eskom executives to formulate response strategy that will be implemented to halt the energy crisis and aid in the identifications of the necessary instrument to improve the energy availability. The initiatives were developed, consulted and implemented through an Eskom Executive Committee approved emergency governance process with the following objectives in mind:

- To address the skills shortage that is necessary to ensure that progressive energy building programs are maintained.
• There should be transformation on all the structures of Eskom leadership ranks and all vital positions should be filled up with competent staff: the environment within Eskom is conducive of a high performance culture.

• All operations are built around the notion of maintaining safety and security as the cornerstone of performance within all structures of Eskom’. The slogan “No operating condition, or urgency of service, justifies exposing anyone to negative risks arising out of Eskom’s business or cause them injury or damage to the environment” was founded.

• Efficient execution of all Eskom priorities across the whole organisation - it is key to secure stable and consistent

• Transparency on performance is vital using a set of identified and agreed upon key performance areas (KPAs), key performance indicators (KPIs) and targets, including the consequences for underperformance.

Load shedding communication as part of stakeholder management

Eskom works with municipalities and other stakeholders to provide information on load shedding. Load shedding schedules are available to communicate the times and the affected areas to customers through the following communication channels:

• The Eskom website for direct Eskom customers.
• Municipality websites for customers supplied by the various municipalities.
• Eskom and municipality call centres. A typical load shedding schedule is attached as Annexure B below.

(Eskom Holdings Corporate Plan 2015/16–2019/20 Revision 3:63)

Figure 4.8 shows plant availability trend for 2016 (Eskom presentation 2016:41):

• Plant availability (EAF) was 70.39 in 2015 and improved to 74.4% by the 16 November 2015 due to the positive impact of planned maintenance.
• Balancing supply and demand remained a challenge for the first quarter of the financial period. The second quarter showed significant improvement with only 2 hours and 20 minutes of load shedding from 8 August until 30 September 2015.
- System stability has improved since August 2015.
- Partial load losses have reduced easing pressure on the constrained power system.
- Plant utilisation remained high at 84.77%.

Eskom is still aspiring to achieve the EAF of 80%, then do 10% maintenance and the remaining 10% is to cater for the unforeseen (unplanned capability losses).

**Figure 4. 8: Energy Availability Factor from 2012-2016**

![Energy Availability Factor from 2012-2016](chart)

Source: Eskom presentation (2016:41)

**System Outlook**

The system outlook remains tight and the probability of load shedding remains a reality for the foreseeable future. The prognosis for load shedding will be low to medium (25%-50%) should no additional risks occur on the system (Eskom, 2016:41). In the event of significant incidents on the power system, the probability of load shedding increases. However, it remains impossible to forecast accurately when Eskom will have to reduce load.
4.2.2 Qualitative data analysis

To perform the qualitative data analysis, both ordinal variables, such as gender (both males and females were employed on the plant) and nominal variables, such as understanding of maintenance (strongly disagree, disagree, neutral, agree, strongly agree), were used for the study. With ordinal variables, the order did not matter, but with nominal variables, the order did matter.

Included in the list of variables were indicators of execution of maintenance, how it was executed, involvement and understanding of staff on the importance of maintenance. The variables also included the skills levels of the employees with the company and the upkeep of their developmental needs, performance management instilled by the company including the reward and punitive measures applied, whether current plant performance was deemed acceptable or not and why and the decision making allowed (employee empowerment) to ensure reliability and availability of the plant.

This research design was chosen because it ensured that we had a stratum input of the different field experts from the business itself who understood plant failures and its impact to plant reliability which if not addressed could lead to poor plant maintenance and eventually load shedding.

Summary

The questionnaire was developed to be both simple and logically structured for ease of understanding. The questionnaire was also design to be both specific to address all the facets which have a contribution to reoccurrence of plant failures and at the same time, be broad as to address all the soft skills and organisational structural challenges and understanding of the climate and culture of the organisation.

The structure and layout of the questionnaire was as follows:

- Section A: Demographical information, namely; gender, age, ethnicity, qualifications, years of experience, individual role in the organisation and the specific department the individual was working for.
- Section B: Skills and development
• Section C: Performance management
• Section D: Plant performance
• Section E: Decision making and planning

In Section A, the respondent had to indicate the applicable answer by marking the designated block with a cross. In Sections B, C, D and E, a five point Likert scale with an additional column for participants to cross if they did not have the required knowledge (Don’t Know) of what was requested was added as an option to measure responses. The five point scale ranged from “strongly disagree” with a value of one, to “strongly agree” with a value of five. The Likert scale gives a consistent measure of the actual position on the scale: respondent to declare if not familiar with the subject and if the respondent was for or against the issue being discussed.

The questionnaires were distributed among Eskom staff via both email and hand delivery, for those in close proximity. Questionnaires were only handed out to those individuals who were deemed to have intimate knowledge of the Eskom Generation business to give a fair assumption of its operation, both plant wise and people wise. Of the 150 distributed, 135 were received back giving a 90% response. Time was said to be the main reason why some individuals did not complete and send back their questionnaires. The statistical analysis was done by a company called Outrospection Research Consultancy (Pty) Ltd which is based in Tshwane.

4.2.3 Section A: Demographical information

4.2.3.1 Gender

The purpose of question A1, in Section A of the questionnaire (refer to Annexure A below) was to determine the gender of the respondents.

Results obtained:

The gender of all employees that responded to the survey is presented in Table 4.1 below.
Table 4.1: Gender of the respondents

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>69</td>
<td>51.1</td>
<td>51.1</td>
<td>51.1</td>
</tr>
<tr>
<td>Female</td>
<td>66</td>
<td>48.9</td>
<td>48.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>135</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 indicates that the respondents were almost a balance between males and females with 69 (51.1%) males and 66(48.9%) females. The challenge was whether the company was pushing gender number instead of skills.

4.2.3.2 Age group classification of the respondents

Purpose of the question

The purpose of question A2, in Section A of the questionnaire (refer to Annexure A) was to determine the age group category of respondents.

Results obtained:

The age groups of all employees that responded to the survey are presented in Table 4.2 below.

Table 4.2: Age group of the respondents

<table>
<thead>
<tr>
<th>Age</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-25</td>
<td>9</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>26-35</td>
<td>76</td>
<td>56.3</td>
<td>56.3</td>
<td>63.0</td>
</tr>
<tr>
<td>35-45</td>
<td>34</td>
<td>25.2</td>
<td>25.2</td>
<td>88.1</td>
</tr>
</tbody>
</table>
Table 4.2 above indicates that more than half of all the respondents in this review were represented by the 26-35 year age group 76 (56.3%) and followed by the 35-45 year age group 34(25.2%). These two categories constituted 81.5% of all the respondents.

The remainder of the groups constituted 8.5% of the respondents. There were only 3% of the respondents who were 56 years and above.

4.2.3.3 Ethnicity

Purpose of the question

The purpose of the question A3, in Section A of the questionnaire (refer to Annexure A) was to determine the demographical representation of Eskom employees.

Results obtained:

The ethnic groups of all employees that responded to the survey are presented in Table 4.3 below.

Table 4.3: Ethnic group of the respondents

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>African</td>
<td>111</td>
<td>82.2</td>
<td>83.5</td>
<td>83.5</td>
</tr>
<tr>
<td>White</td>
<td>13</td>
<td>9.6</td>
<td>9.8</td>
<td>93.2</td>
</tr>
<tr>
<td>Coloured</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>96.2</td>
</tr>
<tr>
<td>Indian</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>99.2</td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Sub Total</td>
<td>133</td>
<td>98.5</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.3 above indicates that the biggest categories in this review were represented by Africans who constituted 111 (82.2%), followed by 13 (9.6%) whites. The remainder of the groups constituted 6.7% of the respondents of Colored’s and Indians.

4.2.3.4 Highest academic qualifications of respondents

The purpose of question A4, in Section A of the questionnaire (refer to Annexure A) was to determine the academic qualifications of respondents.

Results obtained:

The academic qualifications of all employees that responded to the survey are presented in Table 4.4 below.

Table 4.4: Academic qualifications of the respondents

<table>
<thead>
<tr>
<th>Education</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below matric</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Matric</td>
<td>37</td>
<td>27.4</td>
<td>27.6</td>
<td>29.1</td>
</tr>
<tr>
<td>Diploma</td>
<td>46</td>
<td>34.1</td>
<td>34.3</td>
<td>63.4</td>
</tr>
<tr>
<td>Degree</td>
<td>36</td>
<td>26.7</td>
<td>26.9</td>
<td>90.3</td>
</tr>
<tr>
<td>Post Graduate</td>
<td>11</td>
<td>8.1</td>
<td>8.2</td>
<td>98.5</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>134</strong></td>
<td><strong>99.3</strong></td>
<td><strong>100.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4 above indicates that the biggest categories in this review were represented by the respondents with diplomas which constituted 46 (34.1%) respondents, followed by an almost similar split of 37 (27.4%) with matric and 36 (26.7%) of respondents with degrees. Respondents with Postgraduates qualifications only constituted 11 (8.1%) of the total respondents to the survey. Only 2 (1.5%) of respondents did not have matric and another 2 (1.5%) did not specify.
4.2.3.5 Years of experience of all the respondents in Eskom

Purpose of the question

The purpose of question A5, in Section A of the questionnaire (refer to Annexure A) was to determine the number of years the respondents have worked at Eskom Power Stations.

Results obtained

The number of years working at Eskom Power Stations of all employees that responded to the survey is presented in Table 3.6 below.

Table 4.5: Respondents number of years working at Eskom

<table>
<thead>
<tr>
<th>Years of experience</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 years</td>
<td>23</td>
<td>17.0</td>
<td>17.0</td>
<td>17.0</td>
</tr>
<tr>
<td>4-7 years</td>
<td>45</td>
<td>33.3</td>
<td>33.3</td>
<td>50.4</td>
</tr>
<tr>
<td>8-11 years</td>
<td>38</td>
<td>28.1</td>
<td>28.1</td>
<td>78.5</td>
</tr>
<tr>
<td>12-15 years</td>
<td>13</td>
<td>9.6</td>
<td>9.6</td>
<td>88.1</td>
</tr>
<tr>
<td>16 years and above</td>
<td>16</td>
<td>11.9</td>
<td>11.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>135</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5 above indicates that the majority of respondents had between 4 to 7 years’ experience in Eskom 35 (33.3 %) and those between 8-11 years accounted for 38 (28.1%). Employees with less than 11 years’ experience accounted for 78.5% and those with more than 11 years accounted for only 21.5%. This trend is worrisome as it shows than there is not enough experienced staff for effective skill transfer.

4.2.3.6 Role in the organisation

Purpose of the question

The purpose of question A6, in Section A of the questionnaire (refer to Appendix A) was to determine the role of respondents.
Results obtained

The role of all employees that responded to the survey is presented in Table 4.6 below.

Table 4.6: Role of the respondents in the organization

<table>
<thead>
<tr>
<th>Role in the organisation</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technician/artisan</td>
<td>39</td>
<td>28.9</td>
<td>29.5</td>
<td>29.5</td>
</tr>
<tr>
<td>Engineer</td>
<td>12</td>
<td>8.9</td>
<td>9.1</td>
<td>38.6</td>
</tr>
<tr>
<td>Supervisor</td>
<td>12</td>
<td>8.9</td>
<td>9.1</td>
<td>47.7</td>
</tr>
<tr>
<td>Management</td>
<td>18</td>
<td>13.3</td>
<td>13.6</td>
<td>61.4</td>
</tr>
<tr>
<td>Other</td>
<td>51</td>
<td>37.8</td>
<td>38.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>97.8</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.6 above has representation of more than half as others- none technical participants 51 (37.8%) of the total respondents. This is followed by 39 (28.9%) technician/artisans and only 12 (8.9%) each for engineers and supervisors. Of all the respondents, management was only accounting for 18 (13.3%). It would have been preferred to have more engineers and supervisors than management, as they are the ones at the forefront of carrying out the necessary maintenance to prevent plant failures. Management is for decision making.

4.2.3.7 Department the individual is working for.

Purpose of the question

The purpose of question A7, in Section A of the questionnaire (refer to Appendix A) was to determine the respondents’ actual role in the organisation.

Results obtained

The past experience of all respondents to the survey before working at a Power Station is presented in Table 4.7 below.
<table>
<thead>
<tr>
<th>Department of respondents</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>17</td>
<td>12.6</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>Aux Engineer</td>
<td>5</td>
<td>3.7</td>
<td>3.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Elec Engineer</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>19.7</td>
</tr>
<tr>
<td>Maintenance</td>
<td>46</td>
<td>34.1</td>
<td>34.8</td>
<td>54.5</td>
</tr>
<tr>
<td>Training</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>57.6</td>
</tr>
<tr>
<td>Ops training</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>59.1</td>
</tr>
<tr>
<td>Operating</td>
<td>15</td>
<td>11.1</td>
<td>11.4</td>
<td>70.5</td>
</tr>
<tr>
<td>Risk &amp; Assurance</td>
<td>3</td>
<td>2.2</td>
<td>2.3</td>
<td>72.7</td>
</tr>
<tr>
<td>Material Management</td>
<td>7</td>
<td>5.2</td>
<td>5.3</td>
<td>78.0</td>
</tr>
<tr>
<td>Procurement</td>
<td>9</td>
<td>6.7</td>
<td>6.8</td>
<td>84.8</td>
</tr>
<tr>
<td>Projects</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>87.9</td>
</tr>
<tr>
<td>Production</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>89.4</td>
</tr>
<tr>
<td>Quality</td>
<td>3</td>
<td>2.2</td>
<td>2.3</td>
<td>91.7</td>
</tr>
<tr>
<td>Sustainability</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>92.4</td>
</tr>
<tr>
<td>Chemical service</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>93.2</td>
</tr>
<tr>
<td>Health &amp; Wellness</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>93.9</td>
</tr>
<tr>
<td>Process Engineer</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>94.7</td>
</tr>
<tr>
<td>Design &amp; Spec</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>95.5</td>
</tr>
<tr>
<td>Finance</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>96.2</td>
</tr>
<tr>
<td>Coal Management</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>97.0</td>
</tr>
<tr>
<td>Trainee Technician</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>97.7</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>98.5</td>
</tr>
<tr>
<td>Documentation centre</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>99.2</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>.7</td>
<td>.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>97.8</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.7 above indicates that the majority of respondents were employed in maintenance, 46 (34.1%), 17 (12.6%) in engineering and 15 (11.1%) in operating. The above 3 sections account for 57.8% of the total respondents. With the inclusion of Aux engineering, Electrical engineering and Production we have a total of 73.1% of total number of respondents who were directly involved (technical) with the production of electricity and ensuring the reliability of the plant. The other 26.9% were in the support positions. Only 3 (2.2%) of the respondents were unaccounted for in terms of their roles in the organisation. Respondents from maintenance were the highest, which is significant to draw some conclusions since most of the plant reliability issues stem from maintenance planning and execution. The results are acceptable since more of the respondents were technical people.

4.2.3.8 Reliability analysis

Sections B to E below are measuring the reliability of the information received as we developed our own questionnaire. Reliability is measured by the Cronbach’s alpha value (which measures internal consistency reliability). This refers to the degree to which the items (individual questions) that make up the scale ‘hang together’ – in other words, the more they hang together, the more likely it is that they are measuring the same thing/construct. According to (Maree, 2010: 216), ideally the Cronbach’s alpha coefficient of a scale should be above 0.9 for high reliability, 0.80 for moderate reliability and 0.7 has a low reliability.

4.2.4 Section B: Skills and development

Section B measures the skill and development levels to determine if it is line with the high performance culture. It seeks to identify the training needs required to improve the current plant performance.
Table 4.8: Reliability statistics for skills and development

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.905</td>
<td>.903</td>
<td>8</td>
</tr>
</tbody>
</table>

The eight questions under skills and development have a high degree of consistency reliability as they measured above the 0.7 on the Cronbach’s alpha coefficient scale to a value of 0.905 (high reliability). (Maree, 2010: 216). Therefore, the selected items reliably estimate the latent constructs revealed. This means that the questions asked to the respondents did measure the same thing/construct.

Strength of the individual item

Measuring the strength of the individual below for Section B-E, the data will be measured between the mean and the Standard Deviation. A measure above 3.5 of the individual item mean will mean that there is a greater variability of the data between the mean and the individual observations

Table 4.9: Strength of the individual items under skills and development

<table>
<thead>
<tr>
<th>Skills and Development</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 My organisation provides a platform for continuous learning</td>
<td>3.58</td>
<td>1.256</td>
<td>106</td>
</tr>
<tr>
<td>B2 There are opportunities to grow in my organisation</td>
<td>3.47</td>
<td>1.189</td>
<td>106</td>
</tr>
<tr>
<td>B3 My organisation cares about my development</td>
<td>3.23</td>
<td>1.213</td>
<td>106</td>
</tr>
<tr>
<td>B4 I have the necessary skills to do my work well</td>
<td>4.09</td>
<td>.911</td>
<td>106</td>
</tr>
<tr>
<td>B5 I receive regular relevant training in order for me to do my work well</td>
<td>3.25</td>
<td>1.256</td>
<td>106</td>
</tr>
<tr>
<td>B6 My organisation is a high performing organisation</td>
<td>3.67</td>
<td>1.049</td>
<td>106</td>
</tr>
<tr>
<td>B7 My organisation equips staff with relevant skills in order to measure up to work demands/requirements</td>
<td>3.46</td>
<td>1.088</td>
<td>106</td>
</tr>
<tr>
<td>B8 It is easy to ask for training and skills development in my department</td>
<td>3.25</td>
<td>1.324</td>
<td>106</td>
</tr>
</tbody>
</table>
Of the participants who responded to the questions, most said they had the necessary skills to perform their jobs as measured at 4.09 under B4 on the Likert scale. The respondents were of the opinion that the organisation supported their skills and development as seen with the Cronbach alpha coefficient of scale to a value of 0.905 on the table 4.8 above. They even felt that Eskom was a high performing organisation. The majority of the respondents were above the average of three with the lowest at 3.25 of the Likert scale. This is in contrast to the higher standard deviation of 1.324 relative to the mean of 3.25 for B8 above. Employees felt that it is not easy to ask for training and skills development in their respective department.

4.2.5 Section C: Performance management

To measure alignment between individual performance contracts and contractors performance contracts in relation to the agreed contract between both the individuals contract and the agree contract between Eskom and its contractors. It also measures if there is a balance between good performance management and poor performance management, whether there are correlations between recognition and reward systems as well as consequences management. This also determines the effectiveness of contract management.

Table 4.10: Cronbach alpha coefficient for performance management

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.782</td>
<td>9</td>
</tr>
</tbody>
</table>

The 9 questions under performance management had a moderate degree of consistency reliability as they measured at 0.782 on the Cronbach’s alpha coefficient. (Maree, 2010: 216). Therefore, the selected items moderately estimate the latent constructs to on the questions asked to the respondents to measure the same thing/construct. Of note is that the construct is not as strong as in the Skills and development section of 0.905 but still acceptable. Therefore, the selected items reliably estimate the latent constructs revealed.
Table 4. 11: Strength of the individual item under performance management

<table>
<thead>
<tr>
<th>Performance Management</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 My performance contract is aligned to the company objectives</td>
<td>3.70</td>
<td>1.165</td>
<td>97</td>
</tr>
<tr>
<td>C2 I understand the performance management system</td>
<td>3.68</td>
<td>1.160</td>
<td>97</td>
</tr>
<tr>
<td>C3 The performance bonus I receive is a true reflection of my performance</td>
<td>2.88</td>
<td>1.201</td>
<td>97</td>
</tr>
<tr>
<td>C4 My organisation’s reward system promotes a culture of good performance</td>
<td>3.12</td>
<td>1.218</td>
<td>97</td>
</tr>
<tr>
<td>C5 I am always under pressure to perform my work</td>
<td>3.12</td>
<td>1.252</td>
<td>97</td>
</tr>
<tr>
<td>C6 There is tolerance for mistakes</td>
<td>2.90</td>
<td>1.237</td>
<td>97</td>
</tr>
<tr>
<td>C7 There are penalties for poor job performance</td>
<td>3.21</td>
<td>1.117</td>
<td>97</td>
</tr>
<tr>
<td>C8 There are rewards for excellent job performance</td>
<td>3.01</td>
<td>1.335</td>
<td>97</td>
</tr>
<tr>
<td>C9 There is effective contract management in my organisation</td>
<td>3.04</td>
<td>1.353</td>
<td>97</td>
</tr>
</tbody>
</table>

The respondents felt that they did understand and had an appreciation of the performance management system; however felt that it was used more as punitive measure than for rewarding good performance. Respondents also felt that the performance measurement system did not really promote a culture of good performance but rather had very little tolerant for mistake. This culture stifled innovation and creation and thus the organisation was seen to be too strict and using more of a top down approach. This type of management does not promote a high performance culture but an organisation that waits for management to give direction without taking any initiatives.

Another dimension that can be picked up under performance management responses is the relative low Likert scale score of 2.90 for tolerance of mistakes under C6, 3.01 for
rewarding excellent job performance and 3.04 for effective contracts management against high mean score of 1.237, 1.335 and 1.357 respectively. This shows that most employees do not feel the performance management system is working properly and therefore do not feel valued and motivated to perform. The above issues if not address, could lead to low staff morale and high skill turnover.

4.2.5 Section D: Plant performance

To measure the gaps in the plant management tools, processes and system and their link to reoccurring plant failures (UCLF and UAGS).

Table 4. 12: Reliability statistics for plant performance

<table>
<thead>
<tr>
<th>Cronbach’s Alpha</th>
<th>Cronbach’s Alpha Based on Standardized Items</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.594</td>
<td>.594</td>
<td>10</td>
</tr>
</tbody>
</table>

The 10 questions Plant performance did not have a high degree of consistency reliability as the Cronbach’s alpha coefficient of scale was measured to be 0.594. The Cronbach’s α coefficients of these latent constructs were low below the minimum point of 0.7 (Maree, 2010: 216). Therefore, the selected items did not reliably estimate the latent constructs revealed. This means that the questions asked in some areas did not measure the same thing/construct.

Table 4. 13: Strength of the individual item under plant performance

<table>
<thead>
<tr>
<th>Plant Performance</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 Plant failure investigations are done correctly</td>
<td>3.16</td>
<td>1.208</td>
<td>90</td>
</tr>
<tr>
<td>D2 Most plant failures are preventable</td>
<td>3.90</td>
<td>.875</td>
<td>90</td>
</tr>
<tr>
<td>D3 Implementing corrective actions following incidences is time consuming</td>
<td>2.97</td>
<td>1.136</td>
<td>90</td>
</tr>
<tr>
<td>D4 The age of the plant contributes to deteriorating (decreasing) plant performance</td>
<td>4.13</td>
<td>.997</td>
<td>90</td>
</tr>
<tr>
<td>D5 Most plant failures are predictable</td>
<td>3.34</td>
<td>1.153</td>
<td>90</td>
</tr>
</tbody>
</table>
Maintenance or repair work is conducted on a regular basis

Plant breakdowns are a result of known incidents which were not correctly dealt with

Available power plants are being run too hard

Available power plants are provided with necessary maintenance to avoid breakdowns

Engineering changes are implemented in line with improving plant availability

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>Maintenance or repair work is conducted on a regular basis</td>
<td>3.60</td>
<td>1.079</td>
</tr>
<tr>
<td>D7</td>
<td>Plant breakdowns are a result of known incidents which were not correctly dealt with</td>
<td>3.68</td>
<td>1.026</td>
</tr>
<tr>
<td>D8</td>
<td>Available power plants are being run too hard</td>
<td>3.58</td>
<td>.983</td>
</tr>
<tr>
<td>D9</td>
<td>Available power plants are provided with necessary maintenance to avoid breakdowns</td>
<td>3.28</td>
<td>.972</td>
</tr>
<tr>
<td>D10</td>
<td>Engineering changes are implemented in line with improving plant availability</td>
<td>3.49</td>
<td>.986</td>
</tr>
</tbody>
</table>

There is a moderate correlation between the age of the plant and plant performance. There is a strong belief that most plant failures are preventable. This highlights the importance of selecting the ideal plant maintenance strategy for the age of the plant. Application of correct maintenance strategies will reduce the frequency of unexpected and serious damages to the system, therefore increasing the system’s operating life and its reliability. Of concern is that there is a belief that implementing corrective actions following incidences is time consuming. This invariably shows that there is a tendency not to follow up with the implementation of corrective actions after an incident, which then makes the organisation prone to repeat incidents leading to reoccurring plant failures. Therefore, the selected items do not reliably estimate the latent constructs revealed but reveals that the plants have been operated hard limiting the timely execution of maintenance plans and therefore the plants being more susceptible to premature and untimely failures.

**4.2.6 Section E: Decision making and planning**

To measure if decisions are made on the correct level and the effectiveness of the decisions made. It also measures if planning tools, processes, systems and structures are utilised for effective decision making and planning.
The 11 questions under Decision Making and Planning had a very high degree of consistency reliability as the Cronbach’s alpha coefficient of scale is measured at 0.945. This means that the questions asked to the respondents did measure the same thing/construct. Therefore, the selected items reliably estimated the latent constructs revealed. This means that the results under Decision Making and Planning will be highly acceptable.

Table 4. 15: Strength of the individual item under Decision Making

<table>
<thead>
<tr>
<th>Decision Making and Planning</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1 My organisation’s management and key stakeholders always keep me informed about all decisions and plans made</td>
<td>3.07</td>
<td>1.246</td>
<td>87</td>
</tr>
<tr>
<td>E2 Communication about plans is open and honest in my organisation</td>
<td>3.24</td>
<td>1.276</td>
<td>87</td>
</tr>
<tr>
<td>E3 Management takes accountability for their actions</td>
<td>2.93</td>
<td>1.228</td>
<td>87</td>
</tr>
<tr>
<td>E4 The committee structures put in place by my organisation allow me to do my work better</td>
<td>3.30</td>
<td>1.221</td>
<td>87</td>
</tr>
<tr>
<td>E5 Management is responsible</td>
<td>3.40</td>
<td>1.186</td>
<td>87</td>
</tr>
<tr>
<td>E6 My organisation provides all the tools/systems in order for all decisions and planning processes to be efficient</td>
<td>3.49</td>
<td>1.140</td>
<td>87</td>
</tr>
<tr>
<td>E7 There are sufficient funds to execute required maintenance</td>
<td>3.21</td>
<td>1.091</td>
<td>87</td>
</tr>
<tr>
<td>E8 Decisions are made in time in my organisation</td>
<td>2.76</td>
<td>1.141</td>
<td>87</td>
</tr>
<tr>
<td>E9 Management has the capabilities and competence to do their work well</td>
<td>3.24</td>
<td>1.181</td>
<td>87</td>
</tr>
</tbody>
</table>
Decisions are made at the correct levels within the organisation 3.02 1.171 87

Appropriate decisions are made within my organisation. 3.21 1.080 87

Decision making seems to be a challenge for the organisation. The respondents felt that decisions were not made in time in the organisation (2.76) and they were less confident that the decisions were made at the correct level within the organisation (3.02).

Another shortcoming was seen as Management not taking accountability for their actions, which meant that there was a feeling of “passing the buck”. Decision making did not take place on the right level which delayed implementation of corrective actions. People said they had been given all the tools for proper decision making but the let-down seemed to be the escalation of decisions to higher levels (too much bureaucracy) which delayed decision making. This was not in line with the promotion of a high performance culture.

4.3 INTER-CORRELATIONS BETWEEN THE DIFFERENT SECTIONS

4.3.1 Skills and development versus performance management

Table 4.16: Skills and development versus Performance Management

There is practical significance between Skills and Development and Performance Management. Respondents who felt that skills and development were necessary for
them to perform their jobs also felt that the enforcement of a performance management system was imperative for a high performance culture in the organisation.

4.3.2 Plant Performance versus Decision Making

Table 4. 17: Plant Performance versus Decision Making

There is practical association between Plant Performance and Decision Making and Planning. Respondents felt that, for the plant to perform well, management should be prompt to make decisions and ensure that plans were in place for future growth of the organisation and to address current challenges.

4.3.3 Skills and Development versus Plant Performance

Table 4. 18: Skills and Development versus Plant Performance
There is practical visible association between Skills and Development and Plant Performance. Respondents felt that if their skills and development were improved, there would be a positive gain to the organisation which would reduce the number of plant failures and improve power system reliability.

4.3.4 Performance Management versus Decision Making and Planning

Table 4.19: Performance Management versus Decision Making and Planning

<table>
<thead>
<tr>
<th></th>
<th>B_AVE</th>
<th>C_AVE</th>
<th>D_AVE</th>
<th>E_AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spearman's rho</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\text{Correlation Coefficient}</td>
<td>1.000</td>
<td>.444$^{*}$</td>
<td>.399$^{*}$</td>
<td>.577$^{*}$</td>
</tr>
<tr>
<td>\text{Sig. (2-tailed)}</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>\text{N}</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>C_AVE</td>
<td>Correlation Coefficient</td>
<td>\text{.444}$^{*}$</td>
<td>1.000</td>
<td>.506$^{*}$</td>
</tr>
<tr>
<td>\text{Sig. (2-tailed)}</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>\text{N}</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>D_AVE</td>
<td>Correlation Coefficient</td>
<td>\text{.399}$^{*}$</td>
<td>.506$^{*}$</td>
<td>1.000</td>
</tr>
<tr>
<td>\text{N}</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
</tbody>
</table>
All correlations are statistically significant. For a 2 tailed analysis, the correlation is significant at the 0.01 level (2-tailed). A mentioned under 4.3.1- There is practical significance between Skills and Development and Performance Management. As mentioned under 4.3.2- There is practical association between Plant Performance and Decision Making and Planning. Respondents felt that, for the plant to perform well, management should be prompt to make decisions and ensure that plans were in place for future growth of the organisation and to address current challenges.

As mentioned under 4.3.3- There is practical visible association between Skills and Development and Plant Performance. Respondents felt that if their skills and development were improved, there would be a positive gain to the organisation which would reduce the number of plant failures and improve power system reliability.

Under 4.3.4 it can be seen too that between Performance Management and Decision Making and Planning, there is practical significant correlation that suggest that good decision making and planning does result in improved performance management.

<table>
<thead>
<tr>
<th></th>
<th>Sig. (2-tailed)</th>
<th>0.000</th>
<th>0.000</th>
<th>0.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E_AVE</th>
<th>Correlation Coefficient</th>
<th>.577**</th>
<th>.551**</th>
<th>.598**</th>
<th>1.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 5

5.1 INTRODUCTION

The study was undertaken to prove that there was a relation between reoccurring plant failures and load shedding using data obtained from the organisation of the power station performance and conducting a survey using a questionnaire to gauge Eskom staff’s understanding of plant performance and load shedding.

The data showed that, during the incidents of load shedding, the plants were operating unreliably due to reoccurring plant failures. Over and above that, the respondents’ results confirmed that, to eliminate reoccurring plant failures so as to eliminate load shedding, skills and development, performance management, plant performance and decision making and planning all have to be addressed for improved power plant reliability.

5.2 CONCLUSION

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 1</td>
<td>69</td>
<td>2.48</td>
<td>0.949</td>
<td>0.114</td>
</tr>
<tr>
<td>Age 2</td>
<td>66</td>
<td>2.44</td>
<td>0.806</td>
<td>0.099</td>
</tr>
</tbody>
</table>

Since the ages are categorized, a cross-tabulation method seems it would be the best suited to test for the statistical significant between males and females as below.

<table>
<thead>
<tr>
<th>Gender * Age Cross tabulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>0-3</td>
</tr>
<tr>
<td>Gender</td>
</tr>
</tbody>
</table>

75
There is a relative young workforce in Eskom as it is concentrated between 26-45 years of age. The majority of the skills level is concentrated between 4-11 years (81%). Fifty-one percent (69) are males versus 49% (66) females. Both analyses indicate that there is not a statistical significance difference between ages of males and females.

This is both good and bad. It would be good if there was a match in the skills level between males and female but as we all know, males have been in the industry longer. Women have not really caught up to men on the skills level. This then poses a threat of sometimes pushing women to positions higher in the organisation before they have acquired the necessary skills.

<table>
<thead>
<tr>
<th></th>
<th>10.1%</th>
<th>49.3%</th>
<th>27.5%</th>
<th>8.7%</th>
<th>4.3%</th>
<th>100.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>2</td>
<td>42</td>
<td>15</td>
<td>5</td>
<td>2</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>3.0%</td>
<td>63.6%</td>
<td>22.7%</td>
<td>7.6%</td>
<td>3.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>76</td>
<td>34</td>
<td>11</td>
<td>5</td>
<td>135</td>
</tr>
<tr>
<td>% within Gender</td>
<td>6.7%</td>
<td>56.3%</td>
<td>25.2%</td>
<td>8.1%</td>
<td>3.7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Paired Samples Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skills and Development</td>
<td>3.24907</td>
<td>135</td>
<td>1.085597</td>
<td>0.093433</td>
<td>0.23</td>
</tr>
<tr>
<td>Performance Management</td>
<td>2.99835020</td>
<td>135</td>
<td>0.8398545</td>
<td>0.07228</td>
<td></td>
</tr>
</tbody>
</table>
Paired Samples Test

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills and Development versus Performance Management</td>
<td>0.250</td>
<td>1.070</td>
<td>0.092</td>
<td>0.068</td>
<td>0.432907</td>
<td>2.722</td>
<td>134</td>
</tr>
</tbody>
</table>

Some of the respondents said there was practical significance between Skills and Development and Performance Management at a p value of 0.007. In practice however the difference between Skills and Development and Performance Management is only of a small effect (d=0.23). Skills and Development are paramount for a high performance culture in the organisation. Driving Performance Management concurrently with improving Skill and Development guarantee a reduction of repeat plant failure and reoccurring incidents.

There is practical association between Plant Performance and Decision Making and Planning. The respondents felt that, for the plant to perform well, management should be prompt to make decisions and should ensure that plans are in place for the future growth of the organisation and to address current challenges. Prompt decision making responses, means curbing and/or reducing reoccurring plant failures as mitigation plans are put in place and maintenance is carried out promptly. On-line monitoring systems ensure that plant failures are picked up before the plant actually fails and management makes quick decisions to avert plant breakdowns.

There is practical visible association between Skills and Development and Plant Performance. Respondents felt that if their skills were improved and their development ensured there would be a positive gain to the organisation which would also reduce the number of plant failures and improve power system reliability.
### Paired Samples Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Management</td>
<td>3.24907</td>
<td>135</td>
<td>1.085597</td>
<td>0.093433</td>
<td>0.40</td>
</tr>
<tr>
<td>Decision Making</td>
<td>2.80808080808080810</td>
<td>135</td>
<td>1.099954957568600</td>
<td>0.094669049605366</td>
<td></td>
</tr>
</tbody>
</table>

### Paired Samples Correlations between Performance Management and Decision Making

<table>
<thead>
<tr>
<th>N</th>
<th>Correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>135</td>
<td>0.512</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Paired Samples Test

Paired Differences between Performance Management and Decision Making

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig.(2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4409</td>
<td>1.0797</td>
<td>0.0929</td>
<td>0.2572 0.6248</td>
<td>4.745</td>
<td>134</td>
<td>0.000</td>
</tr>
</tbody>
</table>

There is no practical significance between Performance Management and Decision Making and Planning. Good performance management system and implementation has very little to do with decision making and planning. They do not have a mutually beneficial relationship but they are both important for plant reliability improvement.
Looking at the performance of Eskom from 2008 to 2014, it has faced many challenges with the major ones being load shedding and financial instability. The performance has been deteriorating gradually and it has largely been blamed on poor maintenance and delay in augmenting its generating capacity by building new power stations on time to meet electricity demand.

Eskom strategy of keeping the “Light on” at all cost was in contract to good maintenance practice, which led to an increase in plant breakdowns (high Unplanned Capability Loss factor) as seen under figure 4.9 above.

There has been relief in the electricity demand due to large industry saving on energy consumption as per Eskom’s request for the large industries to save 10% of the electricity demand and the slowing down of the economy helped. Even with the above relief for Eskom, this study is paramount to boost the electricity availability of Eskom and stability of the national grid to ensure a reliable power supply.

5.3 RECOMMENDATIONS

The recommendations are based on the findings both from the collected data of Eskom plant performance and questionnaires answered by the respondents.

Discussion 1

During 2008, even though the UCLF for the year was at 5%, there was a brief period when it increased dramatically due to a combination of power generators failing and poor coal availability.

In 2014, the coal availability and quality improved in most power stations but the system unreliability was still high as was observed with the loss of two big machines at Kendal and Duvha. Duvha 3 is still out of service due to the boiler explosion and Majuba Coal Silo collapsed, which caused three machines to be out of service. The above events/plant failures destroyed the power system reserve to the brink of a National blackout.

A drop in UCFL is indicative of a poor generating fleet performance. This can be attributed to deteriorating plant health of an ageing power station fleet. The factors that
contribute to the high UCLF percentage are amongst others, partial load losses, increase boiler tube failures and major/significant load losses mainly as a result of different plant failures.

The results confirmed that there was a relationship between reoccurring plant failures and load shedding.

**Recommendation 1**

Improve the quality of incident investigation and effective implementation of corrective actions to reduce or eliminate reoccurring plant failure.

**Discussion 2**

There is practical significance between Skills and Development, Performance Management, Plant Performance and Decision Making and Planning. The results obtained confirmed that skills were necessary for an improved performance.

**Recommendation 2**

Implement a balanced (equal reward and correcting behaviour) Performance Management systems. This will motivate employees to put more effort to their work and reduce a tendency of feeling like they are not valued. Management to lead effectively, mobilise people to achieve company objectives and ensure company success by being task orientated, relation oriented and change oriented (Hough et al., 2012:292).

**Discussion 3**

There is practical association between Plant Performance and Decision Making and Planning. Respondents felt that, for the plant to performance well, management should be prompt to make decisions and should ensure that plans are in place for the future growth of the organisation and to address current challenges. Prompt decision making responses, means curbing and/or reducing reoccurring plant failures as mitigation plans are put in place and maintenance is carried out promptly.
Recommendation 3 (a)
Implement tools and systems that will support the alignment of ideal maintenance strategies to plant age in order to reduce plant failures.

Recommendation 3 (b)
Provide decision making training to assist management to make prompt decision

Discussion 4
There is practical visible association between Skills and Development and Plant Performance. Respondents felt that, if their skills and development were improved, there would be a positive gain to the organisation which would also reduce the number of plant failures and improve power system reliability.

Recommendation 4
Investigate the reason for the skill gap and implement the programme to address the skill gap. When skills are enhanced, employees will feel more motivated to perform and less bored at work. (Reijseger et al, 2012: 523) concluded that boredom at work is a psychological state that is most likely to exist when both demands and resources are low. In order to prevent boredom, jobs may be redesigned to increase the arousal experienced by employees.

5.4 ACHIEVEMENTS OF THE OBJECTIVES OF THE STUDY
The objective of this research was to investigate the relationship between reoccurring plant failures and load shedding and to provide recommendations to prevent or at least reduce the occurrences of load shedding.

Load shedding is detrimental to the economy of the country and every effort must be made to prevent it. According to Hameed et al. (2010:879–894), reliability of any design is the most important feature and this can be ensured by overwhelming the previous weaknesses and faults occurred in the design and then formulating novel strategies and techniques to minimise these shortcomings. By doing so, the reliability and robustness of that design can be enhanced. One method of achieving this level is to devise and
implement efficient, adaptable and responsive systems of condition monitoring and fault detection systems, especially on Power Plant.

This research has revealed that there was a correlation between the reoccurring plant failure and load shedding. Reoccurring plant failures can be reduced through the execution of proper investigations, implementation of proven maintenance strategies and application of quality maintenance in line with the industry standards. Furthermore, the implementation of the recommendations mentioned above (section 5.3), namely, addressing organisation challenges under Skills and Development, Performance Management, Plant Performance and Decision Making and Planning, will assist Eskom to reduce reoccurring plant failures and thus eliminate/reduce load shedding incidents.

The continuous use of the Tetris tool has assisted Eskom to stabilise the system and perform the necessary maintenance. The addition of a new power station is imperative for a growing economy, so Eskom needs to speed up the commissioning and commercialisation of the new power stations before the GDP picks up again for a stable and reliable power system.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The age of the power stations and stability of the power system are important for the growth of the economy. Future researchers therefore need to determine what led to Eskom’s maintenance strategies not to be in line with the age of the power stations and what management interventions can be put in place to address both skill challenges and somewhat poor decision making and planning.

5.6 SUMMARY

The results confirm that there is a relationship between reoccurring plant failures and load shedding. There is practical significance between Skills and Development, Performance Management, Plant Performance and Decision Making and Planning. This kind of a study is paramount for Eskom and the country at large and therefore more research needs to be carried out by future researchers to support a stable, vibrant growing economy.
REFERENCES


http://intranet.eskom.co.za/CommunicationContentHub/Pages/Presentations.aspx Date of access: 18 June 2016. [PowerPoint presentation].


http://dx.doi.org/10.1108/13552510610654501. [Date of access: 16 November 2016]

http://dx.doi.org/10.1108/1355251121219462. [Date of access: 22 November 2016]


Reijseger, W., Maria, S., Peeters, C.W., Taris, T.W., Van Beek, I & Ouweneel, E. Anxiety, Stress, & Coping: An International Journal. Utrecht University. The Netherlands. Accepted author version posted online: 10 Sep 2012. Published online: 21 Sep 2012.
http://www.tandfonline.com/loi/gasc20
Date of access: 02 January 2016


http://dx.doi.org/10.1108/17542731311299609. [Date of access: 25 October 2016]


http://dx.doi.org/10.1108/13552511011030336. [Date of access: 16 November 2016]


**RESEARCH QUESTIONNAIRE**

This questionnaire explores the factors relating to how well your organisation operates. The information requested from you is being collected for research purposes. Filling out this questionnaire will take approximately 5 minutes of your time. Please note that this is not a test and therefore there is no right or wrong answer. All information collected will be anonymous and kept confidential; therefore you are encouraged to answer openly and honestly.

**SECTION A: DEMOGRAPHIC INFORMATION**

Please indicate your information by marking in the appropriate block with an “X”. Please mark one item only per question.

1. **Gender**
   - Male
   - Female

2. **Age**
   - 18 - 25 years
   - 26 - 35 years
   - 36 - 45 years
   - 46 - 55 years
   - 56 and older

3. **Ethnicity**
   - African
   - White
   - Coloured
   - Indian
   - Asian
   - Other
   - If “other” please specify: ______________

4. **Highest level of education**
   - Below matric
   - Matric
   - Diploma
   - Degree
   - Post graduate
5. Years of experience

<table>
<thead>
<tr>
<th>Years of experience</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3 years</td>
<td></td>
</tr>
<tr>
<td>4 - 7 years</td>
<td></td>
</tr>
<tr>
<td>8 - 11 years</td>
<td></td>
</tr>
<tr>
<td>12 - 15 years</td>
<td></td>
</tr>
<tr>
<td>16 and above</td>
<td></td>
</tr>
</tbody>
</table>

6. Role in the organisation

<table>
<thead>
<tr>
<th>Role in the organisation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Technician/artisan</td>
<td></td>
</tr>
<tr>
<td>Engineer</td>
<td></td>
</tr>
<tr>
<td>Supervisor</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

7. Which department do you work in?

SECTION B: SKILLS AND DEVELOPMENT

Please indicate the extent to which you agree or disagree with the following statements in relation to skills and development within your organisation. The numbers represent the following:

1 = strongly disagree  2 = disagree  3 = neutral  4 = agree  5 = strongly agree

DK = don’t know

- Please mark only one block per statement with an (X)
- Please try to avoid marking 3 “neutral” and do so when absolutely necessary
- You may select any number or "DK" (Don't know) depending on your experience

<table>
<thead>
<tr>
<th>SKILLS AND DEVELOPMENT STATEMENTS</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 DK</td>
</tr>
<tr>
<td>1 My organisation provides a platform for continuous learning</td>
<td></td>
</tr>
<tr>
<td>2 There are opportunities to grow in my organisation</td>
<td></td>
</tr>
<tr>
<td>3 My organisation cares about my development</td>
<td></td>
</tr>
<tr>
<td>4 I have the necessary skills to do my work well</td>
<td></td>
</tr>
<tr>
<td>5 I receive regular relevant training in order for me to do my work well</td>
<td></td>
</tr>
<tr>
<td>6 My organisation is a high performing organisation</td>
<td></td>
</tr>
<tr>
<td>7 My organisation equips staff with relevant skills in order to measure up to work demands/requirements</td>
<td></td>
</tr>
</tbody>
</table>
SECTION C: PERFORMANCE MANAGEMENT

Please indicate the extent to which you agree or disagree with the following statements in relation to performance management within your organisation. The numbers represent the following:

1 = strongly disagree  2 = disagree  3 = neutral  4 = agree  5 = strongly agree

- Please mark only one block per statement with an (X)
- Please try to avoid marking 3 “neutral” and do so when absolutely necessary
- You may select any number or “DK” (Don't know) depending on your experience

<table>
<thead>
<tr>
<th>PERFORMANCE MANAGEMENT STATEMENTS</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 DK</td>
</tr>
<tr>
<td>1 My performance contract is aligned to the company objectives</td>
<td></td>
</tr>
<tr>
<td>2 I understand the performance management system</td>
<td></td>
</tr>
<tr>
<td>3 The performance bonus I receive is a true reflection of my performance</td>
<td></td>
</tr>
<tr>
<td>4 My organisation’s reward system promotes a culture of good performance</td>
<td></td>
</tr>
<tr>
<td>5 I am always under pressure to perform my work</td>
<td></td>
</tr>
<tr>
<td>6 There is tolerance for mistakes</td>
<td></td>
</tr>
<tr>
<td>7 There are penalties for poor job performance</td>
<td></td>
</tr>
<tr>
<td>8 There are rewards for excellent job performance</td>
<td></td>
</tr>
<tr>
<td>9 There is effective contract management in my organisation</td>
<td></td>
</tr>
</tbody>
</table>

SECTION D: PLANT PERFORMANCE

Please indicate the extent to which you agree or disagree with the following statements in relation to plant performance within your organisation. The numbers represent the following:

1 = strongly disagree  2 = disagree  3 = neutral  4 = agree  5 = strongly agree

- Please mark only one block per statement with an (X)
- Please try to avoid marking 3 “neutral” and do so when absolutely necessary
- You may select any number or "DK" (Don't know) depending on your experience

<table>
<thead>
<tr>
<th>PLANT PERFORMANCE STATEMENTS</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 DK</td>
</tr>
<tr>
<td>1 Plant failure investigations are done correctly</td>
<td></td>
</tr>
<tr>
<td>2 Most plant failures are preventable</td>
<td></td>
</tr>
<tr>
<td>3 Implementing corrective actions following incidences is time consuming</td>
<td></td>
</tr>
</tbody>
</table>
4. The age of the plant contributes to deteriorating (decreasing) plant performance
5. Most plant failures are predictable
6. Maintenance or repair work is conducted on a regular basis
7. Plant breakdowns are a result of known incidents which were not correctly dealt with
8. Available power plants are being run too hard
9. Available power plants are provided with necessary maintenance to avoid breakdowns
10. Engineering changes are implemented in line with improving plant availability

SECTION E: DECISION MAKING AND PLANNING

Please indicate the extent to which you agree or disagree with the following statements in relation to decision making and planning within your organisation. The numbers represent the following:

1 = strongly disagree  2 = disagree  3 = neutral  4 = agree  5 = strongly agree

- Please mark only one block per statement with an (X)
- Please try to avoid marking 3 “neutral” and do so when absolutely necessary
- You may select any number or "DK" (Don't know) depending on your experience

<table>
<thead>
<tr>
<th>DECISION MAKING AND PLANNING STATEMENTS</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. My organisation’s management and key stakeholders always keep me informed about all decisions and plans made</td>
<td></td>
</tr>
<tr>
<td>2. Communication about plans is open and honest in my organisation</td>
<td></td>
</tr>
<tr>
<td>3. Management takes accountability for their actions</td>
<td></td>
</tr>
<tr>
<td>4. The committee structures put in place by my organisation allow me to do my work better</td>
<td></td>
</tr>
<tr>
<td>5. Management is responsible</td>
<td></td>
</tr>
<tr>
<td>6. My organisation provides all the tools/systems in order for all decisions and planning processes to be efficient</td>
<td></td>
</tr>
<tr>
<td>7. There are sufficient funds to execute required maintenance</td>
<td></td>
</tr>
<tr>
<td>8. Decisions are made in time in my organisation</td>
<td></td>
</tr>
<tr>
<td>9. Management has the capabilities and competence to do their work well</td>
<td></td>
</tr>
<tr>
<td>10. Decisions are made at the correct levels within the organisation</td>
<td></td>
</tr>
<tr>
<td>11. Appropriate decisions are made within my organisation</td>
<td></td>
</tr>
</tbody>
</table>

THANK YOU FOR YOUR PARTICIPATION
### Annexure B: Load shedding schedule for Alberton

#### Alberton / Thokoza

<table>
<thead>
<tr>
<th>DAY TIME</th>
<th>00h00 - 03h00</th>
<th>03h00 - 06h00</th>
<th>06h00 - 09h00</th>
<th>09h00 - 12h00</th>
<th>12h00 - 15h00</th>
<th>15h00 - 18h00</th>
<th>18h00 - 21h00</th>
<th>21h00 - 24h00</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h00 - 03h00</td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
<td>B4</td>
<td>B5</td>
<td>B6</td>
<td>B7</td>
<td>B8</td>
</tr>
<tr>
<td>03h00 - 06h00</td>
<td>B9</td>
<td>B10</td>
<td>B11</td>
<td>B12</td>
<td>B13</td>
<td>B14</td>
<td>B15</td>
<td>B16</td>
</tr>
<tr>
<td>06h00 - 09h00</td>
<td>B17</td>
<td>B18</td>
<td>B19</td>
<td>B20</td>
<td>B21</td>
<td>B22</td>
<td>B23</td>
<td>B24</td>
</tr>
<tr>
<td>09h00 - 12h00</td>
<td>B25</td>
<td>B26</td>
<td>B27</td>
<td>B28</td>
<td>B29</td>
<td>B30</td>
<td>B31</td>
<td></td>
</tr>
<tr>
<td>12h00 - 15h00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15h00 - 18h00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18h00 - 21h00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21h00 - 24h00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**B1 AREAS**: Randhart Ext 1 & 2, General Alberts Park and Randhart

**B2 AREAS**: Raceview, Souwcrest, Newmarket (Pick n Pay), New Redruth, Alberts and Extensions

**B3 AREAS**: Brackenhurst and Extensions 1 & 5, Mayberry Park and Extention 1, Brackendowns and Extensions 1.2.3 & 4

**B4 AREAS**: Meyersdal, Meyersdal (Eco East & Nature Estate), Thokoza North (Spiltsvent, Phendula Section, Bassoon Section, and Hostels)

**B5 AREAS**: Civic Centre and CBD area, Alberton North and Extensions, Parklands Area, Florentina and Extensions, Verwoerd Park and Extensions

**B6 AREAS**: Brackendowns 5, Albertsdal, Thokoza South (Ext 1 & 2), Thokoza Gardens, Everest, Unit F, Vergenoeg, Edepark & Extensions, Greenfields, Pohla Park & Extensions, Thinsambo

**Please note**: Consumers may be affected by load shedding as per schedule above depending on how much load must be shed. The request from Eskom range from 10 MW to 300 MW and depending on how much must we shed, the affected Areas in a block may be equitably reduced.

---

**Energy**

Reliable and economical, our electricity future in good hands

---

*A partnership that works*
Annexure C: Analysis of Generation Major Incidents (2004-2014)
# Table of Contents

1 Introduction .............................................................................................................. 3  
   1.1 Background ........................................................................................................ 3  
   1.2 High Level Common Themes (IBI Analysis) ..................................................... 5  
2 General Overview .................................................................................................... 6  
3 Incident Stations Trend per Category ..................................................................... 7  
   3.1 Generation Fossil and Koeberg MUTs ............................................................... 7  
   3.2 Generation Peaking MUT’s .............................................................................. 8  
4 Multiple Unit Trips ................................................................................................... 12  
   4.1 Direct Causes of MUTs .................................................................................... 12  
   4.2 Root Causes of MUTs ..................................................................................... 15  
   4.3 Human Factors ............................................................................................... 16  
   4.4 Lessons Learnt ................................................................................................ 16  
   4.5 Recommendations ......................................................................................... 17  
5 Conveyor Fire Incidents ......................................................................................... 18  
6 Turbine Incidents ..................................................................................................... 19  
7 Boiler Incidents ....................................................................................................... 20  
   7.1 Highest Common Failures (Boilers) ................................................................... 21  
8 IBI Analysis ............................................................................................................. 22  
   8.1 Failed Barriers ................................................................................................. 22  
   8.2 Unpacking the High Level Common Themes .................................................... 23  
   8.2.1 Poor Housekeeping (M10) ......................................................................... 23  
   8.2.2 Plant Inspections and Checks not done thoroughly (incl. Plant Testing) (E4)... 23  
   8.3 IBI Analysis Insights ...................................................................................... 25  
9 Conclusion ................................................................................................................. 26  
10 Distribution List ...................................................................................................... 26
1 Introduction
1.1 Background
A trending and analysis exercise was conducted on major (level 1) and significant (level 2) incidents for the period 2004 to 2014 (Figure 1). This was done by reviewing the incident reports that were captured in the “Major Event Register” for each of the incidents. The purpose of the exercise was to identify the common themes (IBI Analysis) to provide the Generation Division with management information to determine the areas to focus on to minimise and prevent these incidents from occurring or re-occurring. Overall there is an increase in incidents.

It should be noted that the integrity of the incident investigation reports and other information sources (“Major Event Register” – Excel spreadsheet) used for this report might not be totally accurate. However this further illustrates the importance of the implementation and utilisation of the new SAP QIM system for issues management. Nevertheless the key issues are relevant and require the necessary attention to help Generation to reduce the frequency of incidents and to improve plant performance.

![Graph of Major and Significant Incidents 2004-2014](image)

Figure 1: Major and Significant Incidents 2004-2014
The comparison of the total incidents for all the power stations (Figure 2 & 3) from 2011-2014 over 2004-2014 show an upward trend (red arrow) on total incidents, similar than the total increase in incidents (Figure 1). The stations with the highest increase in the number of incidents and posing the biggest risks (red arrows) over the past 4 years are Hendrina, Komati, Duvha and Kendal for the fossil stations and Gourikwa and Drakensberg for the peaking stations.
A detailed analysis was conducted of all the incidents and the following main categories (Figure 4) of incidents were identified as the most significant and frequent types occurring:

- Multiple Unit Trips (MUT’s)
- Turbines
- Conveyor Fire Incidents
- Boilers
The comparison of the total incidents (Figure 4) from 2011-2014 over 2004-2014 shows an upward trend (red arrows) on MUTs, Turbines and other incident. On Fire, Boilers, Transformers and Generators there is a decrease of incidents over the same period. However on Fire incidents it is only a marginal decrease. Other incidents include fatality and contact incidents (21 in total – People Safety Incidents) were captured in the “Major Event Register” up to 2011, after 2011 the people safety incidents are part of the safety incident statistics and captured in the EHS system, therefore the increase in other incidents if the safety incidents are excluded.

1.2 High Level Common Themes (IBI Analysis)

The following are the high level common themes of failures that were identified through the IBI analysis that is discussed in section 8, and have contributed mostly to the incidents analysed.

These are ranked according to most common to least common theme:
1. Poor housekeeping
2. Plant inspections and checks not done thoroughly (incl. plant testing)
3. Poor maintenance execution including works management
4. Poor contract management
5. Non to poor procedural adherence and compliance
6. Inadequate corrective action management
7. Poor commissioning execution
8. Inadequate skills levels
9. Role and responsibilities not clear and poor communication
3 Incident Stations Trend per Category

3.1 Generation Fossil and Koeberg MUTs

From the analysis above the stations with the highest risk of MUTs over the past 4 years are Hendrina, Majuba, Camden, and Komati (Red arrows). Overall there is an increase in MUTs over the past 4 years (Figure 7).
3.6 Summary of Incidents

- MUTs are a concern in Generation and the biggest contributors over the past 4 years are Hendrina, Majuba, Camden and Komati (Figure 7).
- Stations to watch in terms of MUTs on the Peaking side are Ankerlig, Drakensberg and Gourkwa (Figure 8).
- The top four power stations in Turbine incidents over the past 4 years are Hendrina, Kriel, Komati and Majuba (Figure 9).
- The top four stations in fire incidents over the past 4 years are Hendrina, Kriel, Tutuka and Lethabo (Figure 10).
- Stations with high risk profile for the period from 2004-2014 are Hendrina, Camden and Kriel (Figure 5).
- Hendrina, Komati and Duvha trends show worst performance for the past 4 years (Figure 6).

In figure 12 below the summary of the individual station’s total incidents contribution per category.

![Figure 12: Individual Station’s Incidents Contributions](image)

3.7 Summary of Incidents from 1989 - 2014

Shown below in figures 13 and 14 are the comparisons between the number of major and significant incidents per station between 1989 and 2014, and only the major incidents between 2011 and 2014. The conclusion from the trend between the two grafts is that the stations with the highest number of incidents over the past 25 years (Hendrina and Duvha) are also the stations with the highest number of major incidents over the past 4 years. The hypothesis is that the stations did not manage to reduce their risks and/or incident rate, and
that the same stations with the highest incident rate continue to have major incidents. Stations with the largest increase in major incidents following Hendrina and Duvha are Majuba, Komati and Kriel, these stations shown also an increase in the overall risk of more major incidents.

Figure 13: Major and Significant Incidents 1989-2014

Figure 14: Major Incidents 2011-2014
9 Conclusion

It should be noted that the integrity of the incident investigation reports and other information sources ("Major Event Register" – Excel spreadsheet) used for this report might not be totally accurate. However this analysis illustrates the importance of the implementation and utilisation of the new SAP QIM system for issues management. Nevertheless the key issues are relevant and require the necessary attention to help Generation to reduce the frequency of incidents and to improve plant performance.

Hendrina, Komati and Duvha are the power stations with the biggest increase of major and significant incidents over the past four years (2011-2014). The stations with the highest risk of MUTs are Hendrina, Majuba, Camden and Komati. The top four stations in fire incidents are Hendrina, Kriel, Tutuka and Lethabo.

Human error is not limited to individuals making mistakes. The barriers that have failed indicated in the IBI analysis are all human factors that have failed because of management, leadership and/or individuals. The three most significant contributors to incidents overall are housekeeping, ineffective plant inspections and the lack of effective routine maintenance.

Management should take control and command through visible leadership and set clear management expectations to sustain the barriers that have not failed and to address all the failed barriers to turn the situation around.

10 Distribution List

Divisional Executive (Generation)
Senior General Managers (Generation)
Power Station Managers
Shireen Prince Senior Manager BIPM & Assurance
Hennie Nel Gx Sustainability Regulatory Compliance
Gert Oosthuizen Gx Sustainability Technical Occurrence Management