Power Delivery Engineering (PDE)

EIT Training Review: Progress Report

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Review Period:	April 2018 - October 2018
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Contents

1 Introduction

The training activities and outcomes that were undertaken and achieved throughout the six month period between the 5^{th} March 2018 and 19^{th} October 2018 is included in this document and serves as the second deliverable in the formalised EiT program. Table 1 highlights the relevant departments within Power Delivery Engineering (PDE) that were included in the training program throughout this period.

Table 1: Departments visited in EiT program to date.

Department	Start-date	End-date	Duration	Program Status
Northrand Customer Network Centre Field Services	2018-03-05	2018-03-22	3 weeks	Completed
Control Plant Maintenance	2018-03-25	2018-04-13	3 weeks	Completed
Network Optimisation	2018-04-16	2018-06-15	9 weeks	Completed
Operations Planning	2018-06-18	2018-08-03	7 weeks	Completed
Protection (PTM&C)	2018-08-06	-	-	Ongoing

A section is dedicated to each particular department, which is primarily concerned with the Practical Exposure and Elective requirements of the program. The technical training received (describe the role of each department within PDE and review any training), the practical training activities participated in (meetings, site visits, projects undertaken etc.), and the important lessons learnt throughout this period are highlighted in the following sections. I am currently at Protection (PTM&C).

2 Northrand Customer Network Centre (CNC)

Training Start date	2018-03-05
Training End date	2018-03-22
Trainer	Helga De Meyer

2.1 Outline

The success of Eskom's business ventures are predicated on the delivery of electricity of an exceptional standard to our customers. In the ideal case, the quality and continuity of supply to our customer base would remain taintless and uninterrupted. Certain factors, such as theft, lightning strikes, storms, and simple deterioration of equipment may compromise this supply. Intervention is required to reinstate the acceptable supply to our customers in such cases. These interventions are the responsibility of the Customer Network Centres (CNC's), which are smaller, more manageable regions located within the 7 national Operating Units (OUs).

Interventions are facilitated through a telephonic feedback system. Customers who experience problems with their electricity supply can report the fault by contacting an Eskom Call Centre. There are 7 such call centres that cater to each of the OUs. The location of the fault is registered, and the call centre agents will then log the fault with all other relevant information. This information is then sent to the dispatch unit who will identify the relevant CNC. Dispatch will then send all relevant information, including fault description and location of the fault, to a technician at the CNC, who will then travel to the destination of the fault to diagnose and correct any problems that may be affecting the distribution of electricity to the customer.

Sustaining adequate supply to the customers may not only be compromised at customer level only. Indeed, the maintenance and repair of higher voltage distribution assets within the CNC, such as distribution substations, lines, and cables, all fall within the jurisdiction of the CNC. This may require the operating of circuit breakers or isolators at substations, which are typically performed by Senior Technical Officers (STO's). In either case, the technicians need to be certified to operate high voltage equipment and must be certified to work at heights. Additionally, technicians must understand (and take serious heed of) the risks associated with driving long distances, working in relatively impoverished environments, and interacting with potentially irascible customers.

The Eskom training standard stipulates that each EiT is required to actively participate in field service operations. I was thus placed at the Northrand CNC for roughly three weeks under the supervision of Helga De Meyer, during which time I participated in a number of activities which form the backbone of the operations at the CNC. Some of these activities are discussed below.

2.2 Training Activities

2.2.1 Replacement of IPC Clamp

Customers in the more informal communities in Johannesburg are typically fed directly from a distribution pole as opposed to cables that are typically found in suburban and metropolitan areas. These distribution lines are easier to maintain but are exposed to the outside environment, making the associated equipment susceptible to damage through theft and unfavourable weather conditions. In this particular case, an IPC clamp, used to join two separate conductors, was found to have weathered considerably, causing the inadvertent disconnection of power to the relevant customers. A report was filed and dispatch requested an investigation. The affected distribution pole is demonstrated in figure 1.

Figure 1: A distribution pole with conductors that are designated to the surrounding residences. A frayed conductor on the bottom right-hand corner of the conductor mesh must be remedied.

Figure 2: The relevant circuit needs to be opened before operation can proceed. In this instance, operating happens directly at the related transformers, which distribute power through a closed fuse. Opening the fuse de-energises the circuit.

Figure 3: Switching of the transformer fuses must be performed using a switch stick (as seen in the picture) to ensure the safety of the technician.

Figure 4: Retrieval of the broken IPC clamp necessitates the execution of working at heights procedures, whereby the regulations must be strictly adhered to. A ladder is secured against a neighbouring wall.

It was determined that live-work would not be feasible or reasonable in this case, and therefore the feed to the distribution pole from the local transformer required disconnection. This disconnection was facilitated through the use of a switch stick, which prevents the need for close physical interaction with the transformer's fuse links. This disconnection procedure can be seen in figure 2 and figure 3. The replacement of the IPC clamp required the need to work at heights, and thus a ladder was retrieved from the truck and secured against the relevant distribution pole. The technician secured herself on the ladder with every step using the Fall Arrest System (FAS) procedure, whereby hooks were used to secure the technician to the ladder with at least three attachment points. The ladder is shown in figure 4. The damaged IPC clamp is removed and is replaced with a new clamp, such as one demonstrated in figure 5. This reinstates the connection from the distribution pole to the customer. Once this connection is re-established, the fuse link of the transformer is once again closed to re-energise the customer's home.

Activities such as the aforementioned IPC clamp replacement can easily be executed ina space of less than an hour by one skilled technician, and whilst such failures are common, these typically do not result in extended periods of disconnection. Larger failures, such as the replacement of a faulty distribution transformer, will require more man-power and more equipment. It is with crucial that such failures be treated with utmost urgency to prevent extended outages for a large number of customers.

Figure 5: The damaged IPC clamp is replaced with a new clamp (seen in the picture).

2.2.2 Replacement of Transformer

Whilst Eskom has diligently addressed its mandate regarding the complete electrification of the entire country over the past 25 years, there are still numerous communities that have no access to this basic human right. These citizens have, thus, resorted to connecting illegally to the Eskom network, resulting in the failure of a significant number of Eskom's assets as a result of the unexpected rise in loading on the distribution lines. Such a failure was logged in Ivory Park during our internship at the Northrand CNC. The faulty transformer is demonstrated in figure 6. The transformer cannot evidently be removed by a single technician, but instead requires a team of technicians operating a crane and a bucket-truck to execute the replacement.

The operation proceeded as follows:

1. Perform risk assessment.
2. Position, secure, and ground crane and bucket truck.
3. Off-load new transformer onto ground level using the crane.
4. Detach old transformer from distribution pole using bucket truck. Support weight of old transformer using crane during this process.
5. Assemble new transformer.

Figure 6: Transformer requiring replacement in Ivory Park. Removal requires the use of a bucket-truck and a crane since. Operation performed under live conditions.

6. Drop old transformer into delivery truck using crane.

7. Lift new transformer to pole using crane and attach transformer to pole using bucket truck.

These steps are demonstrated in figures 7-17 below. This operation was performed under live conditions to prevent any unnecessary disconnection of customers within the area.

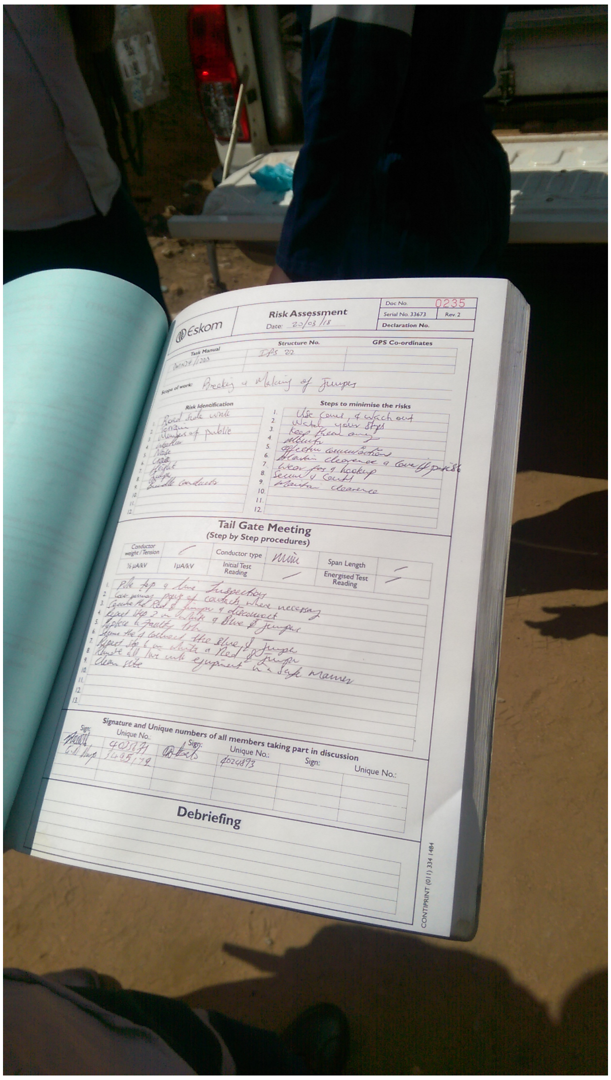


Figure 7: A risk assessment is carried out before the operation as required by the Operating Regulations of High Voltage Systems (ORHVS).

Figure 8: Earth spikes are used to connect the metallic structure of the trucks to the highly conductive earth that sits a few centimetres beneath the surface.

Figure 9: Earth plates are secured on the ground for use by the operators. operators are required to stand on each of these plates to prevent accidental electrocution in the instance when the crane comes into contact with a live conductor.

Figure 10: The crane and bucket-truck each have extensions that secures them firmly to the surrounding ground. The connection pictured above facilitates the grounding of the earth plates.

Figure 11: The operator performing the live work is required to fashion appropriately rated electrically-insulated gloves when performing work under live operating conditions.

Figure 12: The live-work operator begins to remove the fastenings that hold the defective transformer to the distribution pole whilst the crane is used to off-load the new transformer tank.

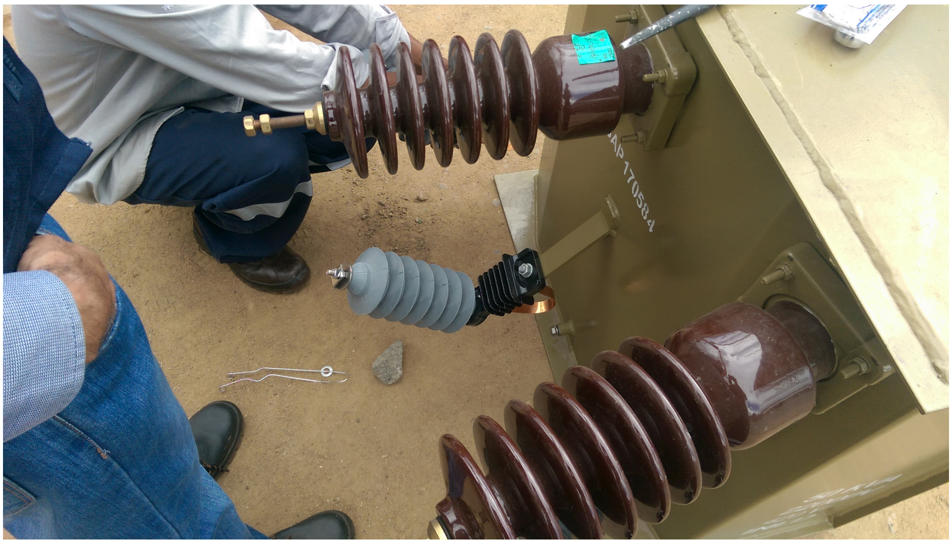


Figure 13: Condenser bushings, surge arrestors, connecting conductors, and earthing strips are added to the transformer tank on-site.

Figure 14: Pertinent details regarding the transformer is recorded for future reference.

Figure 15: The defective transformer, once detached from the pole, is lifted by the crane off the pole onto the ground for inspection.

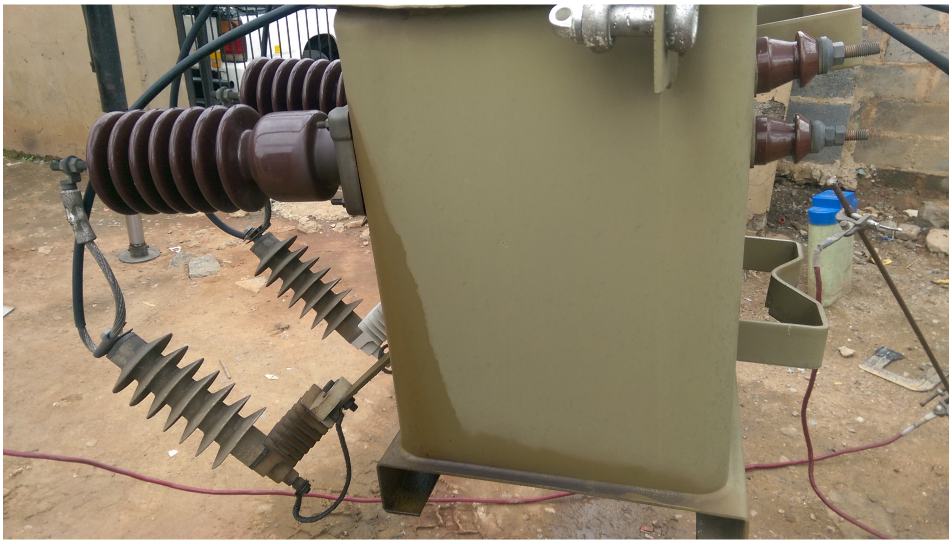


Figure 16: Oil leak on old transformer due to overheating caused by excessive load is evident.

Figure 17: The new transformer is lifted to the pole using the crane. The live-worker attaches the transformer to the distribution pole.

2.2.3 Removal of illicit connections

The Eskom network has been designed to withstand a particular demand, with the planning process spanning across the 25 year period of the post-Apartheid era. As mentioned previously, it is within Eskom's responsibility to ensure that each South African citizen has access to electricity. There are many pockets of the country which have not received this coverage, which has resulted in a number of illegal connections which draw unforeseen levels of load from the Eskom electrical network. Whilst those who have connected to the network illegally may assume that they are simply expediting the electrification project, such practises jeopardise the stability of the existing network and threatens the safety of those within the vicinity of the overloading assets. It is, therefore, the duty of the distribution field services technicians to carry out mass disconnection processes under the instruction of the relevant government officials.

The process involves the removal of cabling and accessory components that are used to tap electricity off from the conductors that have been strung by Eskom onto a number of distribution poles located near the area in need of electrical supply. These cables are then confiscated and are loaded up onto a truck for disposal. Such operations are met with great hostility by those who dwell within the informal areas, and thus a large contingent of policemen typically accompanies the Eskom technicians to prevent intimidation of those involved in the operation. This was indeed the case in the operation I participated in. Our load trucks and service vehicles were escorted by several police squad cars to a Reconstruction and Development Programme (RDP) area near Olifantsfontein, whereby a number of illegal connections were found originating from a nearby informal settlement. The police secured the area and negotiated with residents whilst the technicians removed the cabling. The operation lasted 6 hours and was completed without incident.

Such operations are typically successful, but long-term success is hindered by the ease by which such illegal connections can be established. Additionally, reports by concerned citizens regarding such illicit activities are scarce since citizens dwelling in neighbouring suburbs are typically and violently intimidated by those in the informal settlements. Upon questioning, many of the Eskom employees involved in the operation felt understandably conflicted about their participation. It became evident that, whilst these technicians are obligated to fulfil their duties as the guardians of the Eskom network, they cannot help but feel a great sense of reluctance since their complicity has resulted in the denial of a basic human right to their fellow South Africans.

The majority of these cases originate as a result of the demand for electrification in informal residential areas. It is difficult, in this instance, for Eskom to set up the necessary infrastructure to provide these citizens access to electricity since the informal residences are usually erected in high densities and are subject to regular changes in arrangements. Installing the necessary infrastructure according to the standards set out by Eskom and the energy regulators requires sufficient space and a relatively immutable environment. One can imagine that changes in the arrangements of the residences will frustrate the efforts of those who are responsible for the planning and execution of such a project. So whilst it may seem paradoxical that Eskom is responsible for the disconnection of many of the South African citizens living in informal settlements, it is evident that the risks to the existing network and the seemingly impossible nature of the electrification of such areas leaves Eskom with few alternatives.

3 Control Plant Maintenance (CPM)

Training Start date	2018-03-25
Training End date	2018-04-13
Trainer	Walter Fikizolo & Richard Taylor

3.1 Outline

As with the distribution field services, the Control Plant Maintenance (CPM) department is responsible for inspections of Eskom assets and facilitating any necessary intervention that is required as a result of the presence of faulty assets on the Eskom network. The CPM department, however, exists solely to perform such actions specifically on protection equipment, which include protection relays and their respective circuitry. These protection relays do not directly form part of the HV electrical network in that they do not assist in the transmission or distribution of power, but rather fulfil a crucial role in the preservation of the expensive assets found on the HV network network. These relays are responsible for analysing and processing information retrieved from the network, and will subsequently trigger certain actions (typically the opening of circuit breakers) to prevent damage to assets such as transformers and feeders. There are many types of protection relays and protection philosophies that exist within Eskom, with which the technicians within CPM need to be intimately familiar.

I participated in a number of activities whilst under the supervision of the technicians within CPM. I was designated to the Western sector of the Central OU, which covered suburbs such as Lonehill, Sandton, and Fourways. I have included details regarding a few of these activities below.

3.2 Training Activities

3.2.1 Configuration of 11 kV Ring Main Unit (RMU) Protection Relay in Sandton Area

In this case, the CPM team was called out to inspect the protection relay located on an 11 kV Ring Main Unit (RMU) in the Sandton CBD, shown in figure 18. The RMU was being installed to create a supply to the large commercial building that was under construction at that time (can clearly be seen in the background of the same figure). An RMU is a junction point which facilitates the tee-off of a cable feeder directly onto the customer's premises. The incoming and outgoing feeder connects to a busbar located within the RMU. This feeder energises the busbar, which, in turn, energises the customer feeder. All of these feeders are diagramatically represented on the RMU's operating board (shown in figure 19). This diagram is superimposed onto a set of switches which may be turned using a specialised operating rod. Each switch is labelled on the diagram according to the feeder upon it is located and its function (the customer feeder is on the right of the board whereas the incoming and outgoing feeder are found on the left and middle respectively). In this RMU, there is a circuit breaker that can be used to break the load or energise the customer feeder (top right on same figure). Each feeder can be connected to ground using an earthing switch (three switches located on the bottom-right, bottom-middle, and bottom-left of the board). Additionally, the incoming and outgoing feeder have isolators which segregates the customer feeder from the supply feeders. These switches are interlocked, and thus can only be operated on in a specific sequence. This functionality has been introduced to ensure the safety of the technician responsible for the HV operations. The circuit breaker to the customer feeder is operated using a spring which must be manually charged by the operator. Locks are provided by Eskom to secure the RMU and to prevent any unauthorised operations of the HV feeder equipment.

A combined Overcurrent (OC) and earth-fault protection relay (as shown in figure 20) has been included to monitor the customer's load for any fault currents. This relay interprets the measurements of the load provided by the current transformers (shown in figure 21) which are located below the RMU board and encircle each of the phase conductors) using sophisticated circuitry (which include the combination of a step-down transformer, Analog-to-Digital Converter (ADC), signal squarer, and logic gates) to determine whether certain conditions warrant to automated opening of the circuit breaker contained within the RMU (such as a phase-phase, phase-earth, or three phase fault). As mentioned, the relay implements an OC and earth-fault philosophy, and thus it does not require input from other relays to determine whether a trip is required, as is the case with the current differential relay. The relay is powered by a battery (seen in the same figure) which is charged by the supply feeders. The relay can, therefore, continue to retrieve and process information in the instance where the supply is lost, but only for a limited amount of time. The CPM technicians need to ensure that the relay operates as is expected before the RMU can be commissioned. Failure to do so could result in undesirable switching of the customer's supply, or, in the worst case, damage to the RMU, feeder, or customer assets as a result of excessive load that was not sufficiently interrupted. The CPM technician must, therefore, perform the following tasks:

1. Configure the relay as prescribed by the protection settings department.

2. Test these settings by simulating a fault.

Figure 18: The Ring Main Unit (RMU) set up to distribute power to one of the corporate buildings in the Sandton region. The building was still under construction at that time, but the RMU was scheduled for commissioning shortly after these tests were performed.

Figure 19: The RMU esncapsulates a busbar which facilitates the connection of an incoming and outgoing distribution cable (left and centre) as well as a customer cable (right). Note the Overcurrent (OC) and earth fault protection relay in the top-right hand corner of the board.

Eskom, having a considerably convoluted and intermeshed distribution network, intrinsically requires that the relays respond in a collaborative manner to reduce the impact of a fault current whilst minimising the impact on customers. Conveniently, protection relays are adjustable in that the operating conditions of the relay may be manually set by the CPM technician. These settings include, but are not exclusive to:

1. Trip limit (as a percentage of the rated pu current).

2. Operating time (in seconds).

which can be set for all functions of the relay individually (in this case, for both the OC and earth-fault current functions separately). The parameters alone provide sufficient means by which to coordinate the functions of the relays. One may, for instance, wish to ensure that the relays that are closer to the load will operate before those that are closer to the source. If this is satisfied, then individual customers will be de-energised first before the entire feeder is disconnected, ensuring that the minimum number of customers are affected as possible (evidently, this functionality will work most optimally with relays that contain the auto-reclose function). Altering the trip-limit will alter the sensitivity of the relay, such that, for instance, smaller margins may be selected for newer feeders (which are not subject to a large amount of current leakage) and older feeders may be provided with a greater margin of error. These parameters are calculated for each relay in the network, and are subsequently sent to the CPM team so that the parameters can be configured onto each relay respectively.

Once the settings have been configured, the protection relay is tested using the Omicron (shown in fig 23. The Omicron is used to simulate the current that would typically be seen in an OC or phase-to-earth fault. The Omicron is connected to the protection relay's circuitry by the technician, as shown in figure 22. Once correctly connected, the technician will ramp the current until it surpasses the set trigger limit. If the relay does not trigger the opening of the circuit breaker in this instance, then the relay has failed the test and has to, therefore, be replaced or reconfigured. The amount of time taken to trigger the opening of the circuit breaker can also be determined by accessing information stored on the protection relay. The commissioning of the RMU is contingent on these tests.

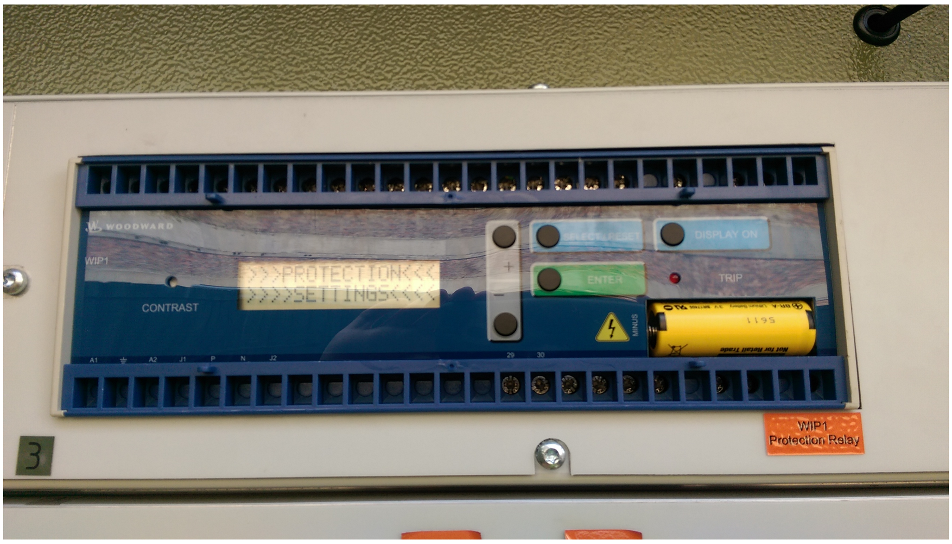


Figure 20: The OC and Earth-fault protection relay. The protection settings can be accessed to grade the relay's response to a fault. Typically, the OC and earth-fault protection relays closer to the load would be set to operate faster than similar relays which are found closer to the source.

Figure 21: Current Transformers (CTs) encircling each of the phase conductors of the customer's feeder. These CTs are used for metering and measurement purposes.

Figure 22: A technician prepares the protection relay for testing. Testing is typically performed with the use of an Omicron (shown in a later figure).

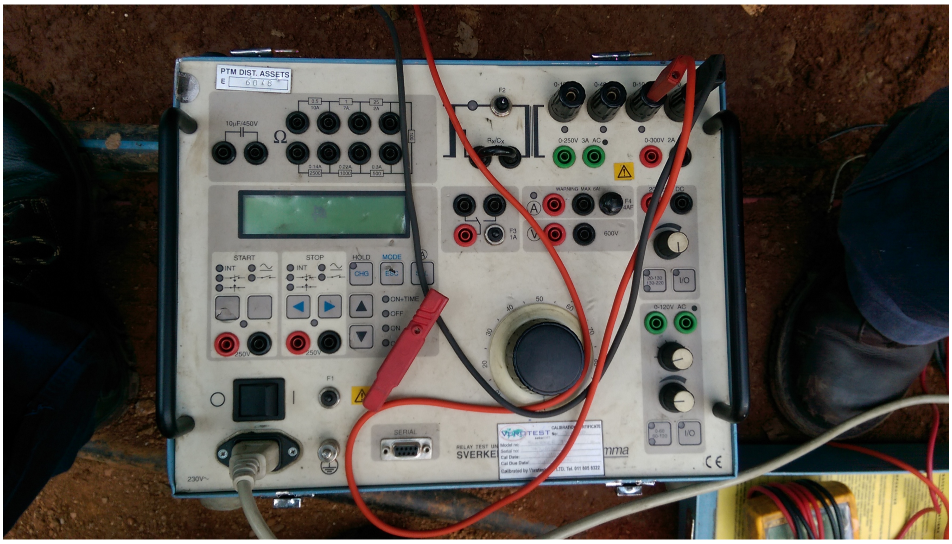


Figure 23: The Omicron; an essential tool in protection testing operations. This instrument can simulate DC and AC signals which are in excess of 110 V magnitude.

3.2.2 Testing of Transformer Buchholz Relay at Manor Substation

The performance of the protection equipment is contingent on the condition of the equipment in the HV yard that measures the required information. The voltage and current transformers are conventionally associated as the main measurement equipment. There are, however, other instruments that record information and determine the states of particular parameters for protection purposes. One such instrument is the Buchholz relay. This relay is unique to large oil immersed power and NEC transformers (typically rated over 500 kVA), and is used to detect electrical faults in the transformer. A standard Buchholz relay is shown in figure 24. The Buccholz relay is connected in the oil pipeline that connects the main tank to the conservator tank (that facilitates the expansion and contraction of oil in differing operational temperatures). The oil thus flows through the relay when the oil is transferred between the main tank and the conservator tank. Typically, the movement of oil is gradual since the temperature of the oil does not fluctuate readily due to its high specific heat constant. The relay does, however, take advantage of a particular phenomenon associated with transformer oil.

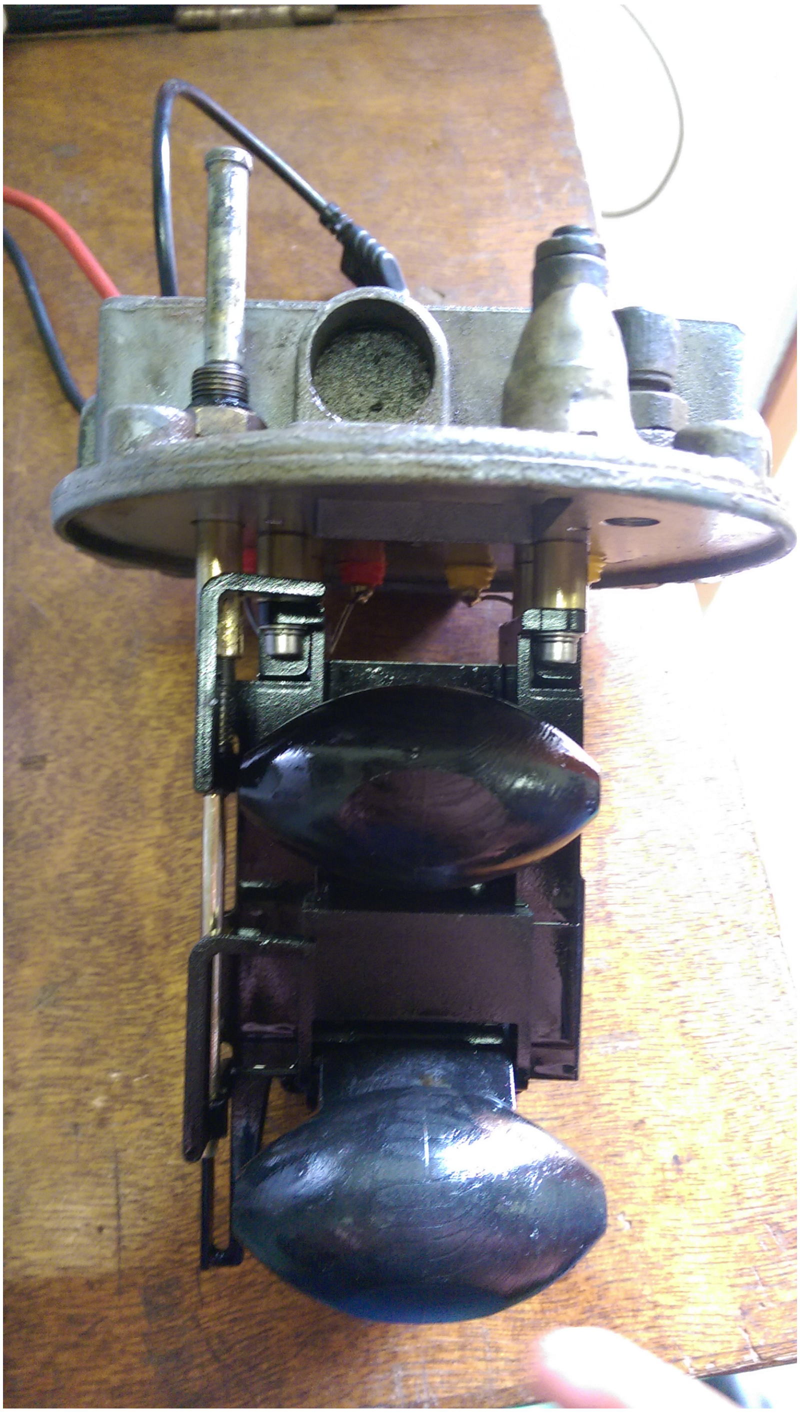


Figure 24: The faulty Buchholz relay that was removed from the transformer for refurbishment purposes. It was determined that the test plunger (cylindrical trigger on top left of picture) had rusted in place, resulting in the false-positive triggering of the Buchholz alarm and trip signals.

Transformer oil degrades into several gases when fault currents flow between the windings of the transformer. These gases accumulate at the top of the relay's chamber since they have a lower density to that of the transformer oil. If a sufficient amount of this gas accumulates over time, a large portion of the chamber will be filled with gas, causing the top floater (the oblong structures seen in the same figure) to drop below the threshold. This will cause contact on a mercury switch which will trigger a Buchholz "alarm" signal on the protection relay inside the control room (which is connected to the relay, in this case, via a copper conductor). This is not a severe condition, and it will not cause the tripping of the transformer, but it requires immediate attention from the HV plant technicians. The gas, which accumulates in the relay, can be tested for composition to determine the cause of the gas accumulation. If the fault current is severe, it will cause the degradation of a significant amount of transformer oil, forming gases which are expelled from the main tank with great force. This gas will push through the Buchholz relay, pushing the bottom floater up. This facilitates the contact of a mercury switch which triggers a "trip" signal. This signal is received by the protection relay, which will subsequently send a trip signal to the circuit breakers that are associated with the transformer, thus breaking the fault. This trip necessitates a fault investigation.

In this particular CPM call-out, the protection system associated with a 88/11 kV transformer at Manor substation (shown in figure 25) had triggered a Buchholz alarm during HV plant maintenance, which required investigation. The Buchholz relay was drained and removed (but still electrically connected to the protection relay). Despite this, the alarm signal on the protection relay persisted despite multiple manual resets (as shown in figure 26). Such a phenomenon can only, therefore, be caused by the following:

1. Faulty switch on the Buchholz relay.
2. Faulty processing in the protection relay within the control room.
3. Discontinuity in the conductor circuit between the two relays.

It is, therefore, quite evident that one should understand how each relay is connected to one another to determine the cause of this persistent alarm signal. The circuit diagram is shown in figure 28. It is clear from inspection of this diagram that the closing of the Buchholz relay (upon the detection of excess gas) will close the circuit, supplying the protection relay with a positive 110VDC supply from the DC board as opposed to a floating voltage. Therefore, a +110VDC signal in this circuit will cause the protection relay to interpret a Buchholz alarm. One can determine whether there is continuity along this circuit through the use of a multimeter on each of the termination points inside the control room and in the junction box (termination in control room for circuit shown in figure 27.

Figure 25: A 88/11 kV transformer at Manor substation that was undergoing HV plant inspection. It was determined that the Buchholz relay (found on the other side of the transformer) was not responding in an expected manner.

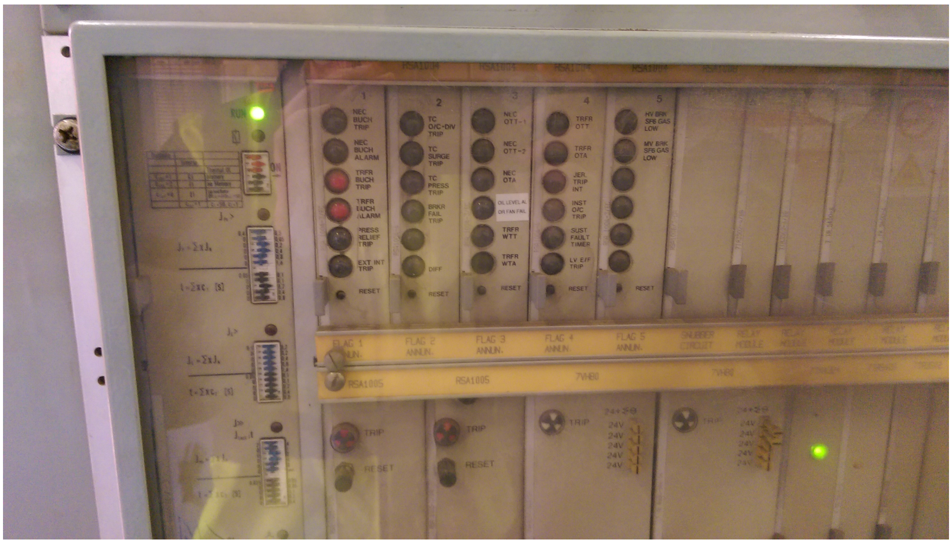


Figure 26: Transformer protection relay for the 88/11 kV transformer at Manor substation. Note the false-positive triggers for the Buchholz relay (red indicators in top-left of figure).

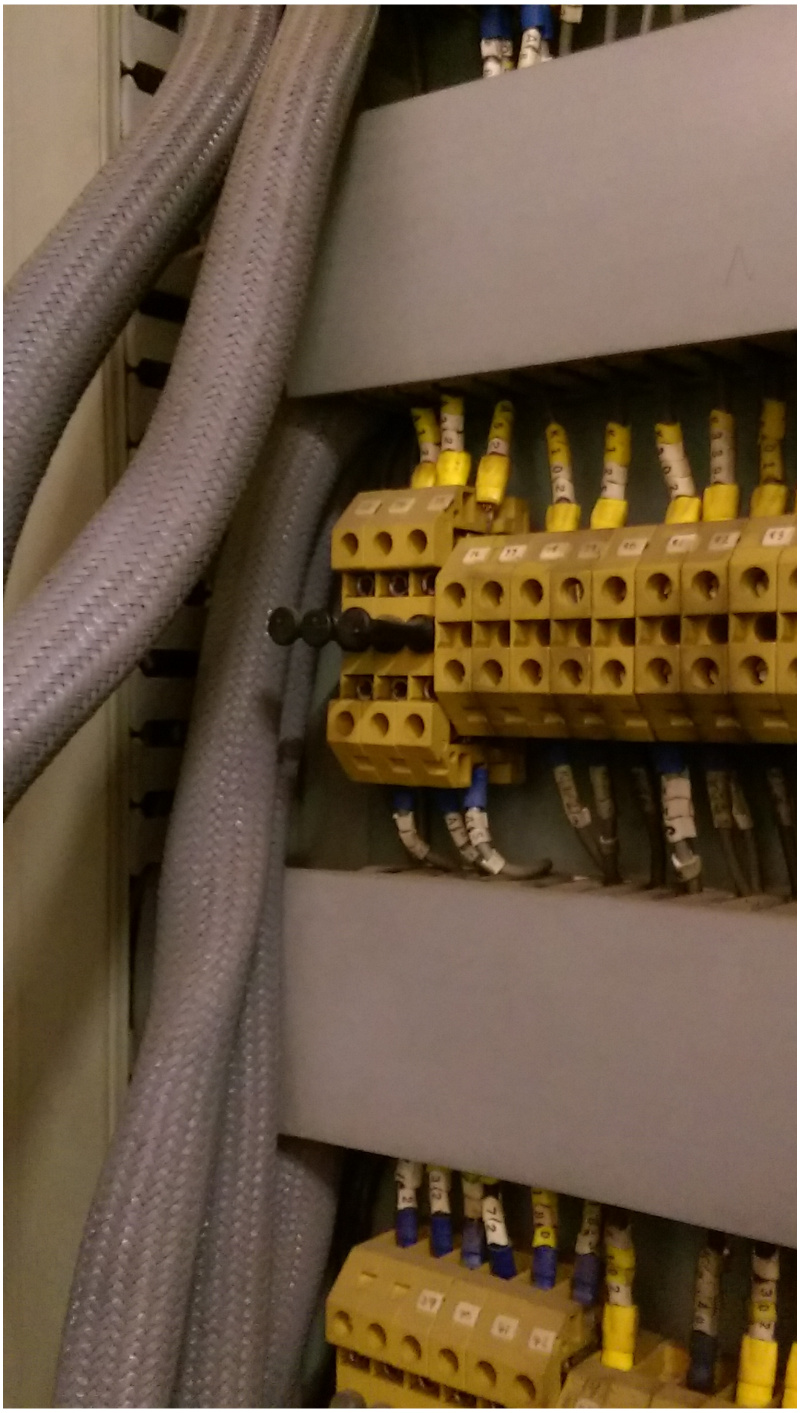


Figure 27: The chrono-blocks which serve as terminating points for copper conductors that are used to transmit trip and alarm signals (as well as other pertinent signals from the yard such as current transformer readings etc.).

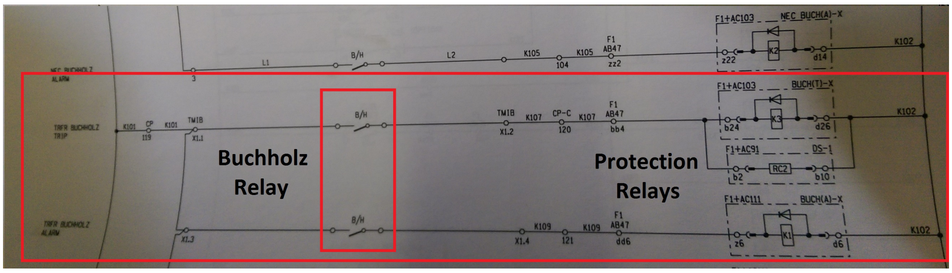


Figure 28: Protection circuit diagram of Buchholz relay on the transformer. Understanding the circuitry assists in the troubleshooting procedure.

Continuity was established, and thus we concluded that the fault could not originate from the connecting circuit. In light of this evidence, the Buchholz relay was disconnected from the protection circuit and was inspected (this is the same relay shown in figure 24). Upon inspection, it was determined that the test trigger (cylindrical metallic structure on the top left of the Buchholz in the figure) had rusted. This trigger, when depressed at varying extents, simulates a Buchholz alarm and trigger by forcing the floaters into the triggering positions. The trigger is typically accompanied by a rubber cap which protects it from exposure to rain and humidity. It seemed that in this case, however, a technician that performed maintenance on the relay during the previous maintenance cycle misplaced the cap. This caused the inner mechanism of the trigger to rust, thus restricting the trigger's movements, preventing the trigger from fully ascending. The relay was refurbished and placed back into operation.

3.2.3 Fault Investigation at Megawatt Park Substation

A feeder protection relay of one of the 11kV feeders of the MegaWatt Park substation in Sandton experienced a transient fault on the 7th of April 2018. This fault was one of many faults that have been experienced on this same feeder over a short period (at least 6 over a space of three months). It is the responsibility of the Control Plant technician to evaluate the trace recordings of the relay to determine whether the trip was justified. I accompanied the technician in this investigation.

The technician identified the protection relay as a current differential relay, which records the current measured on the one end of the feeder and compares it remotely with a current differential relay on the other side of the relay. The current protection relay is shown in figure 29 with the serial connection attached to the output data port, and the current recordings of the day of the fault is shown in figure 30.

Figure 29: A current differential protection relay (centre) located at the MegaWatt Park substation. A technician has connected a serial communication cable to the relay to retrieve information regarding a recent fault.

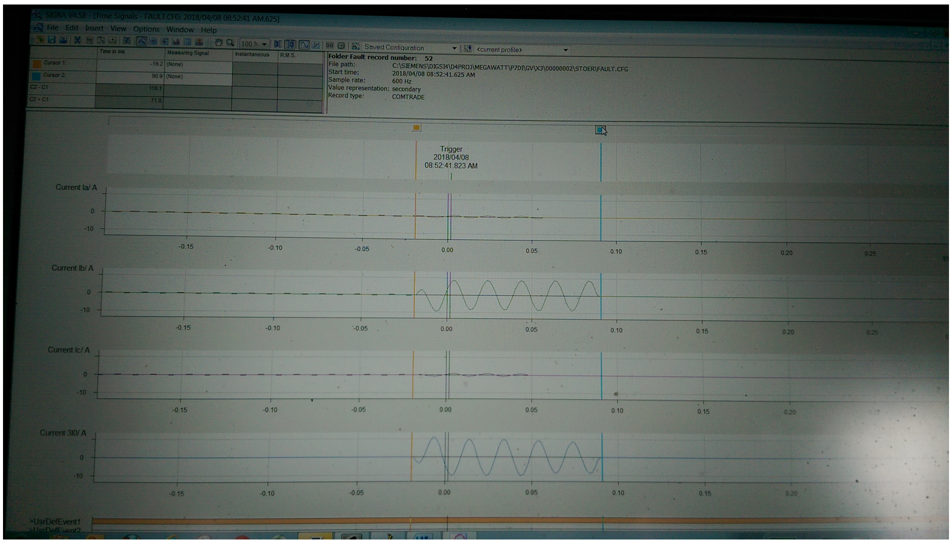


Figure 30: The recorded failure that was downloaded from the protection relay. Note the stark increase in current magnitude on the Phase B conductor. The fault lasted approximately 100ms before being isolated.

A number of programs are required to retrieve information from the multitude of relays found on the Eskom network, with each unique manufacturer paired with a specific program. The information on the relay can only be accessed through this specific program. It is quite evident, therefore, that the protection technician needs to be kept up-to-date regarding the existing protection relays in the system, a process which may be quite onerous. It is evident from the figure that a trip was indeed justified since a large spike in the current (which breaches the protection error band of 20% above rated current) was clearly experienced in the phase B conductor of the feeder. The fault was cleared approximately 100ms after the fault was detected (which is slow, considering that fast clearing circuit breakers should clear the fault within 40ms with latency included). It is suspected that the fault, which is recurring in nature, could possibly be caused by a faulty piece of insulation in the feeder or by a tree branch. The technician has recommended a line inspection to identify any possible causes.

4 Eskom Distribution Network Optimisation (EDNO)

Training Start date	2018-04-16
Training End date	2018-06-15
Trainer	Nwabisa Letsoha

4.1 Outline

The Eskom Distribution Network Optimisation (EDNO) department is dedicated to the sustainment of the Distribution network through the implementation of operational planning methods. Typically, the distribution planning team will attempt to account for every relevant threat to the network in the early design phases, but such planning cannot always guarantee that the developed network will be secure at all times. Changes in the network may be required due to change in energy supply, unexpected failures, or planned outages. Funding towards maintenance programs may, for instance, be compromised, rendering the distribution network increasingly vulnerable to failures as the network ages. It is when such failures occur where personnel within EDNO would recommend operations that will uphold the quality and continuity of supply to customers. Additionally, recommendations are also made by this department concerning the necessary configuration of the network when planned outages are required for maintenance purposes. These recommendations are not based simply on assumptions, but are rather supported by rigorous studies that are performed using power flow simulation software (including ReticMaster and DigSilent).

EDNO is, therefore, responsible for the development of deliverables related to, but not exclusive to, the following activities related to the distribution network (assets rated at 275 kV or lower):

1. Contingency plans.
2. Outage studies.
3. Network appraisals and network risks.
4. Loadshedding scheduling.
5. Technical losses.
6. Load test report.
7. Fault level report.

An in-depth discussion on the importance of these activities is provided below where possible. Not all of these topics could be explored in great detail during our training at EDNO due to time constraints. A short justification is, therefore, included for the activities that were engaged at a more superficial level.

4.2 Databases & Tools

The optimisation of the Eskom distribution network cannot be executed without accurate data and a few useful tools. Data used in regular EDNO functions are stored on databases which can be accessed when required. These databases include:

1. Transmission Energy Management System Evolution (TEMSE)
2. Customer Care & Billing (CC&B)
3. Electronic Network Schematics (ENS)
4. MV90
5. MDMS

The following tools are used in conjunction with ReticMaster and Powerfactory to perform network optimisation:

6. The Integrated Planning Solution (TIPS)
7. Supervisory Control And Data Acquisition (SCADA)

These databases and tools are described in greater detail in the subsections that follow.

4.2.1 Transmission Energy Management System Evolution (TEMSE)

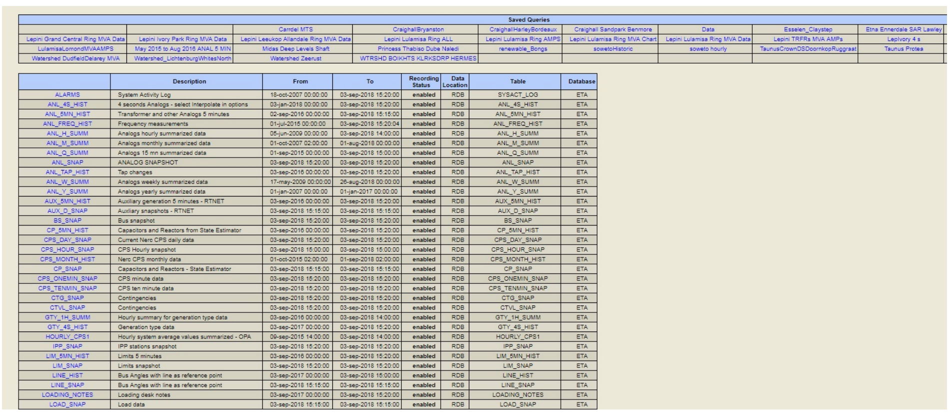
The TEMSE database contains dynamic information of all the elements within the transmission substations, including, but not exclusive to, the lines (supply), loads (distribution), transformers, busbars, shunts, and breakers. Information from these assets may include, and again is not exclusive to, voltage (kV), current (A), apparent power (MVA), reactive power (MVAR), and real power (MW), all of which are dependent on time. This information can be used to determine the loading condition of an asset, which assists in the execution of contingency and outage plans. The most commonly downloaded information from TEMSE is the 5 minute analog data (`ANL_5MIN_HIST`), which retrieves information (such as voltage on a busbar) that was sampled by the meters once every 5 minutes. This information can be accessed via the following web address:

`http://enzweb/eta/default.aspx?section=login`

The webpage shown in figure 31 will load up once the user is successfully logged in. To peruse the behaviour of a particular substation, simply click on the `ANL_5MIN_HIST` link on the top-left hand corner of the screen, resulting in the screenshot demonstrated in figure 32. The substations in the transmission network are listed in alphabetical order, but one can simply click on the relevant letter on the top-left hand corner to prevent the need to click through the ordered list. Figure 33 demonstrates an example of the data that can be retrieved from any particular substation. This database was vital to the completion of both the distribution and sub-transmission studies that were performed as part of the EiT training.

4.2.2 Customer Care & Billing (CC&B)

The CC&B (also referred to as ALFS) is a database that is used to store information that is used to bill large power users that are connected to the Eskom electrical network. Energy consumption is, of course, is germane to this task, and thus the information is recorded in terms of kilowatt hours (kWh, an energy metric) over 30 minute intervals. Understanding the consumption behaviour of large power users is of utmost importance to those performing network optimisation functions within EDNO since the loss of large loads could significantly impact the performance of the distribution network. But whilst information on large power users is germane to the functions of EDNO, it is power consumption, not energy consumption, that is a more useful metric. The engineer/technician at EDNO will therefore need to convert the energy metric units (kWh) to power consumption units (MW) by averaging the total energy consumption over a half-hour (mul-



Saved Queries								
		Carrdel MTS	CraighallBryanston	CraighallHarleyBordeaux	Craighall Sandpark Benmore	Data	Esselen_Claystep	Etna Ennerdale SAR Lawley
Lepini Grand Central Ring MVA Data	Lepini Ivory Park Ring MVA Data	Lepini Leeukop Allandale Ring MVA Data	Lepini Lulamisa Ring ALL	Lepini Lulamisa Ring AMPS	Lepini Lulamisa Ring MVA Chart	Lepini Lulamisa Ring MVA Data	Lepini TRFRs MVA AMPs	LepIvory 4 s
LulamisaLomondMVAAMPS	May 2015 to Aug 2016 ANAL 5 MIN	Midas Deep Levels Shaft	Princess Thabiso Dube Naledi	renewable_Bongs	sowetoHistoric	soweto hourly	TaunusCrownDSDoornkopRuggraat	Taunus Protea
Watershed DudfieldDelarey MVA	Watershed_LichtenburgWhitesNorth	Watershed Zeerust	WTRSHD BOIKHTS KLRKSDRP HERMES					

	Description	From	To	Recording Status	Data Location	Table	Database
ALARMS	System Activity Log	18-oct-2007 00:00:00	03-sep-2018 15:20:00	enabled	RDB	SYSACT_LOG	ETA
ANL_4S_HIST	4 seconds Analogs - select Interpolate in options	03-jan-2018 00:00:00	03-sep-2018 15:20:00	enabled	RDB	ANL_4S_HIST	ETA
ANL_5MN_HIST	Transformer and other Analogs 5 minutes	02-sep-2016 00:00:00	03-sep-2018 15:15:00	enabled	RDB	ANL_5MN_HIST	ETA
ANL_FREQ_HIST	Frequency measurements	01-jul-2015 00:00:00	03-sep-2018 15:20:04	enabled	RDB	ANL_FREQ_HIST	ETA
ANL_H_SUMM	Analogs hourly summarized data	05-jun-2009 00:00:00	03-sep-2018 14:00:00	enabled	RDB	ANL_H_SUMM	ETA
ANL_M_SUMM	Analogs monthly summarized data	01-oct-2007 02:00:00	01-aug-2018 00:00:00	enabled	RDB	ANL_M_SUMM	ETA
ANL_Q_SUMM	Analogs 15 mn summarized data	01-sep-2015 00:00:00	03-sep-2018 15:00:00	enabled	RDB	ANL_Q_SUMM	ETA
ANL_SNAP	ANALOG SNAPSHOT	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	ANL_SNAP	ETA
ANL_TAP_HIST	Tap changes	03-sep-2016 00:00:00	03-sep-2018 15:20:00	enabled	RDB	ANL_TAP_HIST	ETA
ANL_W_SUMM	Analogs weekly summarized data	17-may-2009 00:00:00	26-aug-2018 00:00:00	enabled	RDB	ANL_W_SUMM	ETA
ANL_Y_SUMM	Analogs yearly summarized data	01-jan-2007 00:00:00	01-jan-2017 00:00:00	enabled	RDB	ANL_Y_SUMM	ETA
AUX_5MN_HIST	Auxiliary generation 5 minutes - RTNET	03-sep-2016 00:00:00	03-sep-2018 15:20:00	enabled	RDB	AUX_5MN_HIST	ETA
AUX_D_SNAP	Auxliary snapshots - RTNET	03-sep-2018 15:15:00	03-sep-2018 15:15:00	enabled	RDB	AUX_D_SNAP	ETA
BS_SNAP	Bus snapshot	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	BS_SNAP	ETA
CP_5MN_HIST	Capacitors and Reactors from State Estimator	03-sep-2016 00:00:00	03-sep-2018 15:20:00	enabled	RDB	CP_5MN_HIST	ETA
CPS_DAY_SNAP	Current Nerc CPS daily data	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	CPS_DAY_SNAP	ETA
CPS_HOUR_SNAP	CPS Hourly snapshot	03-sep-2018 15:00:00	03-sep-2018 15:00:00	enabled	RDB	CPS_HOUR_SNAP	ETA
CPS_MONTH_HIST	Nerc CPS monthly data	01-oct-2015 02:00:00	01-sep-2018 02:00:00	enabled	RDB	CPS_MONTH_HIST	ETA
CP_SNAP	Capacitors and Reactors - State Estimator	03-sep-2018 15:15:00	03-sep-2018 15:15:00	enabled	RDB	CP_SNAP	ETA
CPS_ONEMIN_SNAP	CPS minute data	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	CPS_ONEMIN_SNAP	ETA
CPS_TENMIN_SNAP	CPS ten minute data	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	CPS_TENMIN_SNAP	ETA
CTG_SNAP	Contingencies	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	CTG_SNAP	ETA
CTVL_SNAP	Contingencies	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	CTVL_SNAP	ETA
GTY_1H_SUMM	Hourly summary for generation type data	03-sep-2016 00:00:00	03-sep-2018 14:00:00	enabled	RDB	GTY_1H_SUMM	ETA
GTY_4S_HIST	Generation type data	03-sep-2017 00:00:00	03-sep-2018 15:20:00	enabled	RDB	GTY_4S_HIST	ETA
HOURLY_CPS1	Hourly system average values summarized - OPA	09-sep-2015 14:00:00	03-sep-2018 14:00:00	enabled	RDB	HOURLY_CPS1	ETA
IPP_SNAP	IPP stations snapshot	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	IPP_SNAP	ETA
LIM_5MN_HIST	Limits 5 minutes	03-sep-2016 00:00:00	03-sep-2018 15:20:00	enabled	RDB	LIM_5MN_HIST	ETA
LIM_SNAP	Limits snapshot	03-sep-2018 15:20:00	03-sep-2018 15:20:00	enabled	RDB	LIM_SNAP	ETA
LINE_HIST	Bus Angles with line as reference point	03-sep-2017 00:00:00	03-sep-2018 15:00:00	enabled	RDB	LINE_HIST	ETA
LINE_SNAP	Bus Angles with line as reference point	03-sep-2018 15:15:00	03-sep-2018 15:15:00	enabled	RDB	LINE_SNAP	ETA
LOADING_NOTES	Loading desk notes	03-sep-2017 00:00:00	03-sep-2018 15:20:00	enabled	RDB	LOADING_NOTES	ETA
LOAD_SNAP	Load data	03-sep-2018 15:15:00	03-sep-2018 15:15:00	enabled	RDB	LOAD_SNAP	ETA

Figure 31: The TEMSE archive website homepage.

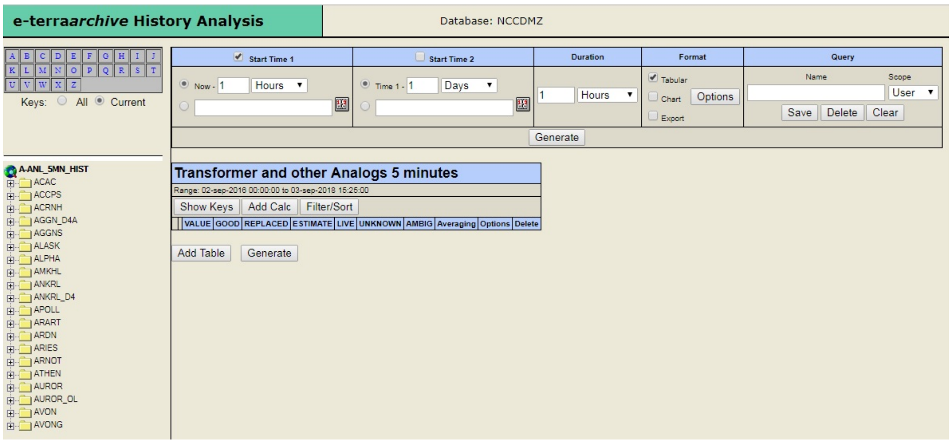


Figure 32: The ANL_5MIN_HIST archive on TEMSE.

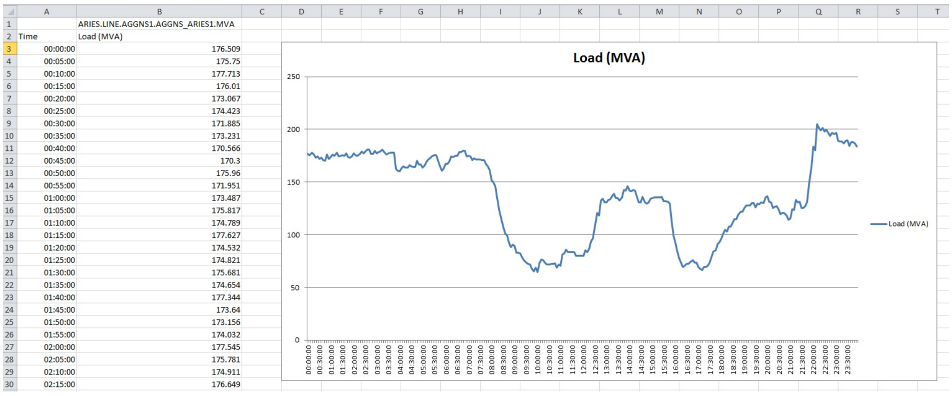


Figure 33: Apparent power load flow information retrieved from TEMSE for the Aries Substation. The data was processed to produce a graph, which is also visible in the figure.

tiplying the energy metric by 0.002). This information can then be used to determine peak loading values, and thus can facilitate the formation of contingency and outage strategies related to the large power users. This database was not utilised throughout the training.

4.2.3 Electronic Network Schematics (ENS)

The Electronics Network Schematics (ENS) database houses diagrams of the substations and feeders found in the Eskom distribution network. These schematics:

1. Give an overview representation of a feeder or substation.

2. Assist the engineer to identify the possible N/O points that can be closed in the instance the conventional supply to a feeder is lost.

3. Can be used to identify inconsistencies in the ReticMaster models that are imported from TIPS.

Two types of schematics can be downloaded from this database, namely *substation* and *feeder* schematics. The substation schematic provides a structural overview of any particular substation in the distribution network, thus demonstrating how certain elements (such as transformers, busbars, and feeders) are connected to one another, along with any relevant information (such as rating, asset identification, transformer configuration etc.). An example of a portion of a substation feeder is demonstrated in figure 34 (Marlboro substation in the Central operating unit). Feeder schematics demonstrate an overview of the distribution networks that connect directly to customers (i.e. the end-of-line feeders). The position of the N/O points and number of customers per feeders is clearly delineated in the diagrams, thus facilitating the formation of contingency strategies. The feeders on these schematics are typically rated between 11-22 kV. An example of a portion of a feeder network diagram is demonstrated in figure 35.

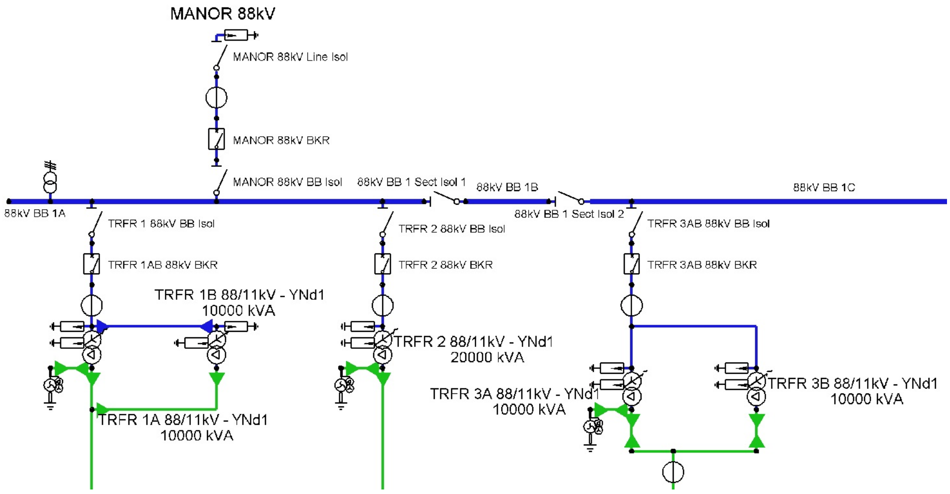


Figure 34: A portion of the Marlboro substation schematic downloaded from ENS.

4.2.4 MV90

The raw loading data that is measured by the statistical meters on the transmission network is directly loaded onto a database called MV90. The

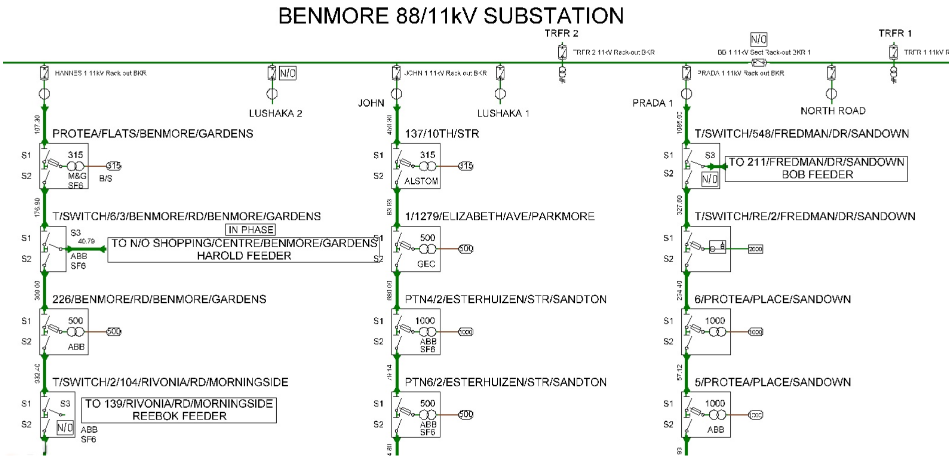
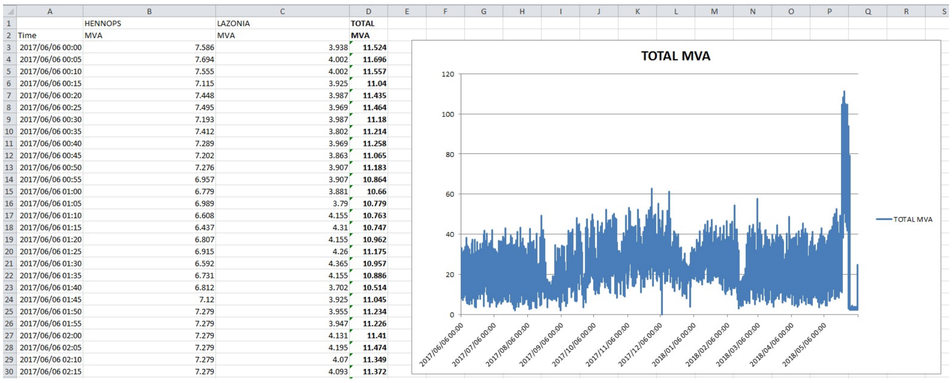


Figure 35: A portion of the Benmore feeder schematic downloaded from ENS.

reactive and real power of the measured load are calculated by the meters using the instantaneous voltage and current signals measured on the line and the phase difference between these signals (which is used to calculate the power factor). These meters retrieve these measurements from the network using current and voltage transformers, which step-down the voltages and currents to levels within the meters' capable range of measurement. This information is germane to the operations of EDNO, but is strictly safeguarded by the Metering and Measurements Support department within distribution. EDNO thus requests this information from the Metering and Measurements support department in System Operators on an annual basis. Data recorded over a period of a year from meters across the transmission network is sent to EDNO for use in the contingency and outage studies. The data is segregated according to meter location and month, and contains information pertaining to the meters identification number, date, time of measurement (in 30 minute intervals), and loading measuremnts (including real and imaginary components). An example of data retrieved from MV90 is demonstrated in figure 36.

4.2.5 Metering Data Management System (MDMS)

The Metering Data Management System (MDMS) is similar to TEMSE, but differs in that it only stores total active and reactive loading as well as power factor data from each transmission substation, rather than representing data from each feeder/transformer. This data is useful when trying to ascertain the efficiency/performance of any substation, as is performed during the technical losses study. The data can be exported as an Excel spreadsheet if



	HENNOPS	LAZONIA	TOTAL
Time	MVA	MVA	MVA
2017/06/06 00:00	7.586	3.938	11.524
2017/06/06 00:05	7.694	4.002	11.696
2017/06/06 00:10	7.555	4.002	11.557
2017/06/06 00:15	7.115	3.925	11.04
2017/06/06 00:20	7.448	3.987	11.435
2017/06/06 00:25	7.495	3.969	11.464
2017/06/06 00:30	7.193	3.987	11.18
2017/06/06 00:35	7.412	3.802	11.214
2017/06/06 00:40	7.289	3.969	11.258
2017/06/06 00:45	7.202	3.863	11.065
2017/06/06 00:50	7.276	3.907	11.183
2017/06/06 00:55	6.957	3.907	10.864
2017/06/06 01:00	6.779	3.881	10.66
2017/06/06 01:05	6.989	3.79	10.779
2017/06/06 01:10	6.608	4.155	10.763
2017/06/06 01:15	6.437	4.31	10.747
2017/06/06 01:20	6.807	4.155	10.962
2017/06/06 01:25	6.915	4.26	11.175
2017/06/06 01:30	6.592	4.365	10.957
2017/06/06 01:35	6.731	4.155	10.886
2017/06/06 01:40	6.812	3.702	10.514
2017/06/06 01:45	7.12	3.925	11.045
2017/06/06 01:50	7.279	3.955	11.234
2017/06/06 01:55	7.279	3.947	11.226
2017/06/06 02:00	7.279	4.131	11.41
2017/06/06 02:05	7.279	4.195	11.474
2017/06/06 02:10	7.279	4.07	11.349
2017/06/06 02:15	7.279	4.093	11.372

Figure 36: MV90 data loading retrieved from the Lomond substation. The measurements were taken between 2017/06/06 to 2018/06/06.

necessary. This database was not used throughout the training at EDNO.

4.2.6 The Integrated Planning Solution (TIPS)

TIPS is database which stores information regarding the physical assets found on the Eskom distribution network and is a subset of the Small World database. This information is represented on an interactive application, whereby the assets are layered on top of a map of South Africa. The position of the asset on the map reflects the position of the asset in the field since it is associated with a particular GPS coordinate. The application contains a search function, which allows a user to locate the asset in question with great ease. This is especially useful since Eskom has such an extensive electrical network. Whilst it may not seem particularly practical to map out all the assets in such a fashion, the usefulness of TIPS lies in its ability to convert schematic information into a format that can be used in a simulation package such as ReticMaster. A feeder may, for instance, be quite difficult to manually construct since the customers are not readily apparent on the TIPS application, and because feeders may extend many kilometres out into arbitrary directions. If one, however, needs a feeder for simulation purposes on ReticMaster, one simply needs to select the feeder on TIPS and use the ReticMaster conversion tool.

4.2.7 Supervisory Control and Data Acquisition (SCADA)

SCADA is a term that is used to describe the guiding principle of feedback control, whereby systems that are required to satisfy certain outputs have control mechanisms which are directly informed by state measurement. Eskom's control system, whose objective is to ensure the quality of electrical supply to Eskom's customers through the control of assets on the electrical network, is indeed guided by this principle. Circuit breakers are opened in the instance when certain conditions are not satisfied (exceedingly high currents, voltages which stray above 1.05pu or below 0.95pu, triggering of a Buccholz relay etc.), transformer tap windings are switched to adjust to changing voltage levels, and shunt reactors and capacitors are switched in to absorb or produce VARs as needed. All of the aforementioned control actions require information, which is provided by the measurement of the voltages, currents, power, and power factor of the power signals across the Eskom electrical network.

The success of SCADA is dependent on current information. The control centre must always be kept apprised of the state of the network. It seems quite evident, therefore, that this information should be shared with departments that are involved in operations (such as EDNO). National Control has, therefore, provided a select number of departments with access to information that has been received by SCADA. These departments cannot initiate any control actions on the network since National Control are the custodians of both the SCADA data and the means to perform control operations, but updated information of the network proves to be invaluable in contingency and outage studies (which informs future operations of assets on the network by National Control). There are a few computers that have, therefore, been allocated to EDNO for purposes of representing current SCADA information. The information is represented on an application that contains schematic drawings of all the substations and feeders on the Eskom network. Components such as busbars, transformers, circuit breakers, and feeders are all represented on the schematics. The user can navigate between these schematics using an interactive directory. The status of the assets as well as the voltages, currents, load flow, and the component ID is all listed next to the asset. The EDNO engineer/technician can use this information to scale measurements on the MV90 data and to configure the template network that will be used in the contingency or outage study.

4.3 Technical Training

4.3.1 Contingency Plans

Contingency plans are strategies that are compiled for execution by the operator to ensure the security and quality of electrical supply in the instance of an unplanned outage. Contingency plans are performed without request from Distribution since the outage is unplanned, and are thus performed for each 11/22 kV distribution feeder every three years. The most fundamental contingency study that can be performed is the feeder contingency, whereby the possible contingency strategies are considered for the unplanned outage of a supply to one particular feeder. Each distribution feeder will be associated with a number of Normally Open (N/O) points, each of which will connect the aforementioned feeder to another energised feeder. There are, of course, a number of permutations of possible strategies that may exist, but each of these contingencies must be considered so that the operator is fully aware of all possible contingencies that are available. The contingency document is not drafted to propose a recommendation, but rather to present a number of options from which the operator can choose to his/her discretion. The EDNO engineer/technician must, however, indicate whether such a contingency is tenable since the loading and voltage requirements of each feeder must not be contravened.

The feeder contingency is performed using ReticMaster, a power flow simulation package that is best suited to lower-voltage distribution networks. When a new cycle of contingency plans is required, the EDNO technician/engineer will inspect the feeder on ENS to identify all available N/O points and associated backfeeders. Once all feeders that are required for the study have been identified, the EDNO technician/engineer will identify all the feeders on TIPS, where a ReticMaster model for each feeder will be created using the ReticMaster conversion tool. Each feeder must then be correctly configured to represent the most onerous condition that can occur on the feeder. This "worst-case scenario" approach ensures that the results of the contingency plan will encompass all possible loading conditions that can occur on the feeder throughout the year. The supply to the feeders are thus initialised to the highest loading values found on the feeder in the previous year. This value can be retrieved through the analysis of the MV90 data for that feeder from the previous year. Once the supply to the feeders have been initialised, the transformer taps need to be set on position 3 across the entire feeder, as is seen on site. The application GetSet.xls can be used to achieve this in an expedient fashion. There cannot be any breach of voltage or loading conditions once this configuration has been performed.

With the configuration complete, the following steps must be followed to complete the feeder contingency study:

1. Import the backfeeder model into the ReticMaster project that contains the feeder under contingency.

2. Identify the N/O point in the system.

3. Use the decouple function to separate the feeder under contingency from its supply whilst simultaneously connecting the N/O points of each feeder together, thus redirecting the supply from the backfeeder into the feeder under contingency.

4. Identify any breach in the loading and voltage conditions (i.e. voltages must fall within a 1.05pu and 0.95pu range. Loading cannot exceed the

nominal load rating of the conductor). Record any discrepancies and enter them into the feeder contingency report. If no discrepancies can be found, then the backfeeder can supply the feeder under contingency without any further intervention.

The second type of contingency study that can be performed is the substation contingency. The results of this contingency study must be entered into a separate report, but it is simply a collection of feeder contingency studies that are performed for the feeders that are associated with one specific distribution substation. The aforementioned methodology can, therefore, be performed for the substation contingency study in an iterative manner until all feeders have been considered.

The training program at EDNO required the execution of both a feeder and substation contingency plan. The results of these studies are discussed in the following subsections.

Feeder Contingencies

A feeder contingency study was requested for the Hadida feeder. The Hadida feeder, which mainly consists of 185 mm^2 Copper XLPE cables, originates from the Houtkoppen substation within the Central OU. There are three N/O points on the Hadida feeder which connect to the following feeders (described by format *substation/feeder)*:

1. Penguin/Parrot feeder.

2. Houtkoppen/Swallow feeder.

LIST OF N/O POINTS						
FEEDER UNDER CONTINGENCY				INTERCONNECTING FEEDER (S)		
NO	SUBSTATION	FEEDER	SWITCH POINT	SWITCH POINT	FEEDER	SUBSTATION
1	HOUTKOPPEN	HADIDA	T/SWITCH/57/GALLOWAY/AVE/DOUGLASDALE	605/GALLOWAY/DOUGLASDALE/X18	PARROT	PENGUIN
2	HOUTKOPPEN	HADIDA	1215/HORNBILL/RD/DOUGLASDALE/X109	39/HORNBILL/DR/DOUGLASDALE	SWALLOW	HOUTKOPPEN
3	HOUTKOPPEN	HADIDA	1432/CASTELANNO/CRES/MAROELADAL	1715/INCHANGA/RD/MAROELADAL 11kV Isolators	KENGIES	FOURWAYS

Figure 37: The N/O points that are connected to the Hadida feeder.

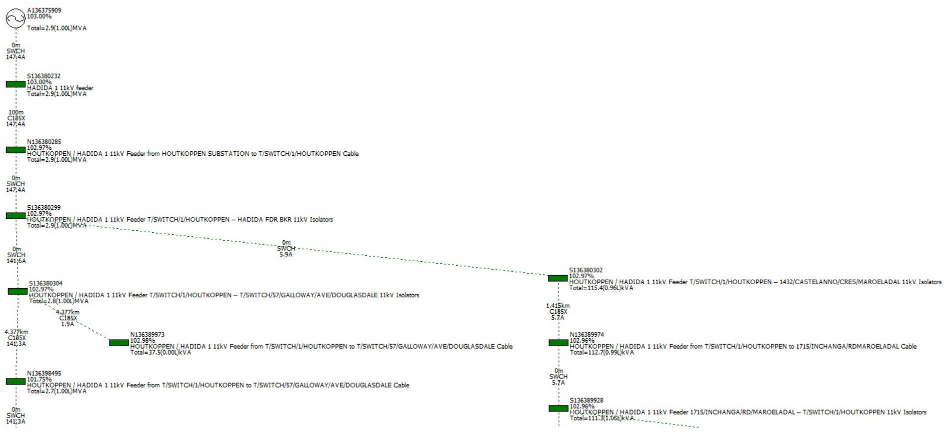


Figure 38: A portion of the ReticMaster model of the Hadida feeder that was imported from TIPS.

3. Fourways/Kengies feeder.

These feeders and their N/O points are demonstrated clearly in figure 37. These feeders can be used to backfeed the Hadida feeder in the instance where the conventional supply to the Hadida feeder is lost. The backfeeding capabilities of each of these feeders were, therefore, tested. Each feeder was imported from TIPS as a ReticMaster model, an example of which is demonstrated in figure 38. All feeders were configured according to the peak load that was observed in the MV90 data from the previous year. An example of this dataset is shown in figure 39. Additionally, the transformer tap positions were set to position 3 using the application GetSet.xls.

The models of each of the backfeeders, once they have been converted into a ReticMaster model from TIPS and configured accordingly, was imported into the Hadida feeder model to simulate the backfeeding scenario. The "Do Switching Between Networks" function is used to decouple the Hadida feeder from its supply whilst simultaneously connecting the two feeders via the N/O point. An example of a closed N/O point is shown in figure 40. The application recalculated the magnitude of the load present and the voltage at each node of the feeder, and these values were analysed for any discrepancies. Results were recorded in the final report, as demonstrated in figure 41. It is evident that all of the backfeeders are able to sufficiently and independently backfeed the Hadida feeder without breaching any voltage or loading constraints.

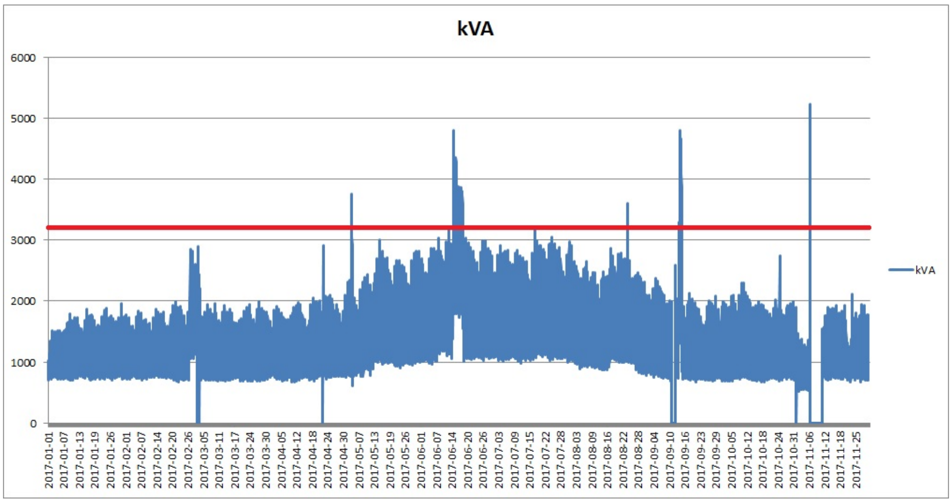


Figure 39: The load profile of the Hadida feeder in 2017. The load peak is highlighted by the red-line (3.18 MVA). There are, evidently, other peaks that exceed this value, but it is suspected that, since their values are uncharacteristic, these peaks are the result of switching phenomena or excess load that results from the backfeeding of another feeder from Hadida.

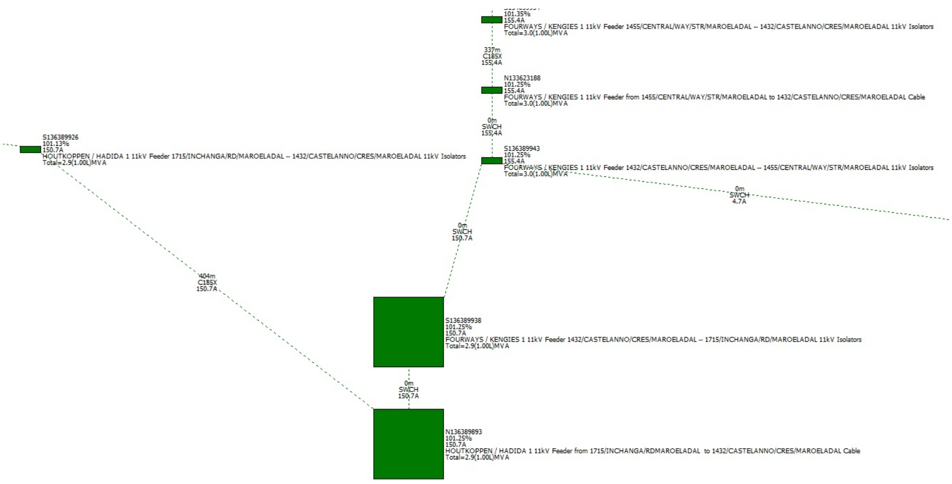


Figure 40: The connection of the two points associated with each side of the N/O points (shown in large blocks). The Kengies feeder is thus backfeeding the Hadida feeder in this instance.

HOUTKOPPEN / HADIDA CONTINGENCIES (OPTION 1)

HOTKOPPEN / HADIDA FED FROM PENGUIN / PARROT (JUN 2017 WINTER PEAK)

NO	SUBSTATION	FEEDER	BEFORE INTERCONNECTION CONDITIONS			SWITCHING SCENARIOS		AFTER INTERCONNECTION CONDITIONS			COMMENTS
			S/S Amps	MVA	V_{min} (%)	Open	Close	S/S Amps	MVA	V_{min} (%)	
1	HOUTKOPPEN	HADIDA	147.4	2.9	101.02	FEEDER BREAKER					SUPPLY ALL.
	PENGUIN	PARROT	121.9	2.4	102.74		T/SWITCH/57/GALLOWAY/AVE/DOUGLASDALE – 605/GALLOWAY/DOUGLASDALE/X18	269	5.3	102.14	

HOUTKOPPEN / HADIDA CONTINGENCIES (OPTION 2)

HOTKOPPEN / HADIDA FED FROM HOUTKOPPEN / SWALLOW (JUN 2017 WINTER PEAK)

NO	SUBSTATION	FEEDER	BEFORE INTERCONNECTION CONDITIONS			SWITCHING SCENARIOS		AFTER INTERCONNECTION CONDITIONS			COMMENTS
			S/S Amps	MVA	V_{min} (%)	Open	Close	S/S Amps	MVA	V_{min} (%)	
2	HOUTKOPPEN	HADIDA	147.4	2.9	101.02	FEEDER BREAKER					SUPPLY ALL.
	HOUTKOPPEN	SWALLOW	242.2	4.8	101.33		1215/HORNBILL/RD/DOUGLASDALE/X109 – 2385/HORNHILL/RD/DOUGLASDALE/X157	392.3	7.7	100.64	

HOUTKOPPEN / HADIDA CONTINGENCIES (OPTION 2)

HOTKOPPEN / HADIDA FED FROM HOUTKOPPEN / SWALLOW (JUN 2017 WINTER PEAK)

NO	SUBSTATION	FEEDER	BEFORE INTERCONNECTION CONDITIONS			SWITCHING SCENARIOS		AFTER INTERCONNECTION CONDITIONS			COMMENTS
			S/S Amps	MVA	V_{min} (%)	Open	Close	S/S Amps	MVA	V_{min} (%)	
2	HOUTKOPPEN	HADIDA	147.4	2.9	101.02	FEEDER BREAKER					SUPPLY ALL.
	HOUTKOPPEN	SWALLOW	242.2	4.8	101.33		1215/HORNBILL/RD/DOUGLASDALE/X109 – 2385/HORNHILL/RD/DOUGLASDALE/X157	392.3	7.7	100.64	

HOUTKOPPEN / HADIDA CONTINGENCIES (OPTION 3)

HOTKOPPEN / HADIDA FED FROM FOURWAYS / KENGIES (JUN 2017 WINTER PEAK)

NO	SUBSTATION	FEEDER	BEFORE INTERCONNECTION CONDITIONS			SWITCHING SCENARIOS		AFTER INTERCONNECTION CONDITIONS			COMMENTS
			S/S Amps	MVA	V_{min} (%)	Open	Close	S/S Amps	MVA	V_{min} (%)	
3	HOUTKOPPEN	HADIDA	147.4	2.9	101.02	FEEDER BREAKER		150.7	2.9	98.74	SUPPLY ALL.
	FOURWAYS	KENGIES	73.5	1.4	102.68		1432/CASTELANNO/CRES/MAROELADAL – 1715/INCHANGA/RD/MAROELADAL	224.7	4.4	101.25	

Figure 41: The results of the Hadida contingency study. All backfeeders are able to backfeed the Hadida feeder satisfactorily without contravening of the voltage and current constraints.

Substation Contingencies

A substation contingency study was requested for the Manor substation in the Central OU. The substation contingency is simply a summary of feeder contingency studies that are performed on the feeders that terminate at the substation. The feeders for the manor substation and their properties are demonstrated in figure 42. The strategy outlined in the previous subsection was applied to each of these feeders. The following is a summary of the results:

Substation	Feeder	KV	Cable/Conductor Type	Rated (MVA)	Peak (MVA)
Manor	Bowling	11	185mm2 Cu XPLE 3 Core	6.7	1.5
Manor	Caddie	11	185mm2 Al PILC 3 Core	6.5	1.7
Manor	Coleman	11	300mm2 Cu XLPE 3 Core	8.5	4.9
Manor	Eastgate	11	300mm2 Al PILC 3 Core	8.4	2.3
Manor	Gallo	11	300mm2 Al PILC 3 Core	8.4	1.1
Manor	Gillord	11	300mm2 Al PILC 3 Core	8.4	4.1
Manor	Glen	11	300mm2 Al PILC 3 Core	8.4	1.6
Manor	JCC	11	185mm2 Cu XLPE 3 Core	6.7	2.2
Manor	Prinia 1	11	185mm2 Cu XLPE 3 Core	6.7	3.6
Manor	Prinia 2	11	185mm2 Cu XLPE 3 Core	6.7	0.9
Manor	Prinia 3	11	185mm2 Cu XLPE 3 Core	6.7	4.4
Manor	Satara	11	300mm2 Al PILC 3 Core	8.4	2.2
Manor	Saville	11	300mm2 Al PILC 3 Core	8.4	0.8
Manor	Tugela	11	185mm2 Al PILC 3 Core	6.5	4.0
Manor	Wynberg	11	300mm2 Al PILC 3 Core	8.4	3.4

Figure 42: The feeders that terminate at the Manor substation. The Manor substation contingency study requires a feeder contingency study to be performed on each of these feeders.

- The Bowling feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Prinia 2 and Buccleuch/Apollo).
- The Caddie feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Satara, Megawatt Park/Tesla, Manor/JCC, Manor/Gillord, Buccleuch/Woodmead, Megawatt Park/Maxwell).
- The Coleman feeder can be supplied sufficiently and independently by the Manor/Gallo feeder, but the Benmore/Hannes, Morningside/Tony, and the Manor/Tugela feeders all experienced overloading conditions. Manor/Tony and Manor/Tugela can, however, be used to backfeed the Coleman feeder together if required.
- The Eastgate feeder can only be backfed by the Marlboro/Dahlia feeder, which experienced overloaded conditions (106.29%). The overcurrent setting of the protection devices on the Marlboro/Dahlia feeder is 540A, and therefore the feeder can backfeed under rate B conditions if necessary.
- The Gallo feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Glen, Manor/Coleman, and Manor/Satara).
- The Gillord feeder cannot be backfed by any of the possible back-

feeders independently since overloading conditions are expected for each backfeeder (Morningside/Monty, Morningside/Jill, and Manor/Caddie). The Gillord feeder can, however, be sufficiently supplied using the following strategies:

1. Manor/Caddie and Morningside/Jill backfeeders simultaneously.
2. Manor/Caddie and Morningside/Monty backfeeders simultaneously.

- The Glen feeder can be sufficiently and independently supplied by the Manor/Gallo feeder without breach in any voltage or loading conditions.
- The JCC feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Caddie and Buccleuch/Rock).
- The Prinia 1 feeder can only be backfed by the Manor/Prinia 3 backfeeder under rate B conditions since it is expected that the Manor/Prinia 3 backfeeder will experience overloading conditions (152.91%).
- The Prina 2 feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Bowling, Manor/Morningside, Manor/Prinia 3, and Morningside/Monty).
- The Prinia 3 feeder can only be sufficiently and independently supplied by the Manor/Prinia 2 feeder without breach in any voltage or loading conditions. The following backfeeding strategies can, however, be used if the Manor/Prinia 2 feeder is unavailable:

    1. Backfeed Prinia 3 with Morningside/Tolly and Paulshof/Emerald simultaneously.
    2. Backfeed Prinia 3 with Morningside/Tolly and Manor/Prinia 1 simultaneously.

- The Satara feeder can be sufficiently and independently supplied by all possible backfeeders without breach in any voltage or loading conditions (Manor/Caddie and Manor/Gallo).
- The Saville feeder can be sufficiently and independently supplied by the Manor/Tugela backfeeder without breach in any voltage or loading conditions.

- The Tugela feeder can only be sufficiently and independently supplied by all the Manor/Saville and Manor/Coleman backfeeders without breach in any voltage or loading conditions. The Buccleuch/Woodmead and Manor/Wynberg backfeeders can be used to simultaneously backfeed the Tugela feeder if the Manor/Saville and Manor/Coleman feeders are unavailable.
- The Wynberg feeder can only be backfed by the Tugela feeder under rate B or C conditions since the Tugela feeder is expected to experience overloading conditions in this instance (141.22%).

4.3.2 Outage Studies

Assets on the Eskom electrical network are subject to theft, damage, and wear and tear, thus justifying the need for regular maintenance. It is not always possible, however, to perform maintenance under live conditions. Instead, the maintenance of an asset typically occurs once it has been isolated from the electrical network. Whilst this seems intuitive, accommodating such conditions places additional stress on the remaining connected assets since the supply to Eskom's customers must remain unaffected. The load that would typically be handled by the offline asset is thus dumped onto the remaining assets, thus increasing the load they would typically accommodate. Taking a transformer at a substation offline for maintenance, for instance, results in the detouring of load through the other transformers in the substation. Assuming that the remaining transformers are equivalent in impedance, the excess load will be equally shared between the remaining transformers. This may not result in any conditions which cannot be handled by the transformers, but there is always a probability that the remaining assets could be overloaded. The reduced redundancy at these substations during maintenance poses further risks. The failure of one of the online transformers during the maintenance of another transformer at the same substation will increase the likelihood that the remaining assets will be overloaded. Supply to customers may be cut in this instance to prevent significant damage to the online assets and mitigate the risk of injury to personnel on site. It is evident, therefore, that maintenance operations cannot be executed without meticulous planning. Outage dates and times need to be carefully selected to reduce the impact on the network. It is also evident that the impact of the outage must be understood before such an outage can take place EDNO is responsible for performing these studies.

Typically, Power Plant Maintenance (PPM) personnel would request to maintain a particular asset, such as a transformer found at a substation. PPM would then contact the Field Service (FS) personnel to issue a work order. The FS personnel would apprise the schedulers of the plan and would thus request a specific outage date for the maintenance. Finally, the schedulers issue EDNO with a request for load studies that demonstrate that the maintenance of the asset will not detrimentally affect the rest of the network. Once EDNO performs the studies, the results would then be sent to the schedulers with recommendations. Such recommendation may include the paralleling of transformers to increase the load carrying capability of the substation (but reduces impedance, thus increasing the fault level of the substation. Such an operation should, therefore, be carefully considered) or suggesting new times in the instance where the suggested times are unsuitable. These results would be shared with personnel at the National Contral Centre, where they would be reviewed and approved. Control would issue instructions FS operators on the day to perform all necessary operations to accommodate the outage.

Outage studies are performed by EDNO on PowerFactory (DigSilent). The results and the recommendations are drafted in a report which is then distributed to the relevant parties. An outage study for the Cosmo feeder at the Klevebank substation (88/44/11 kV) was requested by the schedulers during our training at EDNO since the PPM personnel were required to service an 88 kV circuit breaker and 88 kV line isolator. I performed the study as a part of my training. The results follow.

Cosmo Feeder Outage Study

A load flow analysis of the Lulamisa-Lomond network (including abnormalities, as shown in figure 43) was conducted as part of the training program at EDNO using DigSilent. The load magnitudes were scaled to the maximum predicted load for the Lulamisa-Lomond ring, which was selected from the previous year's data (264 MVA, as shown in figure 44). The simulations showed that the opening of the Klevebank-Cosmo City 88 kV feeder under maximum loadings conditions would potentially cause the overloading of the Northriding Tee Windsor 88 kV overhead line (118.64% loaded, which is Rate B loading conditions). The following recommendations were, therefore, drafted:

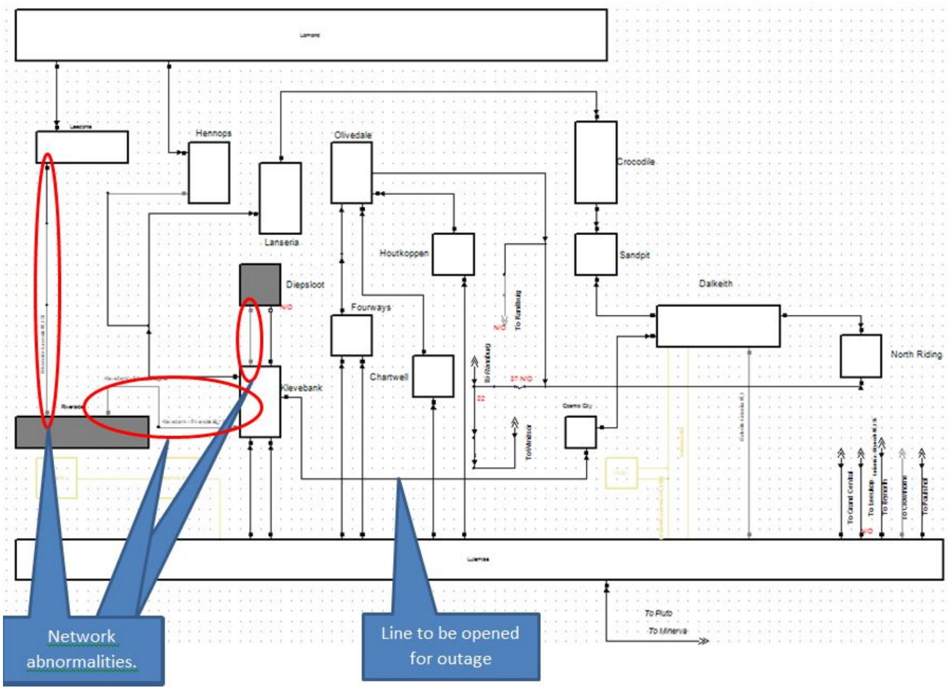


Figure 43: The Cosmo feeder in the Lulamisa-Lomond network ring in the Centrol OU. Network abnormalities present at the time of the study are indicated in red.

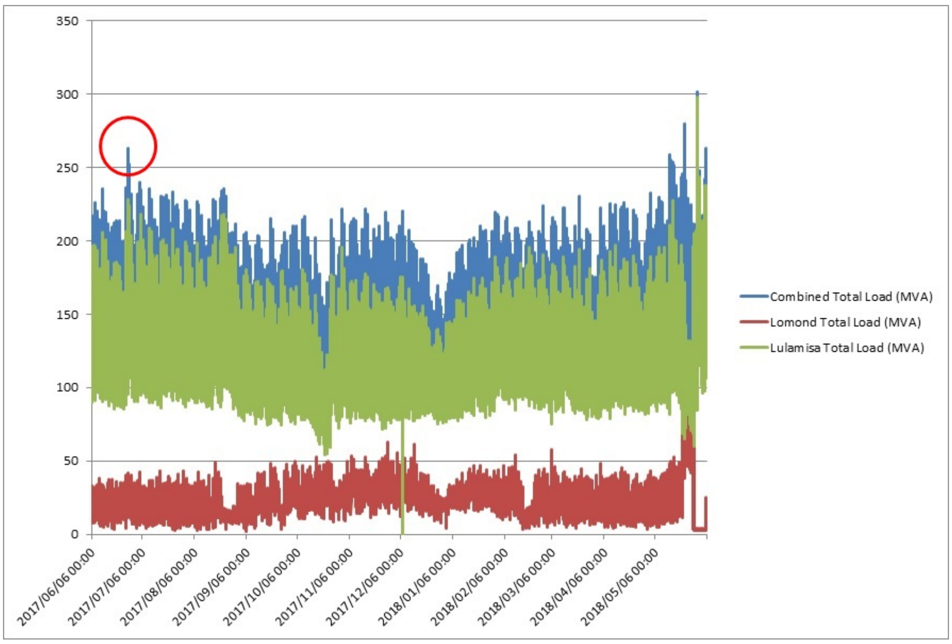


Figure 44: The load profile of the Lulamisa-Lomond ring. Load peak that was selected for the study is highlighted by the red circle.

1. The maintenance team is encouraged to perform the maintenance between 09:00-17:00 to reduce the strain on the potentially overloading line. The load is expected to increase significantly in the hours that follow.

2. The line that is predicted to experience overloading should be visually inspected during the outage across its entire length (4.5 km) to identify any signs of potential failure.

3. The line that is predicted to experience overloading should be scanned using infra-red equipment so that any potential hotspots can be detected before the outage is executed.

4. The colder ambient temperature experienced during this time of the year can potentially increase the loading potential of the line, but this scenario should still be treated with utmost caution.

4.3.3 Network appraisals

The Network Appraisal is a document that is compiled by EDNO personnel that contains a statistical analysis of the loadings associated with the assets within a network. The analysis is performed using the load test case file on DigSilent. Network Appraisal documents are produced for each of the OUs once a year. The results of this document are produced using simulations on DigSilent. The load test case file used for these simulations is scaled according to the system Main Transmission Substation (MTS) peak, which is the most onerous network scenario. The report includes analyses and recommendations for the following:

1. Thermal loading on feeders and trasnformers.

2. Voltage constraints on busbars.

3. Technical losses on feeders.

4. Fault level exceedance on circuit breakers.

5. Firmness and reliability of substations and rings.

Thermal loading on feeders and transformers

The following lists are compiled for the Network Appraisals document for each of the feeders and transformers in the network:

- The number of transformers and feeders that are loaded below 80% of rated capacity (no risk).

- The number of transformers and feeders that are loaded between 80-100% (medium risk).
- The number of transformers and feeders that are loaded above 100%.

Recommendations are made to address risks associated with the feeders and transformers that are found within the 80-100% loading range (to prevent overloading in the future) and those which are above 100% loading (to reduce the impact as soon as possible).

Voltage constraints on busbars

Breaches in voltage constraints are recorded for busbars across the allocated network using the most onerous load test case file on DigSilent. Recommendations are made to address these breaches.

Technical losses on feeders

Technical losses form part of the sub-transmissions studies, and are discussed in further detail in section 4.3.5.

Fault level exceedance on circuit breakers

EDNO personnel simulate the most onerous fault studies on the load test case to determine the number of circuit breakers which are vulnerable to breaches in their breaking capacities. These circuit breakers are recorded in the Network Appraisal document, and EDNO thus makes recommendations to mitigate these associated risks.

Firmness and reliability of substations, feeders, and rings

The firmness of substations and feeders on the Eskom network is based on the principle of redundancy. For instance, if there are two transformers at a substation, will the transformer with the lowest thermal rating be able to hand the total load flow across the substation if the transformer with a larger thermal rating is lost? Do the voltage levels at the busbars remain within the 0.95 - 1.05pu range? The substation will be regarded as being $n-1$ firm if this case is indeed satisfied ($n-1$ redundancy). The same principle can be applied to feeders which terminate at a substation. If there are, for instance, two feeders that facilitate load flow out of the any particular substation, would the feeder with the thinnest conductor be able to carry the load for both feeders if the feeder with the thickest conductor is lost? In either case, the firmness is determined by simulating the most onerous loading case file on DigSilent (the load test case file). Additionally, firmness is voltage level dependent, and therefore assets of varying voltage levels cannot be considered together in any firmness study (eg. a 22kV feeder cannot support an 11kV feeder). Substations which do not satisfy this requirement must be highlighted in the Network Appraisal document. This list of unfirm substations will include substations that contain only one transformer or feeder which can cater to a unique load.

The firmness of ring networks are also analysed and recorded in this section of the Network Appraisals document. Each feeder in the ring network is taken out of service using the load test case file to determine whether the remaining feeders are able to sustain the supply of load without the breach of any loading and voltage constraints. Ring networks are firm if each feeder satisfies the aforementioned requirements.

4.3.4 Loadshedding scheduling

Loadshedding is a strategy within the load reduction scheme that is employed by Eskom to forcefully balance the generation and load on the network in the instances where the capacity to generate power is constrained. The load reduction scheme includes a number of strategies, namely load curtailment, ripple control, current limiting, demand response, and Demand Market Participants (DMP). Loadshedding is employed as a last resort in the load reduction scheme since it involves the systematic and intentional decoupling of customers from the Eskom electrical network, thus posing the most significant threat to Eskom's credibility and public image. The relationship between the magnitudes of generation capacity and load is most clearly represented by the frequency of the power signal. Surplus generation of power will result in the increased rotational speed of the generators at Eskom power stations since there is insufficient load to produce a back-torque on the generator's rotor. A deficit in generation will intuitively reduce the rotational velocity of the rotors in the generators due to excess back-torque. The frequency of the power signal is, therefore, monitored constantly to determine the relationship between the generation and load. A nominal frequency of 50Hz represents a balanced generation and load. The measurement of frequencies below 50Hz may invariably trigger the execution of Loadshedding procedures. EDNO is responsible for drafting the schedules and strategies for these loadshedding procedures.

The loadshedding strategy is informed by NRS048-9, which is a document that was compiled by EDNO in collaboration with muncipalities, the private sector (SABS, Ashanti Gold etc.), the Department of Energy (DoE), and NERSA. The document highlights the schedules as well as the customers that are to be shed. The customers are ranked according to their importance, with residential loads ranking lower than industrial loads (such as smelters and mines). The schedules are created to ensure that loads to customers are shed equally, thus preventing the inadvertent targeting of specific customers. The schedule also ensures that the coverage of the load shedding is minimalised, thus ensuring that large blocks of suburbs aren't shed, reducing the probability of increased crime and accidents in these areas. Areas in the Central OU are typically shed for 4 hours at a time (with the exception of Tshwane, which is shed in 2 hour cycles). There are two techniques of load-shedding that are used at Eskom, and are implemented according to the speed at which the power signal frequency drops. These techniques are termed:

1. Manual Loadshedding (MLS).
2. Under-Frequency Loadshedding (ULFS). Also referred to as Automatic Loadshedding.

The MLS procedure is the most commonly implemented loadshedding procedure. MLS is triggered to forcefully arrest the persistent and slow drop of power-signal frequency, and is triggered by National Control. The frequency drop may be attributed to an unanticipated growth of load, or an interruption in the typical generation of power (eg. outage on generators at power station for maintenance purposes). There are 5 stages of MLS loadshedding, with each of the first 4 stages requiring the shedding of 1 block of the OU in addition to those that have already been shed in previous stages (i.e. cumulative shedding). Stage 5 involves the shedding of an additional allocated number of MW in addition to the 4 blocks of the OU which have already been shed in stage 4. Each stage (with the exception of stage 5) represents the shedding of 5% of the load on the OU. National Control decides which stage of loadshedding must be executed, and will thus the Head of Shift (HoS) will instruct the relevant control officers to open circuit breakers according to the loadshedding schedule. This form of loadshedding is executed manually by control officers according to schedules that are drawn up by the EDNO team.

EDNO is integral to the MLS loadshedding procedure. Before such a procedure is enforced, EDNO is responsible for the preparation of guides and schedules, training controllers within National Control, determine the criticality of loads, and calculating the effects of shedding certain blocks of loads. EDNO is also responsible for the creation and maintenance of the interactive Fault Management System from which customers can access information about any upcoming loadshedding procedures. During loadshedding procedures, EDNO personnel are responsible for the compilation of Provincial Nerve Centre (PNC) reports. Information in these reports include shed MW statistics, schedule deviations, and special requests that were made by customers. Incidents are recorded by the controller throughout the loadshedding procedure. These incidents are included in an incident report that is compiled by EDNO after loadshedding has occurred. EDNO will also be responsible for identifying patterns of failure in the system so that such failures can be remedied or avoided in the next loadshedding cycle.

UFLS procedures are executed when all other load reduction strategies have failed (including MLS) or when the frequency decreases at a rapid pace. This form of loadshedding is not initiated by National Control, but is instead automatically executed when power-signal frequencies are lower than or equal to 49.2 Hz. Such a frequency is representative of a severely compromised system stability, and thus the criticality of customers is no longer as seriously considered at this point. Relays at specific substations have been earmarked to perform this UFLS function, and will thus trigger the opening of their associated circuit breaker when the frequency and time-delay settings have been satisfied.

The UFLS strategy is segregated into 2 sections, namely:

1. Customer Voluntary Automatic (CVA).
2. Mandatory.

The CVA strategy is implemented first, and is further segregated into 3 layers, each associated with a 3.33% shedding of the OU's load:

- CVA1 is executed when the frequency breaches the 49.2 Hz frequency limit for 300ms or more.
- CVA2 is executed when the frequency breaches the 49.1 Hz frequency limit for 300ms or more.
- CVA3 is executed when the frequency breaches the 49.0 Hz frequency limit for 300ms or more.

CVA in its entirety will thus result in a 10% shedding of the OU's load. Customer sensitivity is considered during CVA, but not to the extent at which it is considered in MLS. Mandatory UFLS is the more extreme UFLS strategy, and can be segregated into 4 layers, each associated with a 10% shedding of the OU's load:

- MAN1 is executed when the frequency drops below 48.8 Hz for 2.0s or more.
- MAN2 is executed when the frequency drops below 48.5 Hz for 2.0s or more.
- MAN3 is executed when the frequency drops below 48.2 Hz for 2.0s or more.
- MAN4 is executed when the frequency drops below 47.9 Hz for 2.0s or more.

The load is not shed instantly during the Mandatory stages. Instead, the Mandatory UFLS strategies follow the following procedure:

- 3% of load is shed within 500ms.
- 6% of load is shed within 1.2s.
- 10% of load is shed with 2.0s.

The Mandatory UFLS strategy, in its entirety, will thus result in the shedding of 40% of the OUs load.

4.3.5 Technical losses

Technical losses studies involve the calculation of the amount of energy that is lost due to the characteristics of the Eskom network. These losses, which can mainly be categorised by I^2R losses on the feeders, can be minimised through physical intervention. Thin conductors can, for instance, be replaced with larger conductors with lower impedances, thus reducing I^2R losses. These studies assist in the identification of feeders that contribute abnormally large technical losses. These feeders can then be earmarked for further investigation to determine the cause of the technical losses. These losses can then be minimised through direct intervention. This document is compiled upon request from Eskom Trading.

4.3.6 Fault Level Reports

Protection relays are configured according to two parameters, namely current magnitude and time delay. The current magnitude setting on the protection relay establishes the minimum current level that will trigger a trip signal. The trip signal will be triggered only after the time delay has elapsed. The protection relays must be configured in such a manner to ensure that all relevant fault conditions are accounted for by the current magnitude setting whilst preventing any possible false positive trip signal triggers. Fault level studies are, therefore, performed to determine the values of these parameters for relays across a particular network. Simulation packages such as DigSilent can be used to simulate fault conditions at specific substations to determine its collateral effect on the remaining network. These studies are performed on an Ad-Hoc basis.

5 Operations Planning (System Operators)

Training Start date	2018-06-18
Training End date	2018-08-03
Trainer	Correen Gertzen

5.1 Outline

The System Operator is a division unit located within the Transmission group, and is tasked with ensuring the stability of the electrical network through operational and planning functions. System Operator thus operates essentially as the supervisor of the Eskom Transmission network. System Operator is designated into three specific sub divisions, namely:

1. National Control
2. Grid Code
3. Technical Operations

Information from the Transmission network, collected by current transformers, voltage transformers, and other transducers, is continuously sent to National Control, a centralised control centre that continuously monitors the condition of the transmission network. Two parameters are of paramount importance, namely:

1. Voltage magnitude on the busbars of transmission substations (V).
2. Frequency of the power signal (Hz).

These parameters provide valuable information regarding the relationship between the load and generation as well as the quality of power that is being transmitted across the network. The Transmission network is regulated by the National Energy Regulators of South Africa (NERSA), which requires that the voltages on the transmission network remain within a 0.95-1.05 pu measurement. Voltage discrepancies are created by the misalignment of the phases of the voltage and current signal, which is, of course, indicative of a system that contains both a resistance and an impedance. Larger voltage magnitudes are indicative of a highly capacitive system (surplus of supplied MVARs, which exhibitive of a reduced load) and a lower voltage magnitudes are indicative of a highly inductive system (surplus of MVARs absorbed, which is exhibitive of a high load). Voltages on the Transmission network, therefore, tend to drop toward the 0.95pu boundary during peak load hours and tend to rise toward the 1.05pu boundary during off-peak hours. Additionally, the frequency of the power signal is directly related to the balance of the load and generation, since the generators at the power stations spin faster when loaded insufficiently (increased frequency) and spin slower when excessively loaded (decreased frequency). The personnel at National Control use these measured parameters to fulfil their core responsibility; to initiate immediate actions that are required to maintain the stability of the Transmission network. National Control is the sole custodian of the control operations on the Transmission network. Whilst National Control may issue operations at their discretion, no operating on the transmission network can occur without explicit approval from National Control.

It is evident that stability on the Transmission network can only be ensured through compliance with the standards that have been compiled by NERSA in consultation with government, Eskom, and large power users. The Grid Code sub-division is responsible for ensuring all parties within Eskom and those that wish to connect to the network (such as Independent Power Producers (IPPs)) adhere to these requirements. The importance of this role within System Operator is set to increase in the next few years, since it is estimated that IPPs will contribute to generating 50% of the power that is transmitted on Eskom's transmission network.

The Technical Operations sub-division is further divided into 5 departments, namely:

1. Operation Performance.
2. Ancillary services.
3. Metering and Data Services.
4. National Control System Support (NCSS)
5. Operations Planning.

Whilst I, unfortunately, could not train at all of these departments due to time constraints, I fulfilled my training at transmission under the tutelage of Correen Gertzen at Operations Planning.

Whilst National Control is the sole authoriser of operations of the network, the control officers at National Control cannot initiate any operations without understanding the consequences of such operations.

Recommendations must, therefore, be presented to the control officer before any actions are taken. These recommendations, which are produced by personnel within Operations Planning (Ops Planning) are based on results generated by simulation packages. Ops planning thus fulfils a similar role to EDNO in Distribution, namely to support operations on the Transmission network by recommending short-term operating strategies that are supported by simulated evidence. The ultimate objective of these recommendations is to ensure safe operation across the Eskom electrical network. Whilst National Control is a major stakeholder of Ops Planning, there are others that benefit from the output from Ops Planning, including (but not exhaustive of):

1. National Operations
2. EDNO
3. Transmission Grids and Grids Planning
4. Other System Operator departments such as NCSS and Grid Code management.

The Ops Planning department is divided into four sections, each with a specific set of responsibilities:

1. Network Appraisal.
2. Power Application Software (PAS).
3. Specialised System Studies.
4. Plant Specialists.

The responsibilities and outputs of each of these sections is highlighted below.

5.2 Network Appraisal

The network appraisal section forms the backbone of the Ops Planning department. The personnel within the Network Appraisals subsection are responsible for performing the load studies which are used to recommend short-term operational strategies to Transmission and the rest of System Operator. The studies are performed at request of the stakeholder, and may vary according to the stakeholders requirements. The following studies are typically performed by the Network Appraisal engineer in Ops Planning:

1. Annual operational appraisal - This report represents the critical analysis of all the substations and feeders within the Transmission network to determine weaknesses in the network that need to be addressed through the initiation of future projects. The report is produced once a year and is the most important deliverable of the Ops Planning department. Simulations for this report are performed using initialisations that represent the most onerous loading case according to the previous year's data. This data includes both load and generation patterns. Factors which are highlighted include voltage and thermal loading violations. The results of this study is sent not only to Grid planning and National Control, but also to personnel within the Executive Strategy sectors of the business.

2. Operational projects appraisal of future strengthening projects - Certain strengthening projects will be created in response to the weaknesses identified in annual appraisal report by the Grids planning department. It is important, however, that these strengthening projects do not indirectly cause other issues in the network. The suggested alterations to the network need to, therefore, be simulated and assessed to determine whether such a recommendation will indeed address the inherent weaknesses in the network without simultaneously jeopardising the security of another section of the network. The results of such simulations are recorded in this document along with recommendations for project alterations.

3. Outage studies for National Control and National Operations - Outages are required on a regular basis to facilitate the maintenance, replacements, and commissioning of assets across the Transmission network. Taking certain assets offline for these purposes may, however, place additional strain on the assets that remain online. It is important to understand the effects of taking any particular asset offline so that National Control can be aware of the risks involved in the operation. Network Appraisal engineers are responsible for performing these studies using the system model (initialised with relevant peak flow data) to determine whether such an operation is feasible and to recommend certain strategies or alternatives if the original outage plan is untenable.

4. Transfer limit studies - One of the issues that Transmission must be constantly cognisant of is the transfer limits of the interconnected power network. The majority of the power generation is located in the North-Eastern corner of the country, which needs

to be transferred across the entire network. Losses accumulate on the lines during the transfer, and it is apparent that the transfer of power will be limited by the amount of losses that occur over a particular line. This power transfer limit was regularly reached before the installation of the 765 kV line to the Western Cape. The further strengthening of the Transmission network along with the increased amount of MVAR generated by IPPs located within the Western and Northern Cape have alleviated these issues significantly, but it is integral that the Network Appraisal engineer continues to calculate the transfer limits and ensure that Eskom falls well within the recommended range.

5. Emergency preparedness studies - These plans provide instructions to the operators who are required to restore supply to substations that have experienced faults on supply feeders or major pieces of equipment in the substation (transformers, shunt capacitors and reactors, etc.). Network appraisal engineers are also involved in the planning of the Power System Restoration plans, which highlights the actions that need to be taken to assist in the restoration of power to the interconnected power network when a blackout occurs.

6. Post incident analysis - incidents that have been observed on the power network are simulated using a model to determine the causes of the disturbance and to understand the behaviour of the network in response to such a disturbance. Knowledge obtained from these studies are used to improve the integrity of the system.

7. Network optimisation studies - Similarly to EDNO, the Network Appraisal engineer will recommend strategies for future implementation with the objective of minimising costs and maximise security of supply for each of the feeders on the network. These recommendations are compiled according the results from technical loss analyses of the network and load studies that test the possible reconfigurations of certain substations or assets.

8. Fault level studies - These studies are performed on an annual basis for all substations within the Transmission network to determine the amount of current that will flow through the zones of the substation during fault conditions. These fault levels must fall below the fault level capacity of the circuit breaker within that specific zone. If such a discrepancy is found, the circuit breaker is earmarked in the report. Grid planning can thus begin plans for substation refurbishment or network optimisation procedures to

reduce the fault level in the substation. It is evident that if such a fault were to occur, the fault current will cause the rupturing of the circuit breaker, which endangers the lives of Eskom personnel at the substation and may also risk damage to other assets within the station.

9. Advanced system studies - Whilst the Plant Specialist would typically be responsible for executing advanced system studies, there are certain instances whereby a Network Appraisal engineer will perform an advanced system study. These instances include transient stability studies, voltage stability studies, and special protection scheme studies.

5.3 Power Application Software (PAS)

The main responsibility of the PAS engineer is to facilitate the means by which simulations of the interconnected power network can be simulated and tested. The PAS engineers fulfil this obligation be executing the following functions:

1. Tuning and development of power application software model - The data that is retrieved by the Plant Specialists are used to create the models that need to be integrated in the case-file whenever new assets get added to the interconnected power network. The PAS engineer will ensure that all uploaded ESVD and OEM data is correct and will tune the values accordingly. The PAS engineer will also tune the network case-file according to peak flow data (most onerous case) for simulation purposes. This case-file is made available to all stakeholders through a centralised server.

2. Determining Transmission network operational limits - The success of a simulation is dependent upon whether certain operations can be performed without the violation of operating limits. This can only be known if the operating limits of all the assets on the network are known. A database which contains all these limits has been created by the PAS department and is constantly updated to ensure that all those who perform simulations on the case-file will be able to identify violations in operating conditions.

3. Power application support and training - Simulations of the power network can only be performed if the correct applications have been purchased and licenced. The PAS engineer is responsible for liaising with the PAS vendors to ensure that the software can be easily accessed and utilised by engineers within Eskom.

PAS engineers also provide training to those who need to use the software, ensuring that those who are inexperienced with PAS can begin their investigations without significant delay. DigSilent, PSSE, and Matlab are common applications that are used for power system simulations at Eskom.

4. TEMSE support - TEMSE is a database that contains real-time data that is significant to risk mitigation operations such as those performed by the Network Appraisal engineer. The PAS engineer is responsible for ensuring the integrity of the data that is stored on the database and maintains the online tools that are used by Eskom personnel to access the data on TEMSE.

5.4 Specialised System Studies

There are certain studies that require more expertise than the typical steady-state load studies that are performed by the Network Appraisals engineer. These simulations are performed by the Specialised System Studies engineer, and includes the following:

1. Transient study stability analyses - The interconnect power system is always susceptible to large disturbances, but specific the stability of the network shortly after the occurrence of such disturbances needs to be evaluated for precautionary measures. These stability tests are useful when new generation is being introduced into the interconnected power system (such as what is occurring in the Thabametsi integration project). These studies are used to determine the drop in power signal frequency as a result of a fault, determining current and voltage readings on the network after motor start-up procedures, and determining the ability of power station generators to remain in sync when a disturbance occurs on the network.

2. Small signal studies and PSS tuning - Whilst large disturbances pose a significant threat to the network, these types of transient phenomenons do not occur as much as small disturbances (such as lightning strikes and switching operations on the network). These studies are performed to determine whether the interconnected power system is configured in such a manner that facilitates the sufficient damping of oscillations that result from small disturbances in the network. Such studies assist Power system engineers in determining optimal settings for power system stabilisers in the network, and facilitate the development of sophisticated tools (such as the Wide Area Monitoring System, or WAMS) that

monitors the behaviour of the Eskom network when responding to small disturbances.

3. Sub-synchronous resonance studies - the performance of the power generators on the network is evaluated by the Specialised System Studies engineer to ensure that the behaviour of the turbine rotor does not affect the integrity of the network when operating under certain strenuous conditions. The physical components of the generator may oscillate if the rotor-angle stabiliser equipment is not correctly configured, and thus the Specialised System Studies engineer needs to ensure that the generator will not jeopardise the network under these conditions.

4. Special integrity protection schemes - some special protection schemes are required to ensure the integrity of the interconnected power network. These schemes are developed by the Specialised Studies engineer, and include the UFLS scheme, the Undervoltage scheme, and Inter-tripping schemes.

5.5 Plant Specialists

The reliability of the results that are generated in the simulations performed by the Network Appraisal engineers and other System Operator personnel is dependent on the accuracy of the model. The Plant Specialists at Ops Planning are responsible for ensuring the accuracy of the model by performing the following functions:

1. Dynamic model validation of plant equipment on the interconnected power network - The plant specialist performs the Excitation System Validation (ESVD) test on plant equipment out on the field to determine the exact parameters that would describe the asset's performance. These parameters are updated onto the PSSE case file, thus facilitating the accurate representation of these assets in the simulations. Parameter data may also be requested from the Original Equipment Manufacturers (OEMs) and used as the default parameters for new assets or for assets which have not yet been evaluated by the ESVD test.

2. Supporting the PSSE database infrastructure - the information that is obtained from the OEM or from the ESVD tests are uploaded to a PSSE database by the PAS engineer which is distributed to the necessary stakeholders. It is of utmost importance that the information on the database is always updated. The database is thus centralised, and therefore the updated database

is always made immediately available to those who have access to the server by the Plant Specialist. The database contains OEM parameter data for turbine/governor systems, generator dynamic models, excitation data for all assets, and stabiliser and limiter models. The models that are stored on the database are used by the PAS engineer to create the models and case files that are used for simulation purposes.

3. Offer plant modelling expertise as support for Eskom Generation and the Renewable Energy Independent Power Producer Programme (REIPPP) - Models of assets that enter the interconnected power network need to be modelled according to the OEM parameters and according to the regulations set out by the IEEE 421.5 standard and the Renewable Evaluation Technical Committee (RETEC). The Plant Specialists are not responsible for compiling these models, but are responsible for providing technical support regarding plant modelling.

Whilst it is evident that there are a number of investigations that can be performed as an EiT at the Ops planning department, I was only afforded the time to participate in an outage study at Networks Appraisal under the tutelage of Mrs Gertzen. The following subsection contains details of my technical training at Operations Planning.

5.6 Technical Training

A daily outage for the Hera-Midas 400kV was requested by the protection PPM technicians for between 08:00-16:00 on 2018/07/19 as outstanding protection maintenance at the Midas substation required finalisation. Transmission schedulers requested a study from Ops Planning to determine the feasibility of the outage according to the expected maximum load. The trainees were expected to perform the study in conjunction with an Ops Planning engineer in order to learn about the outage study procedure.

The following steps need to be followed when performing an line outage study for Ops Planning once an updated PSSE case-file is acquired from PAS:

1. Acquire the expected generation pattern from National Control and update the PSSE case-file accordingly.
2. Retrieve loading data from the 5 min Snapshot on TEMSE that most accurately reflects the expected behaviour of the system on

the day of the upcoming outage. The following characteristics should be considered when attempting to predict the load profile:

- Load profiles are unique for each day of the week. Thursdays, for instance, seem to be associated with higher load flows, whereas low load magnitudes are typically experienced on Saturdays and Sundays.
- Greater magnitudes of load are observed on colder days as compared to warmer days. Therefore, Winter loads are typically larger than Summer loads.
- Changes in load profiles are typically large over the change of seasons. We see the highest increase in load on the transmission network when transitioning between Autumn and Winter.
- Public holidays typically result in low load magnitudes regardless of the day of the week.

Update the case-file with the loading profile that is seen in the selected Hera-Midas 5 min snapshot. Use the system 5 min snapshot to inform scaling decisions regarding the rest of the grid.

3. Identify abnormalities in the IPS (such as open lines or transformers which are typically closed) using SCADA and the Morning report. Update the case-file with these abnormalities if they are expected to be present on the day of the outage.

4. Open the line that is expected to be out-of-service for maintenance on the day in the PSSE case-file. Identify any abnormalities in the network. If there are, propose an action that mitigates the risks associated with taking this line is opened (steady-state analysis).

5. Once normal system conditions are reinstated after the line is opened, identify any possible contingencies that may occur whilst the outage is taking place. Note the risks associated with these contingencies and propose actions that will mitigate these risks (contingency conditions).

The following sections outline the details of the aformentioned steps with regards to the outage study that was performed for the Hera-Midas 400kV line.

5.6.1 Generation Pattern

The following information regarding abnormalities in the expected generation pattern for 2018/07/19 were identified upon inspection of the generation pattern report that was sent by National Control:

1. Unit 1 of the Matla Power Station (PS) will be out of service.
2. Unit 3 and 4 of the Duvha PS will be out of service.
3. Unit 2 of the Kriel PS will be out of service.
4. Unit 7 of the Camden PS will be out of service.
5. Units 1,3,4,5,6, and 8 of the Komati PS will be out of service.
6. Unit 2 of the Tutuka PS will be out of service.
7. Unit 3 of the Drakensburg PS will be out of service.
8. Units 2,4,5, and 6 of the Grootvlei PS will be out of service.
9. Apollo Substation is expected to transfer 1158 MW of power.

A snapshot of the generation pattern that is expected on the 19th July 2018 can be seen in figure 45.

Declared Available (Excl Gas)			Refresh	Thu 19/Jul/2018							
Station	U	L_L	Current	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
HCB	01	0	419	650	650	650	650	650	650	650	650
HCB	02	0	659	508	508	508	408	408	408	408	508
Koeberg	01	20	897	910	910	910	910	910	910	910	910
Koeberg	02	0	930	930	930	930	930	930	930	930	930
Arnot	01	176	204	376	376	376	376	376	376	376	376
Arnot	02	85	216	380	380	380	380	380	380	380	380
Arnot	03	79	282	380	380	380	380	380	380	380	380
Arnot	04	135	210	376	376	376	376	376	376	376	376
Arnot	05	40	212	350	350	350	350	350	350	350	350
Arnot	06	0	F 12Jul18 23:00	370	370	370	370	370	370	370	370
Camden	01	19	108	190	190	190	190	190	190	190	190
Camden	02	55	113	190	190	190	190	190	190	190	190
Camden	03	21	109	185	185	185	185	185	185	185	185

Figure 45: A snapshot of the generation pattern that was expected on the 19th July 2018.

5.6.2 Loading data from Hera-Midas 400 kV line

The Hera-Midas 400 kV line peak loading snapshot (634 MVA on Thurs 07 June 2018 at 08:45) was used to scale the loading levels in the Central Grid present on the updated Operations Appraisal PSSE case file. This date was selected as the temperature profile more closely matches that of the forecasted profile for Thursday the 19th of July as compared to any other preceding Thursday. The loading profile on this day for the Hera-Midas 400kV line can be seen in figure 46.

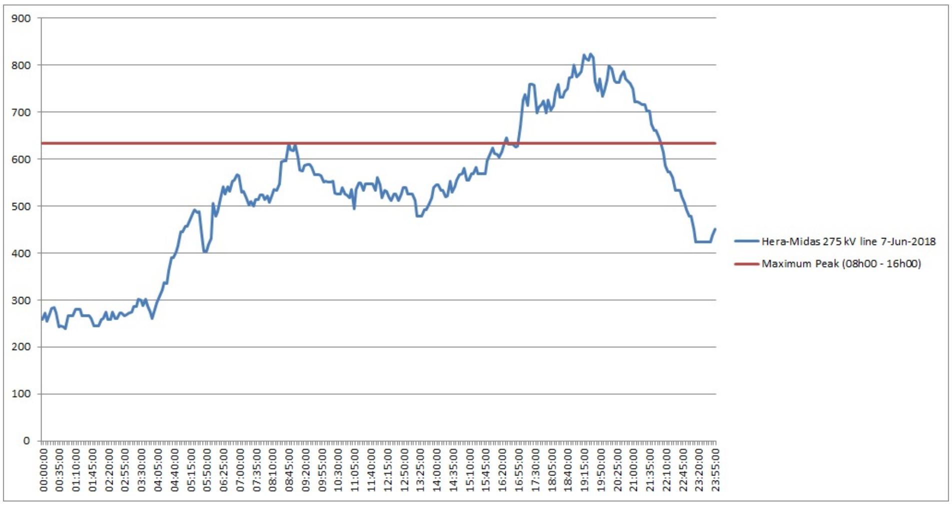


Figure 46: The load profile of the Hera-Midas 400kV line on 2018/06/07. The peak found between 08h00-16h00 (represented by the red line) was used to scale the loads found on the Central Grid along with the 5 minute system snapshot.

5.6.3 Abnormalities in IPS

The following assets, which are typically online, will be opened and isolated on the day of the outage:

1. The Lethabo - Snowdon and Snowdon Brenner 275 kV lines are currently bypassed at Snowdon to form the temporary Lethabo Brenner 275 kV line.

2. Taunus No. 3 275kV 132kV 22kV transformer bay is out of service.

3. Glockner-Kookfontein No.1 275kV line is out of service.

4. Glockner 400kV/275kV/22kV 1 transformer is out of service.
5. Esselen 275kV/132kV/11kV 8 transformer is out of service.

These assets were thus opened on the PSSE file so that the outage conditions can be accurately simulated.

5.6.4 Steady-state analysis

Switching out the Hera-Midas 400 kV line reduces load onto Hera transformers (80% down to 67% for each transformer, or 640.98 MVA drop to 512.08 MVA). Load is redirected to Taunus and Etna via the Eiger-Etna 275 kV line (load increased from 573.8 MVA [49% loading] to 754.03 MVA [65% loading]). This results in an increased loading on the Etna-Taunus line (from 310.7 MVA [26% loading] to 457.7 MVA [40% loading]). Additionally, some load to is redirected through the Pluto-Watershed line (load increased from 286.47 MVA [40% loading] to 361.48 MVA [50% loading]). The loading on the Grootvlei-Hera 400 kV line increases from 798.7 MVA (56% loading) to 1062.8 MVA (75% loading) to compensate for the loss of supply through Hera-Midas.

5.6.5 Contingency Conditions

Each of the contingencies listed below requires the switching in of the Bernina-Hera 275 kV busbar link. In each case, it is important to note that the connection of this link poses a threat to the safety of personnel located at the Hera or Bernina substation due to the insufficiently rated arcing tips of the isolators on the busbars. No work is permitted on these substations when this link is connected. Additionally, closing this link introduces new contingency issues regarding the Bernina-Glockner lines, which are rated above 60% in each scenario. Loss of either of these lines whilst the Bernina-Hera busbar link is online will require the reduction of generation at Lethabo or potential loadshedding.

1. Loss of Hera 400 kV/275 kV transformer 1

   The loss of the Hera 400 kV/275 kV 1 transformer results in the overloading of the Hera 400 kV/275 kV 2 transformer (908.4 MVA at 118%). Additionally, the loss of this transformer results in a number of minimum voltage violations across the western region of the central grid. The connection of the Bernina-Hera busbar link facilitates the transfer of 959.2 MVA of power onto the Hera 275 kV busbar, thus bypassing the Hera transformers. This reduces the loading on the Hera 2 transformer from 908.4

MVA (118%) to 584.5 MVA (72%). Voltage violations may need to be corrected on the Grootvlei 400 kV busbar.

2. Loss of Hera 400kV-275kV transformer 2

   The loss of the Hera 400 kV/275 kV 2 transformer results in the overloading of the Hera 400 kV/275 kV 1 transformer (901.2 MVA at 118%). Additionally, the loss of this transformer results in a number of minimum voltage violations across the western region of the central grid. The connection of the Bernina-Hera busbar link facilitates the transfer of 963.4 MVA of power onto the Hera 275 kV busbar, thus bypassing the Hera transformers. This reduces the loading on the Hera 1 transformer from 901.2 MVA (118%) to 578.1 MVA (71%). Voltage violations may need to be corrected on the Grootvlei 400 kV busbar.

3. Loss of Pluto-Watershed 275 kV line

   The loss of the Pluto-Watershed 275 kV line causes the loading on the Grootvlei line to increase to 1379.4 MVA (100% loading). It is unlikely that some of this load can be redirected through the Eiger-Etna route since the loading on the line increased to 1074.9 MVA (97% loading), and is thus saturated. The loading can be best distributed to the necessary loads by connecting the Bernina-Hera busbar link. Closing this link reduces the loading on the Grootvlei-Hera line and the Eiger-Etna line to 759.4 MVA (53% loading) and 326.3 MVA (28%) respectively. The Bernina-Hera link is loaded at 1051.3 MVA (22% loading). Voltage control may be required to stabilise the voltage on the Watershed 275 kV and the Pluto 275 kV busbars.

4. Loss of Grootvlei-Hera 400 kV line

   Loss of the Grootvlei-Hera 400 kV line results in the overloading of the following lines within the central grid:

   – Pluto-Watershed 275 kV line (803.9 MVA [130%]).
   – Etna-Taunus 275 kV line (717 MVA [161%]).
   – Eiger-Etna 275 kV line (840.3 MVA [215%]).
   – Lethabo-Eiger 275 kV line (1523.1 MVA [116%]).
   – Brenner-Snowden Bypass line (859.9 MVA [110%]).
   – Lethabo-Snowden Bypass line (1133.53 MVA [107%]).
   – Jupiter-Nevis 275 kV line (844.8 MVA [138%]).

- Esselen-Jupiter 275 kV line (1033.6 MVA [115%]).
- Apollo-Croyden 275 kV line (964.2 MVA [106%]).

A number of voltage violations occur across the central grid in addition to the overloaded lines. Closing the Bernina-Hera busbar link will prevent these issues, resulting in the transfer of 1333.7 MVA of power onto the Hera 275 kV busbar. The Bernina-Hera line is loaded at 28% in this instance. Both Hera transformers are bypassed in this setup (0% loading on both transformers). Voltage violations may need to be controlled at the Esselen 132 kV, Esselen 88 kV A & B, Everest 275 kV, and the Grootvlei 400 kV busbars (all of which exceed 105% nominal voltage).

5. Loss of Eiger-Etna 275 kV line

   Loss of the Eiger-Etna 275 kV line results in the overloading of the following lines within the central grid:

   - Pluto-Watershed 275 kV line (123%).
   - Grootvlei-Hera 400 kV line (196%).

     And the following transformers:
   - Hera 400 kV / 275 kV 1 transformer (123%).
   - Hera 400 kV / 275 kV 2 transformer (128%).
   - Matla 400 kV / 275 kV transformer (208%).

   Closing the Bernina-Hera busbar link reduces the transfer of power across the Hera transformers by facilitating the transfer of 1099.2 MVA of power (23% loading) onto the Hera 275 kV busbar. This reduces the loading on the Grootvlei-Hera 400 kV line to 731.2 MVA (51% loading) and the loading on the Hera transformers to 350.1 MVA (43%) and 365.7 MVA (45%) respectively.

6. Loss of Etna-Taunus 275 kV line

   The loss of the Etna-Taunus 275 kV line results in the overloading of the Grootvlei-Hera 400 kV line (1810.9 MVA at 142% capacity) and both Hera 400 kV / 275 kV transformers (631.1 MVA at 135% capacity and 660.7 MVA at 142% respectively). Minimum voltage restrictions are also breached on busbars across the West-rand region of the central grid (including Taunus 275 kV, Westgate 275 kV, and Princess 275 kV busbars). Connecting the

Bernina-Hera busbar link reduces the loading on the Grootvlei-Hera 400 kV line to 652.6 MVA (46% loaded) and the loading on the Hera transformers (318.8 MVA [39% loaded] and 333.7 MVA [41% loaded] respectively). Voltage control may be required on the Pluto 275 kV busbar.

6 Protection (PTM&C)

Training Start date	2018-08-06
Training End date	-
Manager	Andre De La Guerre

EiTs are expected to perform an elective in a department within PDE that is selected by the EiT according to their interests and expertise. The elective period is expected to be approximately 8 months in duration (August 2018 - March 2019). I elected to join the Protection department within PTM&C (Technology). I am currently under Andr De La Guerre's management. I, along with Kavish Mathuradas, have been assigned to a design project which involves the establishment of a replacement strategy that will address some concerns regarding the ageing equipment on the Eskom IPS. There is, unfortunately, nothing to report at this stage since the project is still in its infancy.

7 Summary

7.1 Extent of Training Activities

The training activities that were participated in during the first EiT assessment period are summarised in tables 2.

Table 2: Summary of the theoretical training received during the first EiT assessment period.

Department	Description
Northrand Customer Network Centre (CNC)	• Learnt about the interactions between Eskom residential customers and the field service technicians. • Observed the regulations set out in the ORHVS being used in practise (risk assessment, supervision etc.). • I witnessed how field service technicians work with the police to enforce the law through the disconnection of illegal electrical connections.
Control Plant Maintenance	• Familiarised myself with the typical protection devices that are used in the West sector of the Central Operating Unit. • Observed the execution of ORHVS related procedures (risk assessment, operating of equipment by an appointed operator etc.). • Observed troubleshooting procedures that are performed on transformer protection systems. • Used technical drawings to identify termination points on both the junction box and the protection panel, thus facilitating an understanding of how power plant assets integrate with protection systems.

Eskom Distribution Network Optimisation (ENDO)	• Achieved a basic understanding of how Eskom engineers use sophisticated software to make important decisions regarding immediate operating and maintenance of the distribution network. • Performed contingency and outage studies using DigSilent and ReticMaster, and have thus learnt how to use these programs to achieve EDNO objectives. • Familiarised myself with the databases that are used by Eskom personnel to perform studies (TEMSE, ENS, MV90, etc.). • Learned about how EDNO technicians are integral to the creation of loadshedding schedules.
Operations Planning (System Operator)	• Performed contingency and outage studies using PSSE, and have thus learnt how to use this programs to perform Ops Planning functions. • Further familiarised myself with the databases that are used by Eskom personnel to perform studies, especially the TEMSE 5 min analog database.

7.2 Value added during training

Despite having to follow the EiT program over the past 18 months, there have been opportunities where I have been able to contribute value to Eskom. These instances include

1. The review of the Control application Brownfield integration standard, which included the proposal of a new strategy which would optimise the integration of phase VI protection equipment into substation with older technologies.
2. Performing outage and contingency studies for both EDNO and

Ops Planning, thus assisting in producing deliverables and taking a share of the workload for each department.

3. Participating in the development of a new maintenance and replacement strategy for Protection equipment within transmission, which should be enacted early next year.

4. The development of a PAVICA Aoelian vibration measurement system, which is currently in its design phase. This will allow LES to measure vibrations on lines before damage can be inflicted on the line.

As my training concludes and I transition from a trainee to a permanent engineer, I am confident that I will be able to contribute more value to the business. I am currently stationed at Protection within PTM&C, and I expect that I will continue to work within this department if I am hired as a permanent engineer.

I have not only had the opportunity of adding value to the organisation over the past 18 months, but I have also had the opportunity of receiving technical and practical training from experts in the relevant fields, which has added significant value to my engineering repertoire. The interactions with these experts have helped me understand what is required of an engineer who is working in a professional environment. I also now understand the work ethic and the moral integrity that is required to make changes that will significantly impact people across the country. I regard this as a significant privilege and I intend to liaise with these experts on as regular a basis as I can. Site visits to the substations in the Central Operating Unit have helped me to integrate the theoretical knowledge of engineering systems employed at Eskom that I have learnt at university with the actual equipment and their implementation principles. This visualisation is an integral part of the learning process, and I am deeply appreciative of the opportunities that I have been presented in this regard, especially when I, as an EiT, have been permitted to enter prohibited sites solely for the purpose of training.

7.3 Occupational Health and Safety (OHS) Act

A great amount of emphasis is placed on safety principles in the Eskom working environment. This has been made evident with the ORHVS Responsible person training that I received during this assessment period. The OHS act is an official document that was compiled and amended by the Department of Public Works. It highlights key responsibilities that employers and employees have to themselves and each other with regards to safety in the workplace. A number of subsidiary regulations for specialised work have been appended to this act, which include regulations that must for followed for practises such as construction, electrical installation, and diving. It is of utmost importance that an engineer familiarises themselves with the OHS act and the subsidiary regulations, as the engineer is responsible for acting ethically and ensuring the safety of those who are involved in the projects that they are managing and leading. This is highlighted as one of the outcomes that are required to be satisfied to attain professional engineering status. The OHS act has informed the Eskom's life saving rules, which include:

1. Open, isolate, test, ground, bond and/or insulate before testing.
2. Hook up at heights.
3. Buckle up.
4. Be sober (0%).
5. Have a valid working permit.

The OHS act has also informed the Operating Regulations for High Voltage Systems (ORHVS). I recently attended training regarding these regulations and I am currently qualified as a responsible person (level II). The main responsibility of a responsible person is to assist in the supervision of work being performed on an HV system in the absence of an authorised operator. I learnt that such supervision can only be performed if a working permit is signed by both the authorised operator and the responsible person. Such an action can save lives as it ensures that both the authorised operator and the responsible person are aware of the work that needs to be conducted and on which apparatus such work needs to be performed on, thus preventing accidental contact with other apparatus (which may be electrified) and any work that is unauthorised and may place the lives of the workers at risk.

7.4 Leadership Opportunities and Networking Achieved

The majority of the tasks and activities completed during this assessment have been completed as a team member, working together with other EiTs to accomplish particular objectives. I have, however, taken leadership on the reverse engineering of the PAVICA project that has been assigned to me by chief engineers Bertie Jacobs and Arthur

Burger. As was observed in the first 12 months of my training, I have organised meetings with engineers that I believed would have assisted me in the continuation of this project. I have since completed the design of the analogue measurement circuit and have partially constructed the prototype circuit. The details of this project are outlined in the report I compiled for my 6 month EiT review.

7.5 Pro-activity and Innovation

Whilst being involved in the Eskom training program may take up a significant portion of working time throughout the day, it is important that one actively pursues work that can be taken on as on opportunity of learning and adding value to the organisation. It is thus with this insight that I have pursued to tackle the PAVICA project initiated during the first six months of my EiT evaluation. The research is currently ongoing, but I understand that the success of such a project could potentially save Eskom a significant amount of money (R5 million has already been spent over the past 12 months on replacing conductors that have failed due to insufficient damping). I have thus dedicated a number of my working hours to addressing these concerns whilst adequately satisfying the requirements of my EiT assessment.

7.6 Highest level of responsibility

I am currently the assistant design leader of the Reverse engineering of the PAVICA project. I have also assisted and observed on a number of other tasks which have been mentioned in this document.

7.7 Awareness of professionalism

I learnt that an engineer is responsible for performing their work to the best of their ability, honestly account for their working hours, respecting and considering their fellow employees, never compromising on the quality of work they produce, considering the lives of the people who will interact with their deliverables after project completion, and for with-holding sensitive information of the organisation. Behaving in this manner is a requirement, and must be adhered to as outlined by the Eskom and ECSA Code of Conduct.

8 Conclusion

My third six months EiT assessment period is complete. I will be assessed on the content of this report and my training activities at the EiT assessment presentation on the 19th October 2018. The participation in the training activities and the projects at the aforementioned departments have offered me valuable insight into the functions of PDE, Field Services, and System Operator and the mandate of engineering at Eskom as a whole. I look forward to gaining further theoretical and practical experience and knowledge of the Eskom working environment as my training concludes. I would like to sincerely thank all Eskom employees who were involved in our training over this period.