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Mercury 3rd 400/132 kV
transformer concept design
report**

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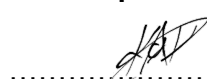
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EXECUTIVE SUMMARY

With limited or no capacity available in many of the transmission supply areas, and with a need to install 16 604 MW of renewable energy (RE) generation by 2027, it becomes crucial to attract and enable RE generation connections in the areas where grid capacity remains, especially those areas where minimal upstream network infrastructure is required. To this effect, areas have been identified for additional transformer capacity at substations that lie within the future areas of interest for RE generation.

Mercury Substation was identified as one such station. Mercury is located near the town of Orkney in the Freestate.

Mercury MTS is a 765/400/132/ kV substation. It consists of 2x 500 MVA 400/132 kV autotransformers. The substation utilises double busbars for all voltage levels. There are 3x 400 kV feeders, 10 x 132 kV feeders, 1x132kV bus coupler, 1x400kV bus coupler and 2 x 132 kV shunt capacitor bank. The 75kV yard is not mentioned because the scope is limited to 400/132kV yards.

A third 500 MVA 400/132 kV transformer is required at Mercury Substation to integrate an additional 980 MW to the 67.9 MW. This will ensure that the total of 1048 MW will be connected at an N-1 level of network redundancy.

The scope of work is as follows:

- Equip 400kV transformer bay.
- Equip the 400kV bus coupler A
- Equip the busbar number 1, 400kV bus section.
- Install 1 x 400/132 kV 500MVA Transformer
- Equip 132kV transformer bay.
- Equip the 132kV bus coupler B
- Equip the busbar number 1, 132kV bus section.

No options were considered since, Mercury substation was previously designed to cater for the addition of the third transformer and future bus couplers and bus sections.

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1. INTRODUCTION

This document provides design status information of the completed concept design phase for the Expedited IPP Program - Mercury 3rd 400/132 kV transformer. This document is a major input to the formal design review process at the end of the concept design phase and describes the design process followed and technical output of the concept phase. The document contents provide an overview of the outcome of the design related activities with references to design and other documents when further detail information is required.

The purpose of the concept design phase is to:

1. Formalise stakeholder requirements, which entails the elicitation, analysis, interpretation and, where needed, re-stating of stakeholder expectations. Stakeholder requirements are formal, once accepted by the stakeholders.
2. Transform all stakeholder requirements into technical requirements of the system, as a whole, and into technical requirements of those major system elements that are significant technical design and cost drivers.
3. Develop one or more technically feasible design solutions. A preferred solution is selected from alternative concept designs and defined, in sufficient detail, to enable its performance, engineering time-scales and life-cycle cost to be predicted in quantitative terms, as required by the Eskom Project Life Cycle Management model. The preferred design solution is selected, based on the results of a cost-benefit analysis and compliance assessment with requirements.

The following generic engineering activities are performed during the concept phase:

- Identify stakeholders and stakeholder requirements;
- Establish maintenance, operations and safety concepts, based on user inputs;
- Establish technical requirements, system boundaries, external interfaces and performance measures;
- Develop alternative feasible solutions;
- Evaluate cost benefits of alternative solutions;
- Identify and assess risks and future mitigation strategies;
- Develop process models, high-level architecture, layouts and operating concepts;
- Select/establish site characteristics;
- Identify applicable design criteria; and
- Assess design for compliance to requirements.

1.1 SYSTEM IDENTIFICATION

The system is identified by Mercury MTS. Mercury is located near the town of Orkney in the Freestate. The proposed system based on the proposed solution documented in this report is indicated by the following Station Electric Diagram and Key Plan:

MTS	Station Electric Diagram	Key Plan
Mercury	Mer23P13-SE-C3, Revision 0	Mer23P13-SE-C4, Revision 0

1.2 SYSTEM OVERVIEW

Mercury MTS is a 765/400/132/ kV substation. It consists of 2x 500 MVA 400/132 kV autotransformers. The substation utilises double busbars for all voltage levels. There are 2x 400 kV feeders, 6x 132 kV feeders and 1x 132 kV shunt capacitor bank.

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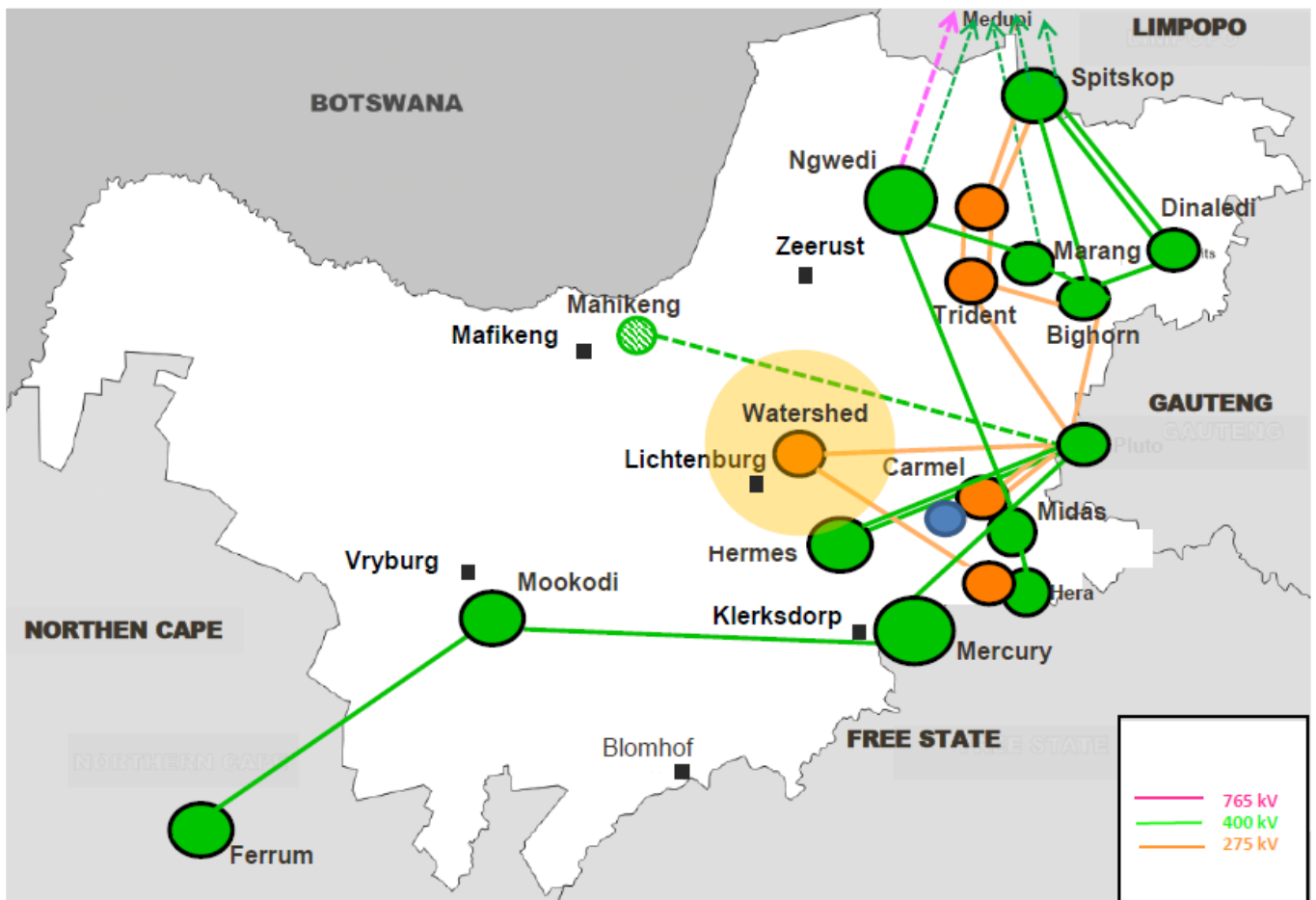


Figure 1: Network diagram

1.3 PURPOSE OF THE PROJECT

A third 500 MVA 400/132 kV transformer is required at Mercury Substation to integrate an additional 980 MW to the 67.9 MW. This will ensure that the total of 1048 MW will be connected at an N-1 level of network redundancy.

2. SUPPORTING CLAUSES

2.1 SCOPE

This document provides an overview of the engineering processes followed and the system design status at the end of the concept phase. The document includes the results of technical assessments to determine compliance with stakeholder requirements, technical risks identified, lessons learned during the design process and outstanding issues for this design phase. This document further provides references to the design output documentation.

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This document does not provide design cost, schedule or other project management type information.

2.1.1 Purpose

This document summarises the status and outcome of the concept phase design related activities and describes the achievement of the design goals, in terms of meeting stakeholder requirements. This document, together with the design output documentation of this phase, is submitted for review.

2.1.2 Applicability

This document shall apply to the Transmission Grid and all relevant stakeholders.

2.2 NORMATIVE / INFORMATIVE REFERENCES

2.2.1 Normative

- [1] Grid Planning Report (GP_22/216 August 2022 Rev0)
- [2] User Requirement Specification (September 2022 Rev0)
- [3] Substation Layout Design Guideline (240-55922824)
- [4] Standard for Implementation of Substation Layouts for Transmission Substations (240-109644476)
- [5] Substation Engineering Product Realisation (240-55921217)
- [6] South African Grid Code
- [7] Occupational Health and Safety Act (OHS Act) 85 of 1993
- [8] Eskom Maintenance Management Policy (32-1205)
- [9] Substation and Facility Maintenance (TST41-794)
- [10] Eskom Generation and Wires Operating policy (240-43008621)
- [11] Eskom Safety, Health, Environment and Quality policy (32-727)
- [12] Operating Regulations for High Voltage Systems (32-846)
- [13] The application of the National Building Regulations (SANS 10400-XA)
- [14] Energy efficiency in buildings (SANS 204)
- [15] Standardized Specification for Civil Engineering Construction (SANS 1200)
- [16] IEEE Guide for Safety in AC Substation Grounding (IEEE std 80)
- [17] Standard for Labelling Outdoor High Voltage Equipment within Eskom Transmission (TSP41-1009)
- [18] Process Control Manual (PCM) for Perform Substation Engineering (240-53459042)
- [19] Process Control Manual (PCM) for Perform Technical Assessment (240-46977482)
- [20] Soil Resistivity Testing For Substation Applications (240-96393507)
- [21] Earth Electrode Resistance Measurement standard (240-101940513)
- [22] The Transmission Substation Earth Fault Application Guide (240-95773230)
- [23] Design Review Procedure (240-53113685)
- [24] Terms of Reference for Design Review Teams presiding over Power Delivery Infrastructure Designs in Eskom (240-606480018)
- [25] Direct Lightning Stroke Protection of Substations (240-109589380)

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[26] The Design Philosophy for 400kV Tubular Conductor Busbar Yards (240-95242252)

[27] Standard for operational floodlighting in substations (240-83382076)

[28] Substation Earth Grid Design Standard rev 2 (240-134369472)

2.2.2 Informative

[29] PTM&C Concept Design document (Document Number Wat22P05-SE-C15)

2.3 DEFINITIONS

2.3.1 Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
CEL	Cost Estimate Letter
CLN	Customer Load Network
CoE	Centre of Excellence
DMRE	Department of Mineral Resources and Energy
EIA	Environmental Impact Assessment
LES	Line Engineering Services
MEC	Maximum Export Capacity
MTS	Main Transmission System
OPGW	Optical Ground Wire
OTDR	Optical Time Domain Reflectometer
SLDG	Substation Layout Design Guideline

Table 1: List of Abbreviations

2.5 ROLES AND RESPONSIBILITIES

Not Applicable

2.6 PROCESS FOR MONITORING

This document will be revised as and when the scope of work of this project changes after it has been Approved by the Tx DRT and subsequently accepted by the Substation Engineering.

2.7 RELATED / SUPPORTING DOCUMENTS

Not Applicable

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3. CONCEPT DESIGN INFORMATION

3.1 SCOPE OF DETAIL DESIGN

3.1.1 Scope of Work

400kV Yard

- Equip 400kV transformer bay.
- Equip the 400kV bus coupler A
- Equip the busbar number 1, 400kV bus section.
- Equip 400kV busbar 1A CVT
- Remove 1 set of CT's from 400kV bus coupler B

132kV Yard

- Install 1 x 400/132 kV 500MVA Transformer
- Equip 132kV transformer bay.
- Equip the 132kV bus coupler B
- Equip the busbar number 1, 132kV bus section.
- Equip 132kV busbar 1B VT
- Remove 1 set of CT's from 132kV bus coupler A

3.1.2 Project Scope limits

The scope is limited to the URS scope.

3.1.3 Project Exclusions

The scope is limited to the works as defined under headings 3.1.1 and 3.1.2.

3.1.4 Adjacent or Related projects

Dependent (Yes/No)	Job ID	Job Name	Design Engineer	Status	Commissioning date
No	Merc22P11	Replacement of high risk CT's	Thabiso Madikgetla	Concept	TBC
No	Merc21P10	Cape Corridor Phase 5	C Thomas	Concept	TBC
No	Merc19P08	National Security project	Dawie Naude	Detail	TBC
No	Merc18P07	Bokamosa 68MW solar PV Plant	TBC	Concept	TBC
No	Merc18P06	Transformer 2 Aux transformer replacement	Alfred Le Grange	Concept	TBC
No	Merc17P05	400kV/132kV Mercury-Midas emergency bypass	Nkosinathi Zulu	Concept	TBC

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3.1.5 Project Stakeholders and Resources

This document shall apply to the Northern Grid and all relevant stakeholders. The stakeholders and resources related to the development of this report are listed below:

- Moses Tshikomba - Eskom Project Manager
- Sibongile Chawe – Senior Engineer Integration
- Lindiwe Motaung – Senior advisor Environmental Management
- Abdullah Kaka - Engineer Substation Engineering
- Tsholofelo Seokamo- Eskom Project Manager
- Thamsanqa Ngcobo - Eskom Transmission Planning
- Keineetse Rankunyane – Chief Engineer- Grid
- Ferdi Hahn – Senior Advisor Electrical
- Christinah Mohloki – Chief Technologist PTMC
- Keso Mothibi – Senior Advisor Electrical

3.2 PROJECT DESIGN INPUTS

The following is a summary of the key substation design aspects for this project:

Network Requirements (Minimum): Factor	Description	Description
Network nominal voltage	132kV	400kV
Normal operating range	±5%	±5%
Equipment highest voltage	145kV	420kV
Minimum Rated lightning / Surge Impulse withstand	550kV	1425kV
Continuous rating	2500A	3150A
Reliability	N-1	N-1

Table 2: Network Requirements

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Rated Physical Environment: Factor	Description
Ambient Temperature, Max	38.3 °C
Ambient Temperature, Min	-9 °C
Lightning Density	7 flashes to ground/km ² /year
Rain Fall (highest per day)	120 mm
Snow (mean)	0.4 days/year
Max. Wind Speed	7 m/sec
Pollution characteristics	Heavy (25mm/kV)
Geographical Area	Inland
Altitude	1301 m

Table 3: Site Conditions

3.3 KEY DESIGN ASSUMPTIONS

The concept design presented in this report is based on the following assumptions:

The information contained in the Grid Planning report [1] and the URS [2] is accurate.

By the time this project goes into construction, the Mercury Refurbishment project is completed.

3.4 DESIGN APPROACH

3.4.1 Planning Inputs

The inputs to this design are the approved Grid planning report [1] and the approved URS [2].

3.4.2 Design Process

The design process followed is in accordance with the Eskom Substation Engineering Product Realisation document [5] and Process Control Manual (PCM) for Perform Substation Engineering [18].

3.4.3 Design Outputs

The design outputs are stipulated in the Substation Engineering Product Realisation document [5]. The concept design output package comprises of the following:

- Concept Design report
- Station Electric Diagram
- Key Plan

3.4.4 Design Verification

The concept design outputs are packaged in the form of a presentation and presented to the Substation Engineering Design Review Team (DRT) for support of the project to be presented to the Transmission Engineering Review Team for approval.

The outputs also undergo a peer review within the Substation Engineering Centre of Excellence (CoE).

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The design reviews are done in accordance with the Design Review procedure [23] and the PDE DRT terms of reference [25]. The design review ensures that the most efficient design solution is selected taking into account the life cycle of the asset. This includes technical feasibility, technical risks, capital cost, life cycle costs, safety, constructability, maintainability and outage management amongst others.

Some of the aspects considered during design review are:

- Compliance of design to stakeholder (user, regulatory, statutory, environmental) requirements.
- Compliance of designs to design standards, philosophies, practices and codes.
- Compliance to the relevant PCM's.
- Demonstration of sound engineering thinking where a unique solution has to be provided (design approach, rationale, assumptions, modelling, calculations, simulations).
- Review, challenge and approval of the technical designs at the various PLCM stage gates.
- Practicality of the implementation proposal for the design solution.
- Ensure that all documents required to procure, construct, install, commission, operate and maintain the designed system or component have been submitted for review and acceptance.
- Safety in design (design is safe to construct, operate, maintain and dismantle).
- The design has considered and incorporated all aspects of constructability, procurement, operability, maintainability, sustainability, reliability, availability, testability, expandability, disposability and including inspection and commission capabilities.
- Risks have been identified, assessed, documented and mitigated.
- Check if design is ready to proceed to the next design phase or to the execution phase.
- Recommendations of previous design reviews have been incorporated in the revised design.
- Design changes and modifications to be referred back to DRT.
- Engineering changes are managed in line with what is described in the PCMs.

Any changes to the design, reported on in this document by any of the DRT committees, will be reported on in a revision of this document.

3.4.5 Design Criteria

The design criteria and guidelines used are based on Section 5-1 of the Substation Layout Design Guide [3] and Standard for Implementation of Substation Layouts for Transmission Substations [4].

3.4.6 Codes and Standards

The designs are governed by the Grid Code [6] and are additionally required to be in compliance with the Occupational Health and Safety Act [7].

3.5 KEY DESIGN DRIVERS

The key design drivers are space constraints, cost reduction, outage reduction, constructability, procurability, maintainability, operability, safety, reliability and expandability.

3.6 DESIGN OPTIONS CONSIDERED

No options were considered since, Mercury substation was previously designed to cater for the addition of the third transformer and future bus couplers and bus sections.

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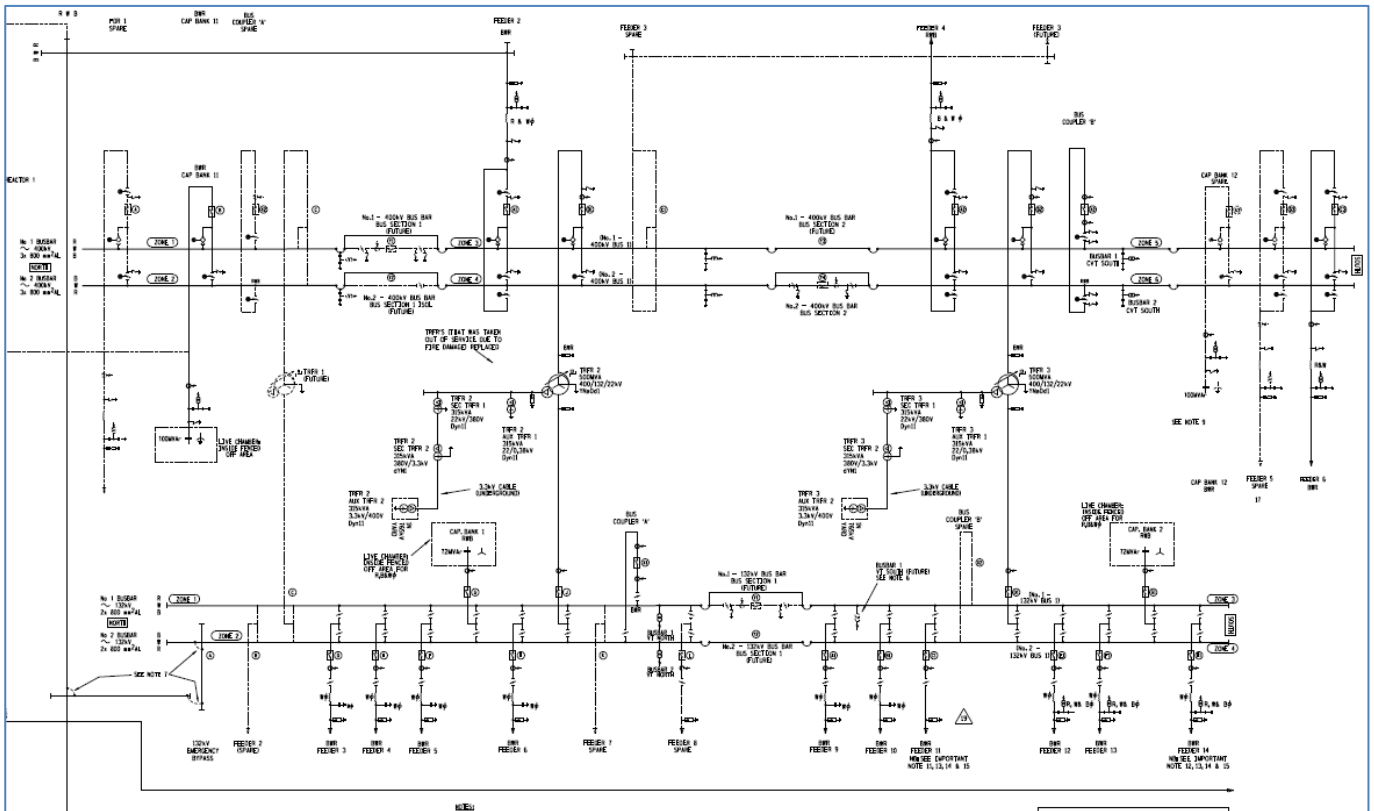


Figure 2: Existing Station Electric

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As can be seen from the existing stations electric and key plan transformer bay, bus coupler and bus section are already included in the station and is shown as future.

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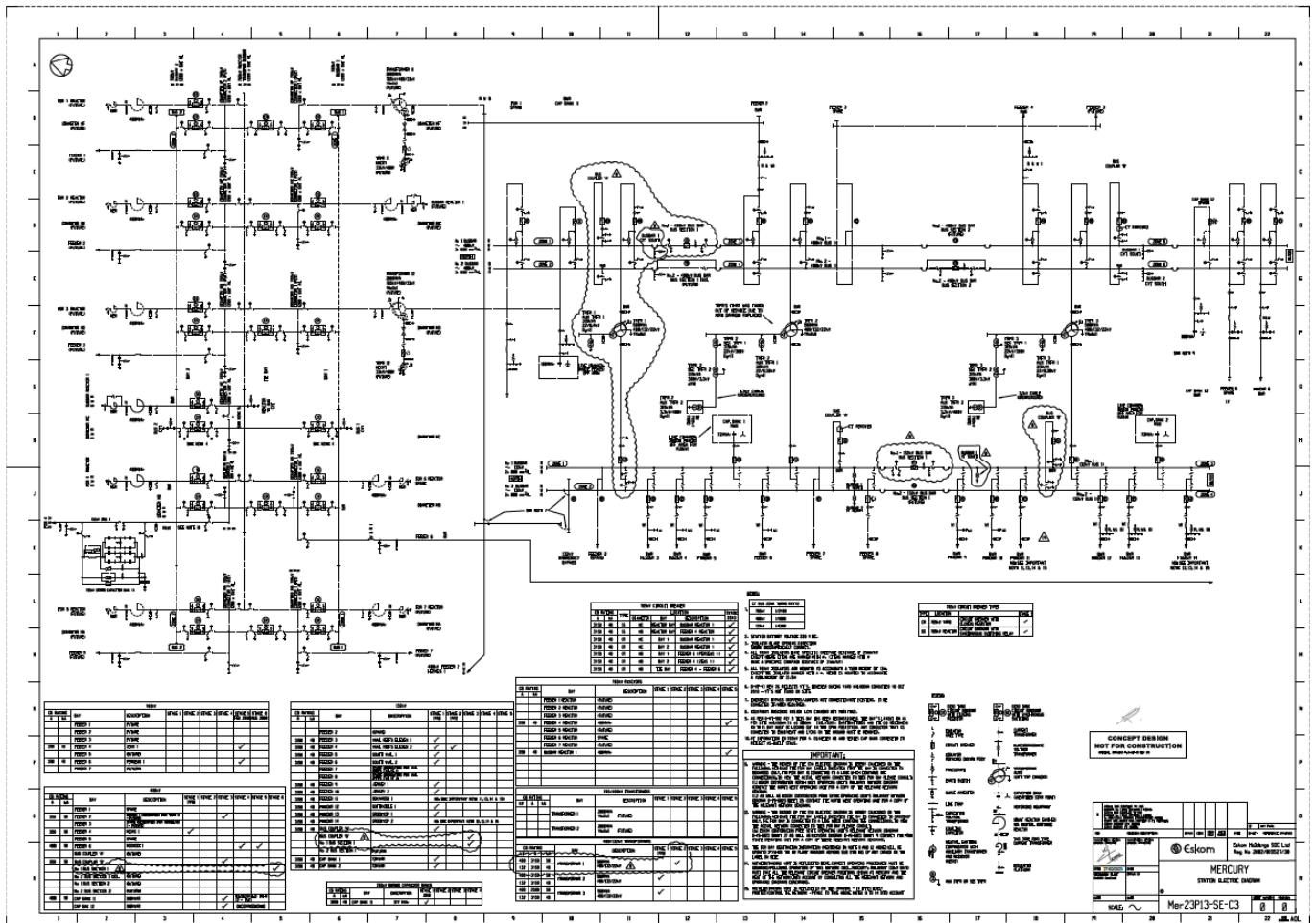


Figure 4: Proposed Station Electric

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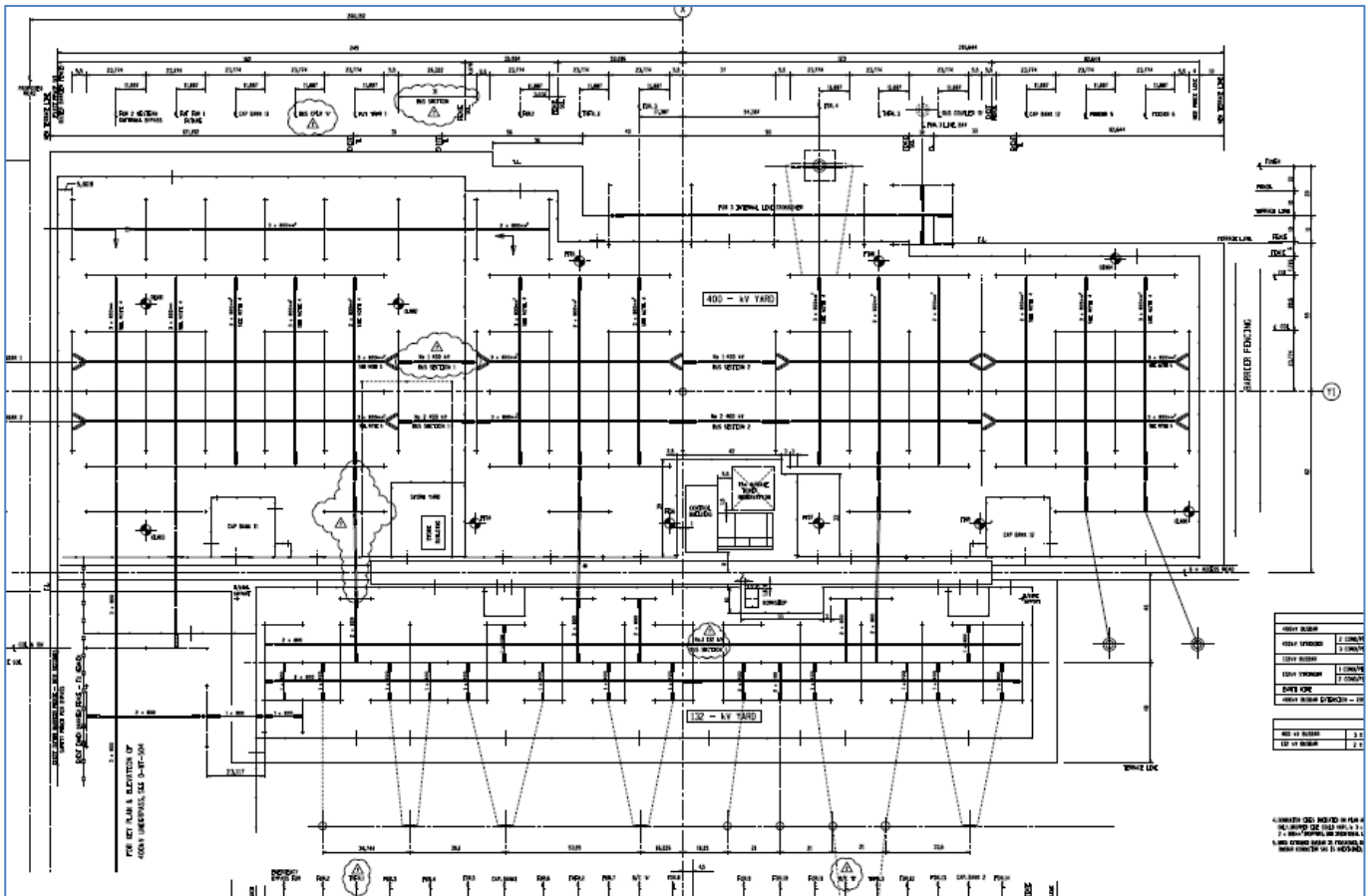


Figure 5: Proposed KeyPlan

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Figure 6: Aerial view

3.7 ELECTRICAL DETAIL DESIGN

3.7.1 Design Philosophies

The existing 132kV and 400kV systems consist of flexible conductor, high strung double busbars. Mercury substation is air-insulated and will consider the applicable minimum phase-to earth and phase-to-phase clearances, as well as the vertical and horizontal working clearances.

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3.7.2 Substation Design Specifications and Configuration

3.7.2.1 Fault Level Studies

The URS provided the fault levels are shown in Table 4.

System Voltage (kV)	1 Φ Fault Level (kA)		3 Φ Fault Level (kA)		Earthmat Designed Fault Current (kA)
	Current	New	Current	New	
132	22.9	37.46	19.4	33.39	40
400	13.1	20	13.1	18.24	40

Table 4: Fault level studies for the Mercury substation

3.7.2.2 Primary Plant Equipment

The major electrical equipment is indicated in table 9, with the main ratings as indicated in Table 5.

System Voltage (kV)	Rated normal current (A, min)	Short-circuit withstand current (kA, min)	CT Bus Zone Ratio	BIL (kV, min)	Minimum Specific creepage distance (mm/kV, min)
132	2500	40	1/1200	550	25
400	3150	40	1/1600	1425	25

Table 5: Equipment/Cable/Conductor Selection and Ratings

3.7.2.3 Busbar Design

The 400kV busbars consist of Triple Bull flexible conductor and its high strung.

The 132kV busbars consist of Twin Bull flexible conductor and its high strung.

System Voltage (kV)	Conductor Rating (A)		Conductor Type	Busbar Configuration
400	2958(@ 75 ⁰)	4059(@ 90 ⁰)	Triple Bull	Double busbar
132	1972(@ 75 ⁰)	2706(@ 90 ⁰)	Twin Bull	Double busbar

Table 6: Conductor and Tubes Selection and Ratings

3.7.2.4 Conductor Selection

The following conductors will be used as shown in table7.

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Description	Maximum Load (A)	Conductor Rating (A)		Conductor Type
132 kV Transformer Bay	2189	1972(@ 75 ⁰)	2706(@ 90 ⁰)	2 x Bull
400 kV Transformer Bay	723	1972(@ 75 ⁰)	2706(@ 90 ⁰)	2 x Bull
132kV Bus coupler	2189	1972(@ 75 ⁰)	2706(@ 90 ⁰)	2 x Bull
132kV bus section	2189	1972(@ 75 ⁰)	2706(@ 90 ⁰)	2 x Bull
400kV Bus coupler	3000	2958(@ 75 ⁰)	4059(@ 90 ⁰)	3 x Bull
400kV bus section	3000	2958(@ 75 ⁰)	4059(@ 90 ⁰)	3 x Bull

Table 7: Cable/Conductor Selection and Ratings

3.7.2.5 Electrical Clearances and Clearance Constraints

The minimum electrical clearances and working clearances applicable to the design are indicated in Table 8.

System Nominal Voltage (kV)	Minimum Electrical Clearances		Working Clearances	
	Phase to earth (mm)	Phase to Phase (mm)	Vertical (mm)	Horizontal (mm)
132	1200	1650	5700	4300
400	3200	4000	4800	3400

Table 8: Electrical clearances of the HV equipment to be used in the design.

3.7.2.6 Station DC Voltage

The station DC voltage is 220 V.

3.7.2.7 Insulator Type

Glass/porcelain type Post insulators will be used to insulate the conductors from the steel structures. Equipment insulator will be ceramic type, unless otherwise dictated by the equipment specification.

3.7.2.8 Station Construction Supply

The existing plug box shall be utilised to provide for a construction supply.

3.7.2.9 Station Auxiliary Supply

The existing station auxiliary supply will be utilised.

3.7.2.10 Yard Lighting

The existing yard lighting is adequate, and no modifications are required. This will be confirmed at the start of the final design stage.

CONTROLLED DISCLOSURE

3.7.2.11 Direct Lightning Stroke Protection

Direct Lightning Stroke Protection is already installed, and it is anticipated that no modifications are required. Direct Lightning Stroke Protection, as per [25], will be undertaken during the final design stage to ensure it meets Eskom requirements.

3.7.2.12 AC Reticulation

The AC Reticulation is detailed in the PTM&C report [29].

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3.7.2.13 Bill of Material for Major Equipment

Item No.	Equipment	Comment	Total Quantity
132 kV Yard			
1	132kV Isolator with E/S	132kV ,2500A, 40kA, M/O, 220 V DC with E/S	2
2	132kV Isolator with 0E/S	132kV ,2500A, 40kA, M/O, 220 V DC with 0E/S	1
3	132kV Isolator with 2E/S	132kV ,2500A, 40kA, M/O, 220 V DC with 1E/S	3
4	132kV Circuit Breaker	132 kV, 3150 A, 40 kA, 3PH ARC,1 Mech, 220VDC Aux, 25mm/kV	3
5	132kV Current Transformer	132 kV, 2500 A, [(2 x TPS, 2400/1, MR-P), (2 xTPS, 1200/1, F-BZ), (2 x M, 2400/1, MR-M)], 25mm/kV	9
6	132kV Earthswitch	132kV, 40kA, 25mm/kV Earthswitch	3
7	132kV Surge Arrester	132 kV, Station Class, 25 mm/kV	3
8	132kV Post Insulator	C10-550, 10 kN min, 25 mm/kV 118	TBC
9	132kV Voltage Transformer	132 kV/110V, 100/50VA, 25mm/kV	3
400 kV Yard			
10	400 kV Isolators (RH ES)	400 kV, 3150 A, (Motorised), 220 V DC, 25 mm/kV	2
11	400 kV Isolators (LH ES)	400 kV, 3150 A, (Motorised), 220 V DC, 25 mm/kV	2
12	400 kV Isolators (2 ES)	400 kV, 3150 A, (Motorised), 220 V DC, 25 mm/kV	1
13	400 kV Pantograph Isolators	400 kV, 3150 A, (Motorised), 220 V DC, 25 mm/kV	1
14	400 kV CTs	400 kV, 3150 A, 6C [(2 x TPS, 2400/1, MR-P), (2 x TPS, 1600/1, F-BZ), (2 x M, 2400/1, MR-M)],25 mm/kV	9
15	400 kV Circuit Breakers	40kV 3150A, 50kA, 3PH ARC,1 Mech, 220VDC Aux, 25mm/kV	3
16	400 kV Post Insulators	C12.5-1050, 12.5 kN min, 25 mm/kV	TBC
17	400 kV Surge Arresters	400 kV Metal Oxide Arrestor, 80 % Effectively Earthed, 25 mm/kV	3
18	500 MVA 400/132/22 kV Power Transformer	400/132/22 kV 500 MVA ONAF Auto Transformer	1
19	400kV Earthswitch	400kV, 40kA, 25mm/kV Earthswitch	3
20	22/0.4 kV Auxiliary Transformer	22/0.4 kV 500 kVA ONAN Auxiliary Transformer	1
21	22 kV Surge Arresters	22 kV Station Class, 25 mm/kV	3
22	22 kV Post Insulators	22 kV, 25 mm/kV, 6 kN	3

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Table 9: Bill of Material for Major Equipment

3.7.3 Substation Earthing

The existing earth mat/grid shall be utilised. All equipment shall be earthed at three places according to the Transmission Substation Earth Fault Application Guide (240-95773230) to cater for a maximum fault rating of 40 kA. After installation, continuity checks shall be performed to ensure the earthing connections are adequate. This shall be confirmed at final design stage.

3.7.4 External Interfaces

The Project will be required to interface with Distribution. The PTM&C contents are discussed in the PTM&C report [29].

3.7.5 Facilities Required

The following facilities required for the housing, storing, maintenance and operating of electrical equipment are exist existing:

- Control building,
- Workshop
- Consumable store
- Cladded store
- Access Control building/guard house
- Access roads and
- Fencing.

3.7.6 Maintenance Concept

The detail designs are to be developed considering that the maintenance activities as required by the Eskom Maintenance Philosophy [8] are achievable. The policy refers to a number of standard/specification documents that must be coherently adhered to in order to achieve its purpose.

Safety of personnel is of paramount importance when designing a substation. The designs cater for maintenance needs by arranging equipment such that there are sufficient working clearances, and portions of the system that can be isolated to work on. While working clearance to live metal is desirable for the safety of personnel engaged on operations or maintenance, it is not practical to ensure that such clearance exists from every position in an H.V. yard which a person might conceivably be able to occupy. Since personnel cannot be prevented from getting off the ground it is concluded that:

Working clearances shall apply at ground level only. A person stepping off the ground cannot rely on having working clearance and must take whatever other measures may be necessary to ensure his own safety.

Maintenance schedules will be conducted according to the service intervals as recommended by the original equipment manufacturers (OEM), and is the responsibility of the applicable Transmission operating unit to execute

For all the substations in this scheme, the maintenance standard: [9] shall be applied to perform maintenance.

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3.7.7 Operating Concept

The operating activities as required by the Eskom Operating Philosophy [10] shall be taken into account and achieved.

3.7.8 Safety Concept

The detail design will be developed considering the associated risks to provide an environment that is safe for people to work in, including members of the public, thus ensuring that the requirements of the Eskom Safety, Health, Environment and Quality Policy [10] are achievable. The policy refers to several standard/specification documents that must be coherently adhered to in order to achieve its purpose.

It is paramount that substations be safe for the public and for operating and maintenance personnel.

Practical approaches include the employment and training of qualified personnel, appropriate working rules, procedures, designs and correct construction. The safeguarding of equipment is also to be considered in substation design.

Personnel working standards are prescribed by regulations issued by [10]. Furthermore, all operating, and maintenance personnel should work within the rules and regulations stipulated in [12].

The designs follow the requirements of the [8] and [9]. The earthing system designs of the existing substations are, and any new earthing system designs will be,

in accordance with [16]. The objective of effective earthing of a substation is of the utmost importance in ensuring the safety of personnel and protection of equipment. This is achieved by providing a means to dissipate electric currents into the earth under normal and fault conditions without exceeding any operating/equipment limits or adversely affecting continuity of supply [16]. The earthing design constraints are to limit the touch and step voltages to within their limits. Additionally, the touch voltage must not exceed the safe mesh potential. The Grid Potential Rise is limited to 5000 V.

3.8 SITING

3.8.1 Site Selection

Mercury MTS is an existing substation.

3.8.2 Site Characteristics

3.8.2.1 Geotechnical

This site is existing and the geotech studies done to initially establish this substation terrace will be applicable.

3.8.2.2 Topographical Survey

No surveys or any additional mapping is required for this project as this site exists.

3.8.2.2 Hydrological Characteristics

The identified site is within Mercury substation and therefore hydrological characteristics are not a concern.

CONTROLLED DISCLOSURE

3.8.3 Site Layout

Mercury is located near the town of Orkney in the Freestate.

3.9 CIVIL AND STRUCTURAL DESIGN

3.9.1 General

The civil infrastructure is to be designed in accordance with the SANS standards [12], [14] and [15] during the Detail Design phase.

3.9.2 Buildings

This project does not require new building.

3.9.3 Earthworks

This project does not required earthworks.

3.9.4 Foundation, plinths and trenches

Standard foundations will be required for all new equipment steelwork. All new works will be done in accordance with the SANS standards [14] and [15].

3.9.5 Fencing

No modifications are required to the existing fencing.

3.9.6 Roads

The existing access roads are sufficient to allow for the project works to be completed, and do not require modification.

3.9.7 Structural Steel

Standard steelwork will be required, and this steel must comply with SANS standard [15].

3.9.8 Drainage

The drainage is existing at Mercury MTS. Due to the required scope of work, no modifications will be done to the existing drainage at this site.

3.10 CONTRACTING AND PROCUREMENT STRATEGY

3.10.1 Identification of Long Lead Items

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Description	Delivery time (months)
Isolators (Conventional)	6 – 9
Pantograph Isolators	6 – 9
Circuit Breakers	6 – 9
Current Transformers	6 – 9
Earth Switches	6 – 9
Capacitive Voltage Transformers	6 - 9
Voltage Transformers	6 - 9
Surge Arrestors	6 – 9
Post Insulators	6 - 9
Long Rod Insulators	6 - 9
Tubular Conductors	6 - 9
Transformers	9 -12

Table 10: Long Lead Items

For the list of long lead items containing a complete technical description and the quantity of each, refer to table [9].

3.10.2 Alternative Materials considered

Equipment will be ordered from Eskom National Contracts that will be in place at the time of ordering equipment. Where no ENC's are in place at the time of placing orders, equipment will have to be sort by following the latest applicable Treasury/Eskom Commercial processes.

Plant or equipment failures and any outages necessary to carry out maintenance can have a major impact on Eskom's performance. For this project only equipment and materials on Eskom's contracts are to be used.

The advantage of using equipment and materials that are on Eskom's contracts caters for readily available spares, as well as a guarantee that sourced equipment and materials are technically suitable for their intended application.

3.11 DESIGN ASSESSMENT

3.11.1 Operability Assessment

Double Busbar or BAH configurations have proven to be safe to operate provided that the operation is done according to the approved operating procedures. Operating risks associated with these configurations are no greater than at any other Eskom substation employing other standard configurations.

All controlling apparatus will be permanently labelled to identify the system or part of the system on the electrical machinery which it controls, and where such control apparatus is accessible from the front and back these markings shall be on both the front and the back of the label. An Operating Diagram will also be made available during commissioning of the proposed Substation and existing Line Bays to assist with operating the station.

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3.11.2 Reliability, Maintainability, Availability Assessment

The substation is designed on the n-1 contingency philosophy in accordance with the requirements of the Grid Code [7]. The topologies of substation in this project, viz. double busbar possess proven reliability, as detailed in [4].

3.11.3 Procurability Assessment

All the primary plant equipment (e.g., Isolators, Circuit Breakers, Current Transformers, Earth Switches, Post Insulators, Long Rod Insulators, Capacitive Voltage Transformers, Voltage Transformers, Surge Arrestors, Bull Conductor, Clamps and Hardware etc.), required to construct the extension will be procured from ENC's that will be in place at the time these projects go into execution.

Tubular Conductors and Clamps will be procured by going out on tender during the execution phase.

All equipment support steel and caps as well as all earthing and earthing accessories will be procured by the appointed Civil Contractor.

3.11.4 Constructability Assessment

The high-level construction sequence at Mercury MTS will be as follows:

The scope of work for construction includes the following:

- Site establishment
- Demarcation of the construction area and control of access to the live yard
- Set out foundation areas and excavate foundations
- Prepare and place reinforcing steel and holding down bolts
- Cast concrete and manage concrete curing
- Backfill around foundations and compact
- Assemble and erect steel structures and earth
- Install primary plant equipment and earth
- Install junction boxes
- Install panels in control room and install all wiring between primary plant equipment, junction boxes and new and existing panels in control room
- Perform cabling, stringing and bonding, excluding stringers to busbars and jumpers to the overhead line
- Perform cold commissioning (pre-commissioning) of primary plant, including setting of isolators, etc
- Test and commission PTM&C equipment
- Through intermittent outages on the busbars, install busbars clamps to existing busbars and stringers to the busbars
- Clear and vacate site

3.11.5 Inspectability and Testability Assessment

These designs will be done such that there is provision for inspection and testing of the equipment.

After isolating the appropriate circuits or parts thereof, all associated tests can then also be carried out on the required equipment on site.

3.11.6 Expandability Assessment

The expandability of Mercury MTS has been considered by the provision of future and spare bays for feeders and transformers etc. as shown in the proposed Station Electric Diagram found in figure 5.

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3.11.7 Technology Assessment

The technology of the equipment currently being considered as part of this design is based on the currently approved specifications of the equipment that is currently available on ENC. During execution the technology of the equipment that is to be considered will be based on the approved equipment specifications approved at the time equipment as well as the equipment that would be approved as part of the Eskom National contracts at the time of procurement.

As far as practicable, the designs of the proposed works will ensure that no failure leads to life threatening situations for any person or to unacceptable damage to the environment or the installation.

A Safety assessment is aimed at ensuring that a safe, practicable concept design is carried forward to more detailed design. The safety assessment is based on adhering to safety rules as specified in Section 5-1 of the Substation Layout Design Guide [4]. The safety considerations are inherent in the design layout.

The more common dangers include electric shocks, arc-flash incidents, and transformer explosions. Following the design guide as specified in the Substation Layout Design Guide [4] mitigates the dangers.

Only standard and proven equipment are envisaged to be utilised during the execution of the applicable scope of work at this substation. The equipment will be supplied off Eskom National Contracts in place at the time of procurement and execution or where ENC's do not exist; Commercial will procure the required Primary Plant equipment by going out on tender with the existing HV Plant Specifications and associated Tender Technical Strategies.

3.11.8 Design Simplification

This will be based on the design parameters as per the User Requirement Specification [2]. Also applicable is the Substation Layout Design Guide [4] which serves two main objectives. The first objective is to assemble into one manual (or set of manuals) as much basic design data as possible and the second objective is to introduce a measure of Standardisation. During the Concept and Detail stages of the project, multidisciplinary design review sessions are to be held with the various stakeholders to ensure that the objectives of the project are met, and all stakeholders are satisfied that the best and correct design is delivered. Refer to Eskom Group Technology Engineering Design Review procedure [24] for further details regarding this process. All relevant COE's within the project perform their departmental internal reviews. This procedure is applicable to this project in its entirety.

3.11.9 Value Engineering Procedure

Only standard and proven equipment is envisaged to be utilised in this design. The equipment will be supplied off Eskom National Contracts.

In the construction industry, value engineering, value analysis and value management are all titles used to describe a structured process to examine the function of infrastructure to ensure that it is delivered in the most cost-effective way.

The value engineering was achieved through following the design approach detailed in section 3.3 of this report and following the design review procedure [24]. The analysis of the design involves subjecting the design proposal to systematic review during the concept design stage to ensure that the concept design meets user requirements, without over-specification.

3.11.10 Dismantling and Demolition Requirements

None.

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3.12 SAFETY ASSESSMENT

3.12.1 Industrial Safety Assessment

A Safety assessment is aimed at ensuring that a safe, practicable concept design is carried forward to detailed design. The safety assessment is based on adhering to safety rules as specified in the Substation Layout Design Guide [3].

As far as practicable, the designs at Perseus Substation, ensure that no failure will lead to life threatening situations for any person or to unacceptable damage to the environment or the installation.

The safety considerations are inherent in the design layout.

The more common dangers include electric shocks, arc-flash incidents, and transformer explosions. Following the design guide as specified in the Substation Layout Design Guide [3] mitigates the aforementioned dangers.

3.12.2 Fire Safety Assessment

Sufficient space between equipment is catered for to prevent fires from spreading to other equipment.

Fire Safety assessments will be performed during the detail design phase.

3.12.3 Environmental Assessment

An Environmental Authorization and Environmental Impact Assessment will not be required for the scope of work that will be taking place, since Mercury MTS is an existing substation. An EMP will however be required for the scope of work that is to be carried out and will be compiled during the execution design phase.

3.13 SECURITY DESIGN

The security/anti-terrorism enhancements are based on the standards developed by Corporate Risk. During construction, access will be limited to site construction and Eskom staff only, that will be controlled by site security as appointed by Eskom.

The fencing system design includes the inner and outer barrier fence, a non-lethal electric fence between the inner and outer barrier fence and will have an alarm installed on it.

3.14 TESTING AND COMMISSIONING

Testing and commissioning will be done according to relevant standards and procedures, and these are captured in the PTM&C design report.

3.15 PLAN OF IMPLEMENTATION

3.15.1 Project Outage Requirements

An outage on both the 132kV and 400kV busbars and will be required.

3.15.2 Transportation Plan

The existing access roads will be utilised for the transportation of equipment to site.

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3.15.3 Construction Plan

This is contained in the constructability assessment in Section 3.11.4.

3.16 RISK ASSESSMENT

A risk register has not been developed for this project yet. One is to be developed by the project manager responsible for construction. No major constructability risks are foreseen at this stage of the project.

The worst-case failure mode would be a circuit breaker stuck pole in a bus coupler or bus section where the removal of two zones of busbar can occur. Occurrence of such faults are however rare and have a very low probability of happening.

Single contingency failures which have a relatively higher probability of occurring are designed for in accordance with the [9] by having a sectionalised double busbar arrangement where circuits are spread evenly over the zones of the busbar.

The double busbar arrangement is widely used in the Eskom systems from 22kV up to 765kV. It is well known by designers, operators, and National Control. Operating risks at the substations concerned will therefore be no greater than at any other Eskom substation employing the same busbar configuration.

Designers are well versed with the busbar arrangement and the design principles associated with it, so design risks are at a minimum. These design principles are well documented in the [6].

3.17 ENGINEERING COST ESTIMATION

No engineering cost estimation was done for the project except for Substation Engineering Concept Design fees.

3.18 LESSONS LEARNED

Nothing to report at this stage.

4. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
Subhas Maharaj	Senior Manager – Substation Engineering
Andile Maneli	Middle Manager (Civil) - Substation Engineering

5. REVISIONS

Date	Rev.	Compiler	Remarks
March 2023	01	Rukesh Ramnarain	First issue

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Abdullah Kaka

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7. ACKNOWLEDGEMENTS

None.

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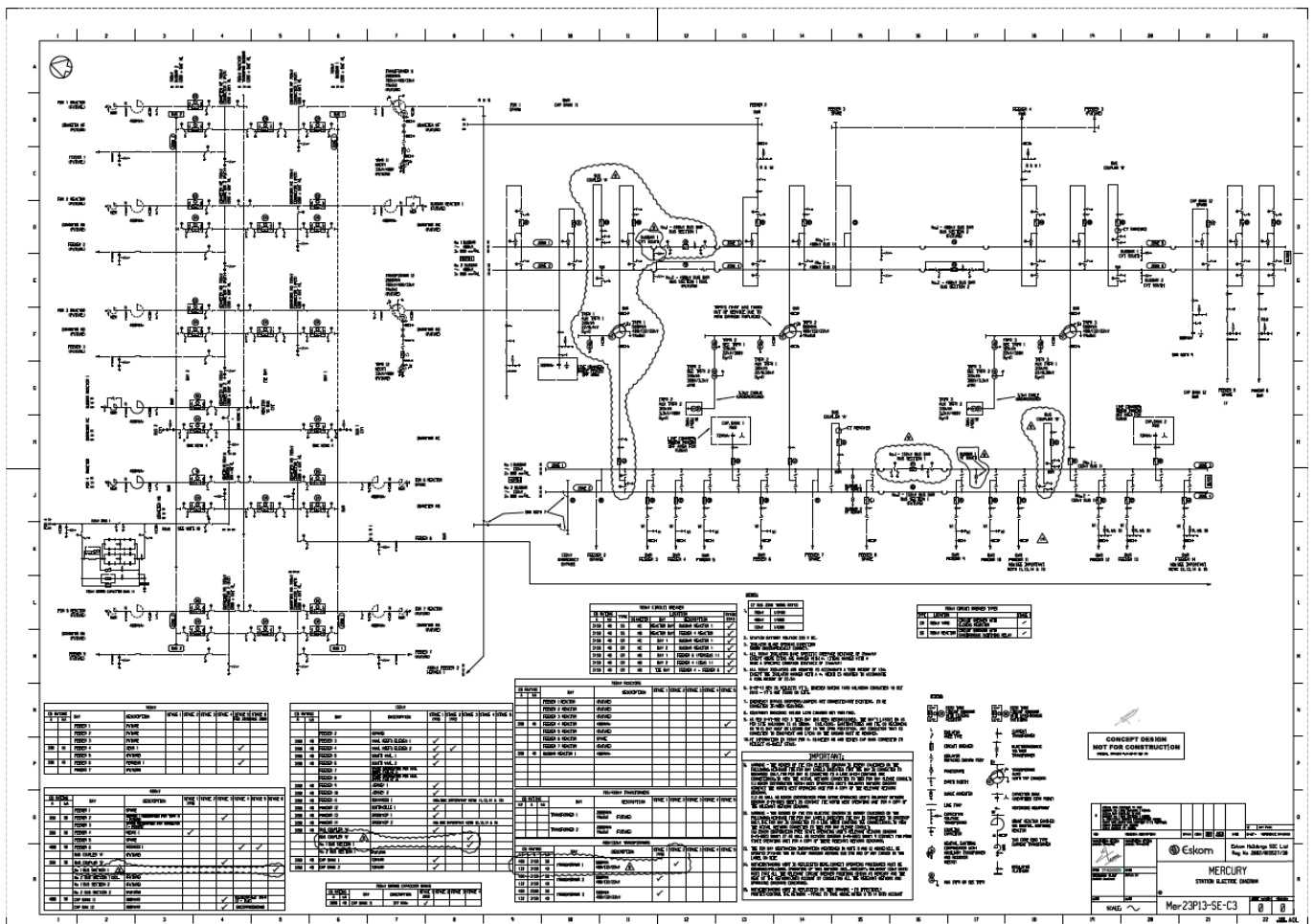
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APPENDIX A: CONCEPT DESIGN OUTPUT DOCUMENTS

Document Number	Rev.	Document Title	Remarks
Mer23P13-SE-C12	01	Substation Concept Design Report	First issue
Mer23P13-SE-C3	00	Station Electric Diagram	First issue
Mer23P13-SE-C4	00	Key Plan	First issue

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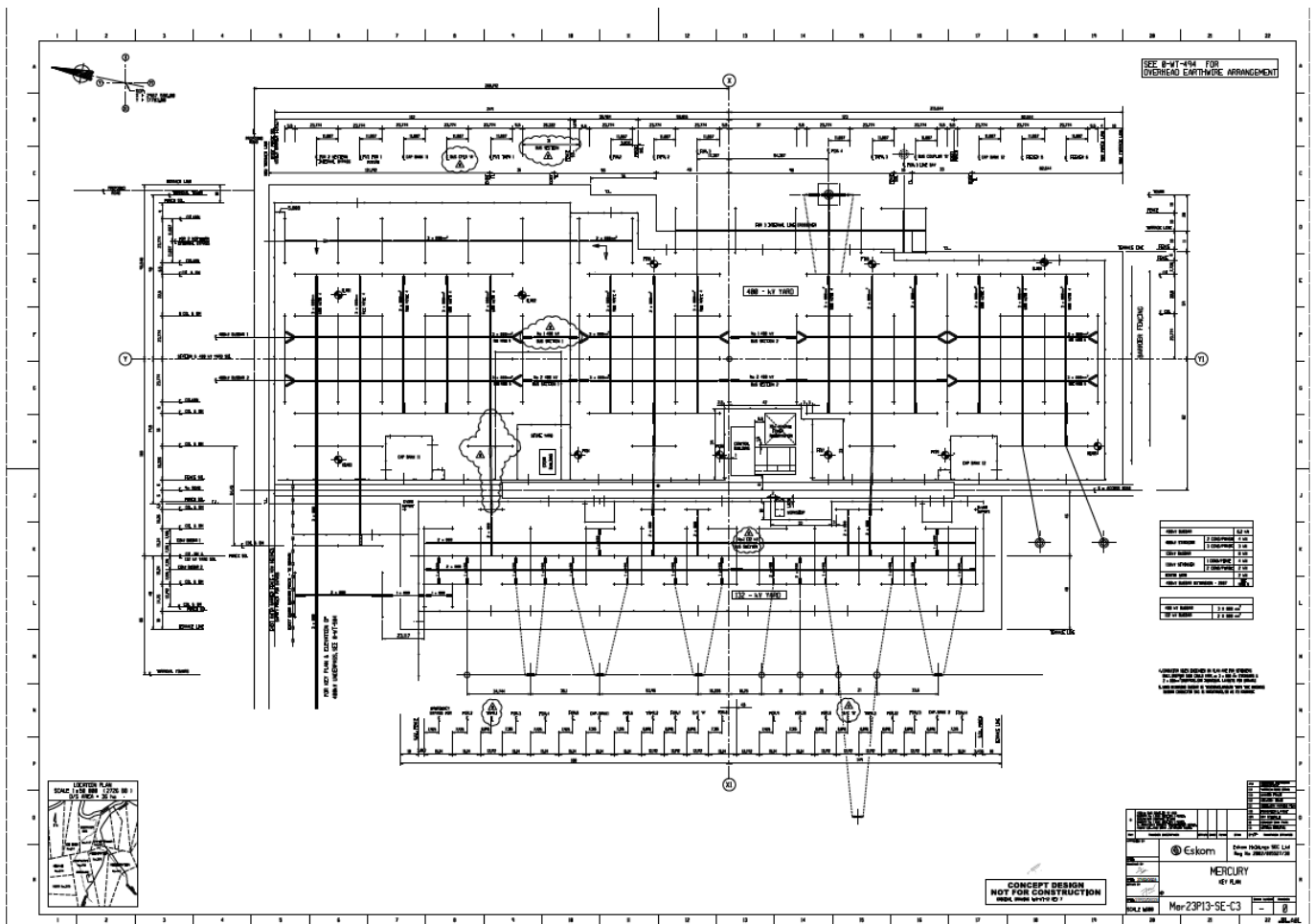
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Station Electric Diagram

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Key Plan

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