Eskom	Report	Technology

Title:	**Expedited IPP Program - Mercury 3rd 400/132 kV transformer - Basic Design Report with Scope of Work**	Unique Identifier:	**Mer23P13-SE-C16**
		Alternative Reference Number:	**N/A**
		Area of Applicability:	**Engineering**
		Documentation Type:	**Report**
		Revision:	**1**
		Total Pages:	**31**
		Next Review Date:	**N/A**
		Disclosure Classification:	**CONTROLLED DISCLOSURE**

Compiled by	**Functional Responsibility**	**Authorised by**
………………………………	………………………………	………………………………
R Ramnarain	**C Thomas**	**N Pompi**
Chief Engineer (Electrical)	**Senior Engineer (Electrical)**	**Middle Manager (Substation Engineering)**
Date: 10/01/2024	Date: 10/01/2024	Date: 11/01/2023

Co-compiled by	**Functional Responsibility**
……… p.p Andile.Maneli……	………………………………
S Duma	**A Maneli**
Engineer (Civil)	**Middle Manager (Civil)**
Date: 11 - 01 - 2024	Date: 11 - 01 - 2024

PCM Reference: **Perform Substation Engineering**
SCOT Study Committee Number/Name: **Substation**

CONTENTS

1. INTRODUCTION

The Expedited IPP Program - Mercury 3rd 400/132 kV transformer Project has been selected to follow the Eskom EPC implementation strategy.

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.
- Equip 400kV Busbar 1A CVT.
- Remove 1 set of CT's from 400kV bus coupler B.
- Install 1 x 400/132/22 kV 500MVA Transformer.
- Install 1 x 22/0,4kV 315kVA Auxiliary Transformer
- Equip 132kV transformer bay.
- Equip the 132kV bus coupler B.
- Equip the busbar number 1, 132kV bus section 1.
- Equip 132kV busbar 1B VT.
- Remove 1 set of CT's from 132kV bus coupler A.

This document specifies Eskom's requirements and provides direction to the EPC Contractor on the specific design outcomes required for the detail design phase. It includes:

- Project scope of work,
- The EPC Consultant's scope of work,
- Design Requirements for the scope of work,
- Eskom design review / acceptance processes and requirements, and
- Design Output deliverables to be produced by the EPC Contractor.

This document only covers the scope, requirements, and deliverables as it relates to substation site infrastructure, buildings, yard and primary plant equipment.

1.1 SYSTEM IDENTIFICATION

The project for the Mercury 3rd 400/132 kV transformer Project is provisionally identified by the Station Electric Diagram (SED) Mer23P13-SE-C3 Revision 0 and Key Plan Mer23P13-SE-C4 Revision 0 (Appendix A).

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.

2. DESIGN PROJECT

2.1 SCOPE OF WORK

This scope of the project is to install the third 400/132kV Transformer at Mercury MTS in the Eskom Transmission Grid and comprises:

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.
- Install 1 x 22/0,4kV 315kVA Auxiliary Transformer
- Equip 132kV transformer bay.
- Equip the 132kV bus coupler B.
- Equip the busbar number 1, 132kV bus section 1.
- Equip 132kV busbar 1B VT.
- Remove 1 set of CT's from 132kV bus coupler A.

2.2 ROLES AND RESPONSIBILITIES

2.2.1 The EPC Consultant

The EPC Consultant is required to perform the detail design of the Mercury 3rd 400/132 kV transformer Project which entails the scope of work as indicated in Section 2.1 above and to capture all information pertaining to the design in the detail design report (Appendix E), detail design presentation (Appendix E), as well as in the relevant design drawings.

The EPC Consultant is further required to present the detail design presentation to the Substation Engineering and Transmission Design Review Team (DRT) committee meetings for design review, as well as to prepare and issue the full detail design package to Eskom, at the following milestones:

- Twenty-Five (25) working days prior to the Substation Engineering DRT meeting at which the EPC consultant wishes to present the project. All civil designs must be presented to the Civil DRT at least seven (7) working days prior to the presentation at the Substation Engineering DRT,
- An updated design package at least ten (10) working days prior to the Substation Engineering DRT meeting at which the EPC consultant wishes to present the project, with all queries addressed and all corrections completed,
- After addressing and resolving any additional requirements/clarifications/amendments requested by the Substation DRT chairperson/committee during the deliberation for support at the Substation Engineering DRT, but still prior to the Transmission DRT meeting, and
- Within twenty-five (25) working days after the detail design acceptance of the project at the Transmission DRT meeting, after addressing and resolving any additional requirements/clarifications/amendments requested by the Transmission DRT chairperson.

The full detail design package components are detailed in Section 4.2.3 further below.

The EPC Consultant is also required to submit the following to Eskom Transmission:

- Construction Package, including a Bill of Equipment (BoE) and Bill of Material (BoM), once the detailed designs are verified/validated with the equipment that has been sourced for the project,
- Revisions of affected drawings as and when new construction drawings are issued to the construction site on an ad hoc basis,

- As-Built Drawings, reflecting final construction details, upon completion of the project and within a timeframe as stipulated by Eskom Transmission, not exceeding four weeks after completion,
- Completed Quality, Inspection and Test Plans (QITP's) with supporting evidence (e.g. photos, test results etc.), and
- Operating Diagram to enable commissioning of the project.

Any deviation from the accepted design, must be submitted to Eskom for review and support, prior to executing the deviation.

All aspects of responsibility, accountability and liability lies with the EPC Consultant for the engineering, design, construction and construction safety, operational safety, and commissioning, of the project.

2.2.2 Eskom

Eskom's role is to receive and accept or reject the detail design of the Mercury 3rd 400/132 kV transformer Project as performed by the EPC Consultant.

Receiving the design will refer to the transmittal of the design package from the EPC Consultant to the Eskom Project Manager, thereafter to Integration Engineering and further to the individual COE's.

Accepting the design will refer to the final acceptance of the project design package by the Transmission DRT, subsequent to the EPC consultant receiving provisional support from all the relevant Centre of Excellence (CoE's) i.e. Substation Engineering, Lines Engineering and PTMC (Protection, Telecommunications, Metering and Control) via the CoE DRT committee meetings.

3. SUPPORTING CLAUSES

3.1 NORMATIVE / INFORMATIVE REFERENCES

3.1.1 Normative

[1] South African Grid Code

[2] Occupational Health and Safety Act (OHS Act) 85 of 1993

[3] Occupational Health and Safety Act No. 85, 1993 – Construction Regulations 2014

[4] 240-43008621, Eskom Generation and Wires Operating policy

[5] 240-114967625, Operating Regulations for High Voltage Systems

[6] 240-57130114, Standard for Implementation of Substation Layouts for Transmission Substations

[7] 240-68972170, Standard for Independent Power Producers Connections at Main Transmission Substations

[8] IEEE STD 80, IEEE Guide for Safety in AC Substation Grounding

[9] 240-96393507, Soil Resistivity Testing for Substation Applications

[10] 240-101940513, Earth Electrode Resistance Measurement standard

[11] 240-95773230, The Transmission Substation Earth Fault Application Guide

[12] 240-134369472, Substation Earth Grid Design Standard

[13] 240-139282493, Copper Conductors Used for Earthing in Substations (standard)

[14] 240-170000349, Copper -Clad Steel Conductor used for Earthing

[15] 240-109589380, Direct Lightning Stroke Protection of Substations

[16] 240-68973110, Specification for power transformers rated for 1.25MVA and above

[17] 240-57648800, New Oil Filled Auxiliary Transformers Rated 1 MVA and Below and 33kV And Below

[18] 240-68970990, Standard for Auxiliary Transformers for Main Transmission Substations

[19] 240-116206790, Standard for Tertiary Bay Requirements when Power Transformers are used to Supply Station Auxiliary Loads and Rural Supplies

[20] 240-65063756, Specification for outdoor circuit breakers for systems with nominal voltages from 6.6kV up-to and including 765kV standard

[21] 240-56063815, Specification for high voltage outdoor disconnectors and earthing switches standard

[22] 240-56062864, Current transformers Eskom specific requirements for voltages up to 132kV in accordance with NRS 029 standard

[23] 240-170000559, Eskom Standard for Top Core Current Transformers rated from 132kV up to 765kV.

[24] 240-56062765, Inductive Voltage transformers Eskom specific requirements up to 132kV in accordance with NRS 030 standard

[25] 240-56030645, Eskom Standard for Capacitive Voltage Transformers.

[26] 240-75540566, Specification for station class metal oxide surge arresters

[27] 240-56030435, Specification for outdoor ceramic post insulators for systems with nominal voltages up to 765kV standard

[28] 240-75883174, Outdoor post and long rod insulators for new and refurbished powerline up-to and including 33kV

[29] 240-77125772, Specification for Polymeric Longrod Insulators for AC Transmission Voltages of 220kV and Above

[30] 240-75883896, Outdoor Post and Long Rod Insulators for New and refurbished Powerlines for 66kV and 132kV Standard

[31] 240-77125760, Glass cap and pin insulator for Eskom transmission HVAC

[32] 240-60777474, Specification for Suspension and Strain Assemblies and for Hardware for Transmission Lines

[33] 240-56063792, Specification for Medium Voltage XLPE And Impregnated Paper Insulated Cables Standard

[34] 240-56063710, Medium Voltage Cabling in Substations

[35] 240-56063805, LV Power and Control Cable with Rated Voltage Standard 600/1000V

[36] 240-56030637, General Information and Requirements for Low-Voltage Cable Systems Standard

[37] 240-56030640, General Information and Requirements standard for AC High-Voltage, AC Extra High-Voltage and DC Cable systems

[38] 240-56030625, Specification for XLPE Insulated Power cables and Accessories for systems with Nominal Voltages of 44kV TO 132kV

[39] 240-53113927, Specification for Substation Clamps for Stranded Aluminium Conductors

[40] 240-83534936, Specification for Substation Clamps – Additional for Tubular and Stranded Conductor Clamps

[41] 240-152844641, Phase Conductor Standard for Eskom Overhead Line

[42] 240-120804300, Standard for the Labelling of Electrical Equipment within Eskom Wires Networks

[43] 240-75660336, The Standard for Design, Manufacturing, and Installation of Eskom Wires Business Equipment Labels

[44] 240-132747382, Safety Signs in Transmission Substation Buildings

[45] 240-83563472, Drawing Standard for Substations: Power Plant

[46] 240-68972308, Standard Procedure for Single Line Diagram Development

[47] 240-68972746, Standard Information Required for the Production of Substation Drawings

[48] SANS 1200, Standardized Specification for Civil Engineering Construction

[49] SANS 10400, The application of the National Building Regulations

[50] SANS 204, Energy efficiency in buildings

[51] SANS10400-XA-2021, Energy Usage in Buildings

[52] 240-83382076, Standard for operational floodlighting in substations

[53] 240-82172806, Standard for Air Conditioning in Tx Substation Buildings and Telecom Sites

[54] 240-100183119, Standard for the Substation HV Yard Fences

[55] 240-76368574, High Security Mesh Fencing

[56] 240-101811486, Standard for Crusher Plant

[57] 240-94743192, Standard for Fabrication Steelwork used in Eskom Transmission Substations

[58] 240-108982466, Standard for HV Yard Stones in Eskom Substations

[59] 240-153000199, Substation Drainage

[60] 240-56177186, Battery room standard

[61] 240-85067224, Substation Platform and Access Road Design Standard

[62] 240-170000153, Security Lighting for Eskom Applications

[63] 240-57127953, Execution of Site Preparation and Earthworks Standard

[64] TCP 41-141, Inspection Sheets for Substation Equipment to be taken over by the Asset Owner

[65] 240-97364498, The Design philosophy for 132kV strung flexible stranded conductor busbar yards

[66] 240-95242258, The Design philosophy for 400kV strung flexible stranded conductor busbar yards

[67] 240-85524358, Standard for Determining Busbar Conductor Short-Circuit Forces and Phase Conductor Displacement in Outdoor Substations

[68] 240-85524376, Standard for Determining Dropper Conductor Short-Circuit Forces on Equipment in Outdoor Substations

[69] 240-68972408, Standard for Flexible and Tubular Conductor Heights and Phase Spacing

[70] 240-68972898, Standard for the Choice of Single and Three Mechanism Circuit-Breakers

[71] 240-75908051, Application of Bus Couplers and Transfer Bus Couplers at Eskom Main Transmission Substations

[72] 240-75305807, Application of AIS and GIS Switchgear at Eskom Main Transmission Substations

[73] 240-68971742, Standard for Corona Studies

[74] 240-68971854, Standard for Power Frequency Electric and Magnetic Analysis in Substations

[75] 240-53113685, Design Review Procedure

[76] 240-606480018, Terms of reference for Design Review Teams Presiding over Transmission and Distribution Infrastructure Designs in Eskom

[77] 240-59083220, Substation DRT requirements additional to the DRT ToR applicable for 2021/22

[78] 240-55151946, AC Reticulation Philosophy for Substations

[79] SANS 10161, The design of foundation for buildings.

[80] SANS 10100-1, The structural use of concrete (specifically Part 1: Design)

[81] SANS 10162, The structural use of steel

[82] SANS 10163, The structural use of timber

[83] SANS 10164, The structural use of masonry

[84] SANS 10114 lighting for interiors part 1 and 2

[85] SANS 10142 The wiring of premises – Part 1: Low-voltage installations

[86] SANS 10108 The classification of hazardous locations and the selection of equipment for use in such locations

[87] SANS 10186 The installation, inspection and maintenance of equipment used in explosive atmospheres

[88] TST41-224, Passive Fire Protection for Oil Filled Equipment in High Voltage Yards

[89] 240-50807380, Specification for Gas Insulated Switchgear (GIS) and associated auxiliary Equipment

[90] Detailed Design DRT Presentation Template

[91] 240-140073760, Detailed Design report Template

[92] SANS 1936, Development of dolomite land

[93] SANS 16160, Basis of structural design and actions for buildings and industrial structures

[94] 240-103414344, Eskom Corporate Identity

[95] 240-56737448 Fire Detection and Life Safety Design Standard

[96] 240-94743194, Specification for the Erection of Steelwork used in Eskom Tx and Dx

[97] 240-84854974, Continuity Measurement of Substation Earth Grid Systems

[98] 240-82736997, Stringing, Earthing, and Erection Specification for Transmission Substations

[99] 240-171000164, Technical Tender Evaluation Criteria for Substation Civil works

[100] 240-171000165, Technical Evaluation Standard For Stringing , Earthing and Erection at Transmission Substations

[101] 240-171000161, Technical Evaluation Standard for Substation Stranded Conductor Clamps - EPC Contracting

[102] The Geotechnical Division of SAICE – Site Investigation Code of Practice

[103] Guidelines for Human Settlement Planning and Design Volume 1

[104] Guidelines for Human Settlement Planning and Design Volume 2

[105] SANS 2001 Series, Construction Standards

[106] SANS 10249:2012, Masonry Walling

[107] SANS 10145:2013, Concrete Masonry Construction

[108] BS 8215:2013, Design and Installation of Damp-Proof Courses in Masonry Construction

[109] SANS 10100-2, The structural use of concrete (specifically Part 2: Materials and Execution of Work)

[110] IEC 60865-1, Short Circuit Currents – Calculation of Effects

[111] Cigre 214, The Mechanical Effects of Short-Circuit Currents in Open Air Substation

[112] Eurocode 3, Design of Steel Structures

[113] PAN22P01-SE-02, Geotechnical/ Dolomitic Stability Investigations Scope & Specification

[114] 240-84418186, Roads Specification Manual

[115] 240-180000668, Guideline on how Contractors can select material to use to build the Substations or Infrastructure on the Self-build or Turnkey

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

[117] Replace With New 132 kV Circuit-Breakers Rated For 50 kA and Above at The Substations with Fault-Levels 30 kA And Above (240-148617190)

[118] Engineering Instruction to Install Pantographs On 132 kV and 88 kV Busbar Selection Upon Design Layout Requiring Inline Arrangement (240-180000653)

[119] Install Surge Capacitors On 88 kV and 132 kV Feeder Bays to Mitigate Overstress of CB's by Switching Transients upon Permanent Faults (Sustained Faults) (240-180000036)

[120] Guideline On How Contractors Can Choose Material to Use to Build the Substations or Infrastructure on The Self-Build or Turnkey (240-180000668)

[121] Transmission: Substation Engineering: Primary Plant: Functional Parameters (240-170001073)

[122] Transmission Standard Electrical Package

[123] Transmission Standard Civil Package

3.1.2 Informative

[124] 32-1205, Eskom Maintenance Management Policy

[125] 32-727, Eskom Safety, Health, Environment and Quality policy

[126] 240-146353995, Substation and Facility Maintenance

[127] 240-77297024, Standard for Operating Diagrams for Eskom

[128] 240-68971972, Standard for Stranded Flexible Conductor Selection

[129] 240-100176272, Determination of conductor rating in Eskom

[130] 240-100907733, Guideline for the Application of Stranded Flexible Conductor Versus Round Tubular Conductors in Substation Design

[131] 240-97758043, Short Circuit Capability of Substation Portal Structures from 6.6kV to 765kV

[132] 240-55921217, Substation Engineering Product Realisation Work Instruction

[133] 240-56063877, RTV Silicone Rubber Insulator Coating and Shed Extender Applications Standard

[134] 240-56062705, RTV Silicone Rubber Insulator Coating and Shed Extender Supplier Specification

[135] 240-180000653, Engineering Instruction to install pantographs on 132kV and 88kV busbar selection upon design layouts requiring inline arrangements

[136] 240-148617190, Replace with New 132 kV Circuit-breakers rated for 50kA and above at the Substations with fault Levels 30kA and above

[137] 240-180000036, Install Surge Capacitors on 88kV and 132kV Feeder bays to Mitigate overstress of CB's by switching Transients upon permanent faults (sustained faults)

[138] IEC 60071, Insulation Co-ordination

[139] IEC 60815, Selection and Dimensioning of High-Voltage Insulators Intended for Use in Polluted Conditions

[140] SANS 60060-1

[141] Stringing Conductor and Clamp Installation Quality Inspection Plan - Guideline

[142] Earthing Quality Inspection and Test Plan – Guideline

[143] Scoring - Stringing earthing and erection Technical Evaluation criteria – Scoring

[144] Scoring – Substation Civil Works at Substations

[145] 240-128559117, Method Statements for Eskom Transmission substations – Stringing, Erection and earthing.

[146] 240-170001074, Civil design file calculations

3.2 DEFINITIONS

3.2.1 Classification

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

3.3 ABBREVIATIONS

Abbreviation	Description
BoE	Bill of Equipment
BoM	Bill of Material
CLN	Customer Load Network
CoE	Centre of Excellence
DRT	Design Review Team
EIA	Environmental Impact Assessment
EPC	Engineer, Procure and Construct
GPR	Grid Potential Rise
MTS	Main Transmission Substation
PI	Post Insulator
PTMC	Protection, Telecommunication, Metering and Control
QITP	Quality, Inspection and Test Plan

RE	Renewable Energy
SLDG	Substation Layout Design Guideline
TPD	Transmission Project Delivery
URS	User Requirement Specification

Table 1: List of Abbreviations

4. DESIGN REQUIREMENTS

4.1 SCOPE OF DETAIL DESIGN

4.1.1 Scope of Work

The scope of work for Mercury 3rd 400/132 kV transformer Project includes the following (Refer to the SED and Key Plan included in Appendix A):

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

4.2 DESIGN APPROACH

The EPC consultant shall be provided with the relevant concept design outputs which is to be used as design inputs for the detail design phase, to culminate in the detail design deliverables.

A guideline on the high-level substation engineering design process to be followed, for this project specifically, is provided below in 4.2.2.

4.2.1 Design Inputs

A basic design as indicated herein and:

- Station Electric Diagram (Appendix A), and
- Key Plan Drawing (Appendix A)

must be used as inputs by the EPC Consultant for the detail design development.

4.2.2 Design Process

Since Mercury MTS is an existing MTS, with an existing busbar and terrace at the position where the 3rd transformer is required, the standard practice is to use the existing transformer bays (400kV, 132kV and

22kV) as a reference and to update it with the latest applicable specifications and standards, as well as with the latest HV Equipment as per the Primary Plant Selection Guideline [23], and current standard steelwork and foundation design base [26].

The original Mercury MTS design allocated a specific bay for the spare third transformer. The existing design base for Mercury MTS is provided in Appendix B. The expected design changes to the design base are discussed in further sections.

4.2.3 Design Outputs

The detail design package comprises specific design outputs for the detail design of this project and shall include but are not limited to:

- Substation Engineering Detail Design Report including specialised studies
- Substation Engineering Detail Design Presentation
- Station Electric Diagram
- Key Plan Drawing
- Foundation and Trench Drawing
- Earthmat Layout Drawing
- Steelwork Marking Plan
- Overhead Earthwire Drawing
- Bay Layout Schedule
    - 400 kV Transformer 1 Bay
    - 132 kV Transformer 1 Bay
    - 22 kV Transformer 1 Tertiary Bay
    - 400 kV Transformer 1 Earthing Bay
    - 132 kV Transformer 1 Earthing Bay
    - 400 kV Transformer 1 Plinth Earthing Bay
    - 22 kV Transformer 1 Tertiary Earthing Bay
    - 400kV bus coupler A Bay
    - 400kV bus coupler A Earthing Bay
    - 400kV busbar 1 bus section Bay
    - 400kV busbar 1 bus section Earthing Bay
    - 400kV busbar 1A CVT bay
    - 400kV busbar 1A CVT Earthing Bay
    - 400kV bus coupler B Bay
    - 400kV bus coupler B Earthing Bay
    - 132kV bus coupler B Bay
    - 132kV bus coupler B Earthing Bay
    - 132kVbusbar 1 bus section Bay
    - 132kVbusbar 1 bus section Earthing Bay
    - 132kV busbar 1B VT Bay
    - 132kV busbar 1B VT Earthing Bay
    - 132kV bus coupler A Bay
    - 132kV bus coupler A Earthing Bay

- Detailed Bill of Equipment (BoE) and Bill of Materials (BoM),

All drawings, reports and presentations are to be provided in its original format (MS Word, MS Excel, MicroStation), as well as in Adobe (pdf) format. Simulation models, that may be referenced in the reports, must also be provided in its original format (e.g.CDEG's, RELUX).

All design reports and drawings may only be signed by engineers and technologists registered with and/or recognised by the Engineering Council of South Africa (ECSA) as competent signatories.

Draughtspeople must be registered with and/or recognised by the South African Institute for Draughting (SAID) and/or equivalent international bodies recognised by the SAID to perform such work in the RSA. Membership numbers must be indicated on all sign-offs.

The project has been assigned a unique identifier number, Mer23P13, and all deliverables are to be identified according to the Substation Engineering Document Issue Checklist for this project (Appendix E).

Upon completion of the project and finalisation of the As-Built Drawings, the drawing numbers (using unique identifier numbers) are to be reverted to the original drawing numbers as per the original design base (Appendix B), or with numbers as provided by Eskom (as will be the case for new drawings).

4.2.4 Design Verification

The outputs shall undergo a peer review within the Substation Engineering Centre of Excellence, prior to presentation at Substation Engineering DRT and Transmission DRT.

Some of the aspects considered during the design review are:

- Compliance of design to stakeholder (user, regulatory, statutory, environmental) requirements.
- Compliance of designs to design standards, philosophies, practices and codes.
- Demonstration of sound engineering thinking where a unique solution has to be provided (design approach, rationale, assumptions, modelling, calculations, simulations).
- 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 also 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 that are to be referred back from DRT.

It is important to note that the above-mentioned assurances were obtained at a level commensurate with the design level completed. It is incumbent upon the EPC Consultant to review the design for the aspects indicated above and ensure that all requirements are met prior to presenting at the Substation DRT committee meeting.

4.3 DESIGN CRITERIA

Detail designs for Mercury Substation 3rd 400/132kV 500MVA Transformer are to be performed in accordance with the guidelines, criteria and general rules that are outlined in the Transmission Substation Engineering Functional Design Parameters [24]. All designs are to be performed using Eskom approved products.

4.3.1 Codes and Standards

Designs are governed by South African Grid Code [1] and are additionally required to be in compliance with the Occupational Health and Safety Act [2], and any other relevant legislation.

4.4 DESIGN BASIS

The concept design approved at Substation and Transmission DRT is as follows:

- Equip Transformer 1 bay in the allocated position. See Figure 1 below for the Approved Station Electric Diagram (SED) and Figure 2 for the Approved Key Plan Drawing.

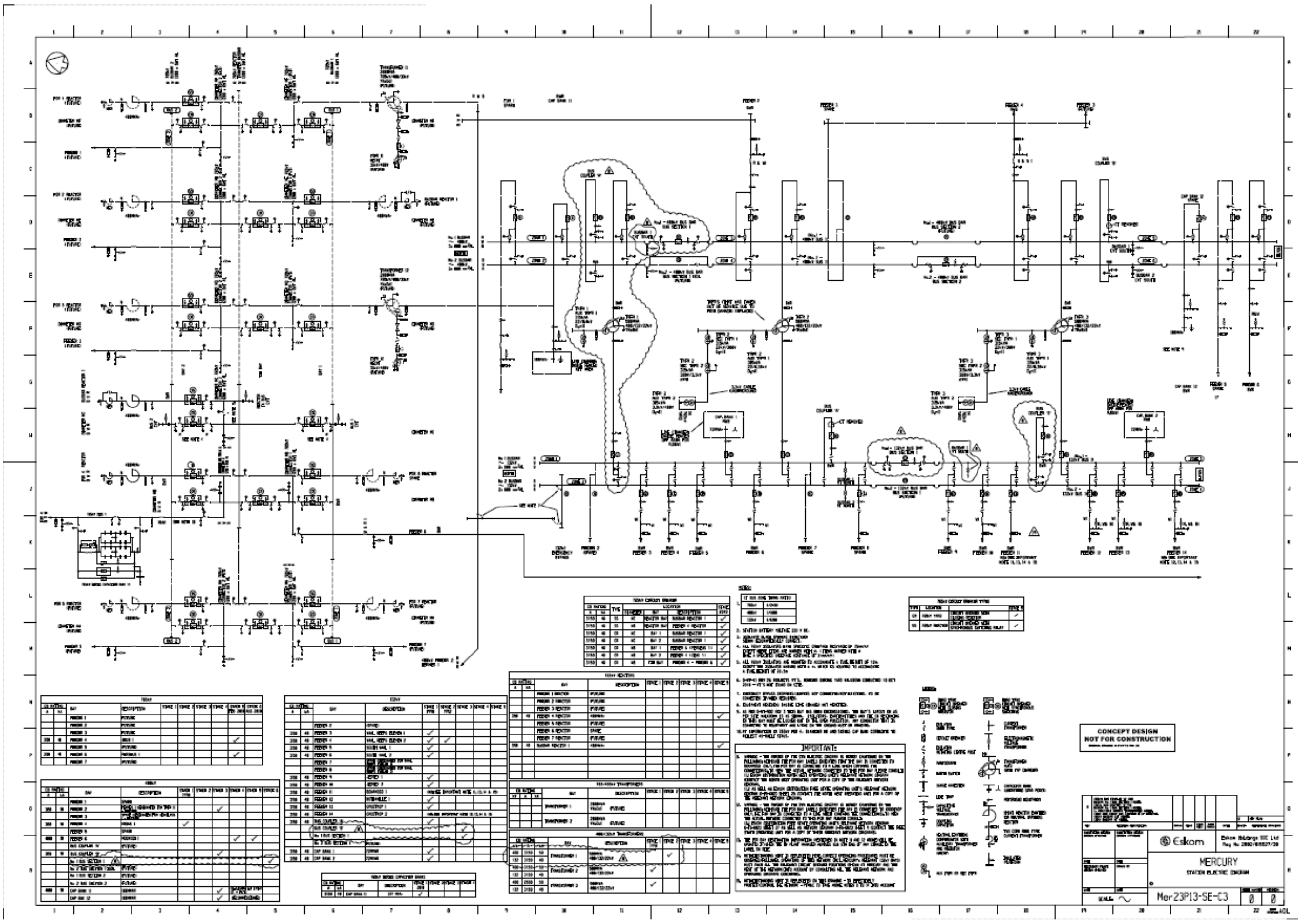

Figure 1. Approved Station Electric Diagram

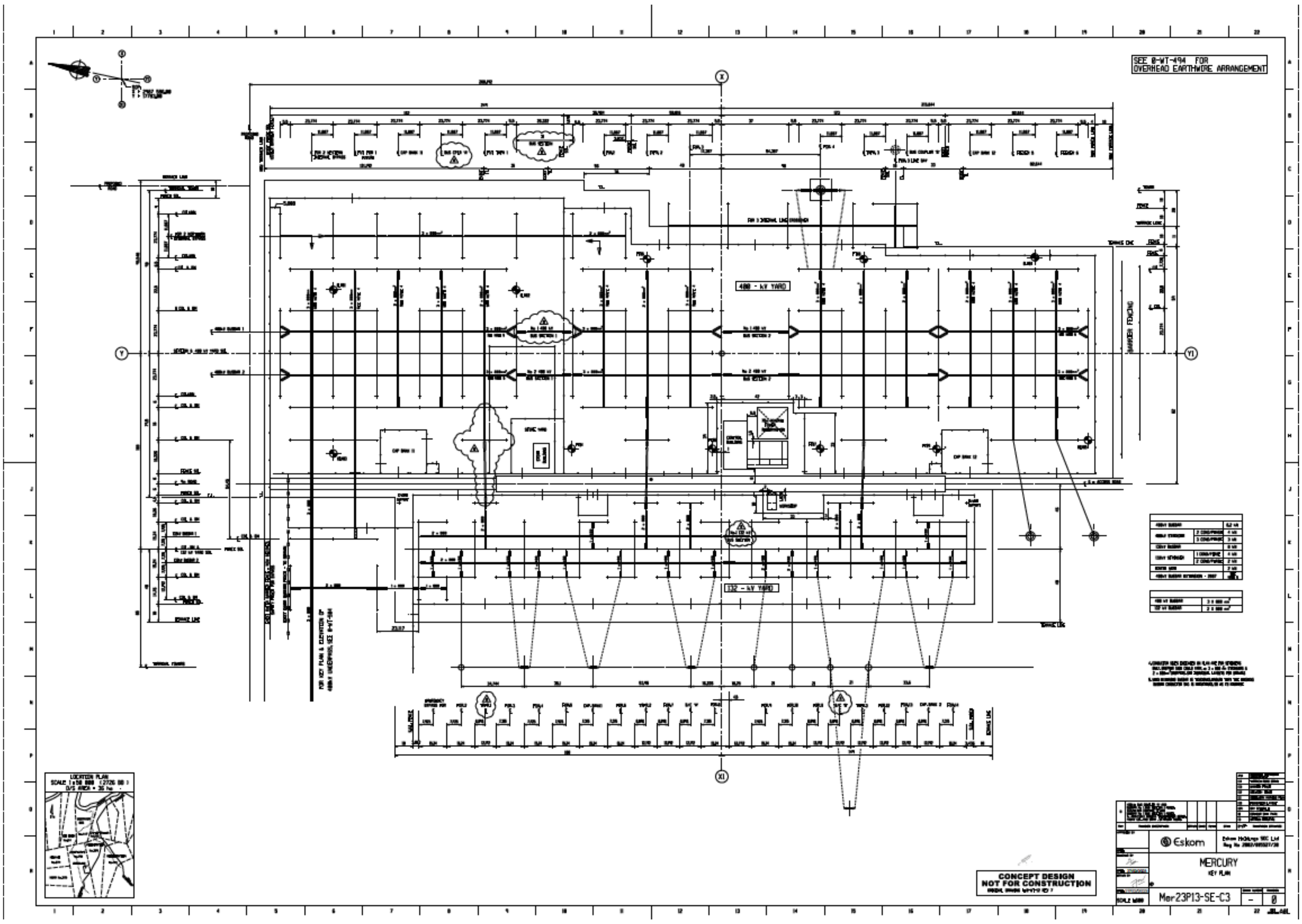

Figure 2. Approved Key Plan Drawing

4.5 ELECTRICAL DETAIL DESIGN

4.5.1 Design Philosophies

The design philosophy for this project is governed by the initial scope of works since the original Mercury MTS design allocated a specific bay for the spare second transformer bay. For this reason, the drawings contained in Appendix B are provided to the EPC Consultant.

The arrangement of the substation consists of a 765kV ,400 kV and 132 kV yard, with various other services such as buildings, security, etc.
The existing 132kV and 400kV systems consist of flexible conductor, high strung double busbars. The arrangement and layout of the yard and all bays are in accordance with the Eskom standards.

4.5.2 Substation Design Specifications and Configuration

4.5.2.1 Fault Level Studies

System Voltage (kV)	Designed Fault Current (kA)
400	40
132	40

Table 2: Fault level studies for the Mercury MTS

The fault levels indicated in Table 2 are to be used for earth tail determination and earth grid design.

4.5.2.2 Primary Plant Equipment

The primary plant proposed for the design is based on technically pre-qualified plant equipment only. Selected equipment for the 400 and 132 kV yards will as a minimum comply with the ratings as summarised in the Table 3 below.

Voltage Level (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)
400	3150	50	1/1600	1425	25
132	2500	40	1/1200	550	25

Table 3: Equipment/Cable/Conductor Selection and Ratings

All primary plant must be selected from the Primary Plant Selection Guideline [23] and may only be selected if the primary plant conforms to the Eskom standard steelwork and standard foundation design base.

4.5.2.3 Busbar Design

The busbar design for Mercury MTS is as follows:

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 4: Conductor and Ratings

4.5.2.4 Conductor Selection

Conductor Selection must be performed considering the maximum expected load, as well as Eskom typical design standards and alignment to existing selections in the substation.

Description	Maximum Load (A)	Conductor Rating (A)		Conductor Type
400kV Transformer Bay	722 A	1972 @ 75°C	2706 at 90°C	Twin Bull
132kV Transformer Bay	2187 A	1972 at 75°C	2706 at 90°C	Twin Bull

Table 5: Cable/Conductor Selection and Ratings

The EPC Consultant shall verify all selections prior to finalisation of the detail design phase.

4.5.2.5 Electrical Clearances and Clearance Constraints

The minimum safe working clearances and electrical clearances are to be applied for the design are summarised in Table 6 below.

System Nominal Voltage (kV)	Minimum Electrical Clearances		Working Clearances	
	Phase to earth (mm)	Phase to Phase (mm)	Vertical (mm)	Horizontal (mm)
400	3200	4000	5700	4300
132	1200	1650	3700	2300

Table 6: Electrical Clearances and Working Clearances

4.5.2.6 Station DC Voltage

The station DC voltage is 220 V.

4.5.2.7 Insulator Type

Insulator assemblies that are to be used for Mercury substation:

- 400 kV suspended connection of conductors to the primary bushings of the 400/132 kV power transformer
- 132 kV strain assemblies for the stringers between the 400 and 132 kV yards

Mercury MTS is in a High pollution area, and as such:

1. Minimum specific creepage distance is 25mm/kV
2. Composite / silicone rubber insulation.

All insulator hardware assemblies will be in accordance with the 0.54/412 [25] series of standard details. The 400 kV suspended connection will be a V-string assembly.

The insulator type that is to be used, is as per existing application at Mercury MTS.

4.5.2.8 Station Construction Supply

Transformer 2 and its auxiliary transformer is commissioned and energised; therefore, it is possible that the construction supply may be provided by the MTS.

4.5.2.9 Station Auxiliary Supply

The primary source for auxiliary power supply to the substation is a 315 kVA 22/0.4 kV auxiliary transformer in accordance with the Eskom AC reticulation philosophy standard for substations. The auxiliary transformer is connected to the tertiary winding of the 400/132/22 kV auto transformer.

4.5.2.10 Yard Lighting

The illumination levels for the substation is according to the design for the establishment of the MTS. No changes are expected to be made during this project. The EPC Consultant shall perform a lighting assessment and verify that no further changes are required, using RELUX software and ensuring that the relevant design requirements as required for floodlighting designs are satisfied as per the Transmission Substation Engineering Functional Parameters Standard [24]. If additional light masts and associated infrastructure are required, it is to be included in the design, and constructed.

The EPC Consultant is to reference the Foundation and Trench Drawing, Operational Floodlighting Cable Route and Mast Location Layout, as well as Security Lighting Pole and Cable Route Layout, as provided in Appendix B, for consideration in the design of this project, not only for the lighting assessment as mentioned above, but also to avoid clashes in underground services.

4.5.2.11 Direct Lightning Stroke Protection

The lightning protection for the substation is according to the design for the establishment of the MTS. No changes are expected to be made during this project. The EPC Consultant shall perform a lightning protection assessment and verify that no further changes are required as part of the detail design, by verifying that the existing design complies to the Direct Lightning Stroke Protection Standard [18], as per the Transmission Substation Engineering Functional Parameters Standard [24]. If additional lightning masts and/or associated infrastructure (OHEW spans) are required, it is to be included in the design, and constructed.

The EPC Consultant is to reference the Overhead Earthwire Layout Drawing, as provided in Appendix B, for consideration in the design of this project.

4.5.2.12 AC Reticulation

The AC Reticulation design is detailed in the PTM&C report.

4.5.2.13 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

Table 7: Bill of Material for Major Equipment (For Information Purposes Only - TBC in detail design)

The equipment listed in Table 7 above was identified as suitable for the project. This high level list is to be reviewed and verified by the EPC Consultant, and thereafter used to select specific equipment from the Primary Plant Selection Guideline [23] during finalisation of the detail design phase and before procurement.

4.5.2.14 Substation Earthing

3 x earthtails will be used to earth the 400kV and 132kV equipment, based on the fault levels indicated in Table 2 above.

The EPC Consultant is to reference the Earthmat Layout Drawing, as provided in Appendix B, for consideration in the design of this project.

4.5.2.15 External Interfaces

None identified but to be reviewed during detail design development by EPC Consultant.

4.5.2.16 Facilities Required

All building facilities required for the housing and operation of electrical equipment have been established as part of the establishment of the MTS.

4.5.2.17 Maintenance Concept

The maintenance philosophy for this substation shall be strict adherence to [2], [3] and [7] in addition to the Original Equipment Manufacturers (OEM) requirements. The maintenance policy refers to a number of standard(s)/specification(s) documents that must be coherently adhered to achieve its purpose.

Safety of personnel is of paramount importance when designing a substation. The design must 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 a high voltage 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 that may be necessary to ensure his own safety.

The EPC Consultant shall ensure that the final detail design package is submitted to the relevant Eskom Transmission Grid HV Plant Manager and Grid Chief Engineer via the Project Manager, for scrutiny, review and acceptance of all aspects prior to the project being submitted to the Substation DRT. Acceptance from the Grid must be obtained in writing, in the form of an email or official minutes of a suitable Grid meeting such as the Grid Operations Meeting which is held monthly by the Grid. This acceptance must be documented in the Detail Design Report.

Furthermore, the Operating Diagram is to be updated and submitted to the relevant Eskom Transmission Grid HV Plant Manager via the Project Manager, prior to submission to National Control as further outlined below, to ensure that maintenance aspects are considered by the Grid and the Grid is duly satisfied with the maintenance and operational aspects of the design.

4.5.2.18 Operating Concept

Operating philosophy for the substation shall be designed in accordance with [4] and [5]. The policy refers to several standard/specification documents that must be coherently adhered to in order to achieve its purpose.

Mercury substation has double busbar with bypass (400 kV) and double busbar (132 kV) arrangements which is widely used within the Eskom network of substations. The arrangements are standard and is well known by designers, operators and National Control. Operating risks at these substations will therefore be no greater than at any other Eskom substation employing the same busbar configurations.

All controlling apparatus shall 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 shall be made available to the substation to assist with operating. This drawing serves to indicate all motorized switching equipment (e.g., circuit breakers, isolators, earth switches etc.) within the substation along with their relevant labels.

Operating requirements shall be in accordance with the requirements as set out in with [5].

The EPC Consultant is to reference the Operating Diagram, as provided in Appendix B, for consideration in the design of this project.

The Operating Diagram must be updated and submitted to Eskom during the execution phase of the project, at an appropriate time, as advised by Eskom National Control and the Eskom Project Manager to ensure that the required schematics are updated timeously to commission the project.

The EPC Consultant is to consult directly with Eskom National Control via the Project Manager in this regard to verify the timing of the drawing update.

The operating diagram is to be updated and revised as per the Operating Diagram Standard, as indicated in the Transmission Substation Engineering Functional Design Parameters [24].

4.5.2.19 Safety Concept

It is important that substations be safe for the general public and for operating and maintenance personnel, as well as all employees who enter the substation. Practical approaches include the employment and training of qualified personnel, appropriate working rules and procedures, proper design, and correct construction. The safeguarding of equipment is also considered in substation design.

Personnel working standards are prescribed by regulations issued by [2],[3],[4]. Furthermore, all operating, and maintenance personnel should work within the rules and regulations stipulated in [5] and [7]. The substation designs are performed in accordance with relevant Eskom standards, including the South African Grid Code [1].

The earthing system design shall be performed in accordance with [15] and associated references. Effective earthing of a substation is of 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. The earthing design limits the touch and step voltages to within safe limits and the Grid Potential Rise (GPR) to acceptable limits.

The EPC Consultant is to reference the following drawings, as provided in Appendix B, for consideration in the earthing design for this project:

- Earthmat Layout Drawing,
- 400kV Transformer 1 Earthing Bay
- 132kV Transformer 1 Earthing Bay
- 400kV Transformer 1 Plinth Earthing Bay

The earthing design for the project shall be comprehensive and shall comply to the Transmission Substation Engineering Functional Design Parameters [24] and Substation Earth Grid Design Standard [240-134369472].

The earthing design shall include but shall not be limited to the following:

- Simulation Studies on an Eskom approved Earthing and Grounding Software Programme (CDEGs) only,
- Soil Resistivity Test,
- Earth Grid Test, and
- Earth Continuity Test.

All the above studies and test results are to be done according to Eskom Standards [13,14,15] and the results are to be documented and appended to the Detail Design Report.

Tests that are required to be conducted post construction, must be submitted in the As-Built package.

4.6 SITING

4.6.1 Site Selection

Not applicable. This is an existing site.

4.6.2 Site Characteristics

3.8.2.1 Geotechnical

Not applicable. Geotechnical studies for this project are not required.

3.8.2.2 Topographical Survey

Not applicable. Topographical survey was conducted previously during site establishment.

3.8.2.2 Hydrological Characteristics

Not applicable. Hydrological characteristics were determined during the original design for this MTS.

4.6.3 Site Layout

Not applicable. The optimal site layout was determined as per the original design for the MTS.

4.7 CIVIL AND STRUCTURAL DESIGN

4.7.1 General

The civil infrastructure for Mercury Substation is existing in accordance with the SANS standards [8][9][10]. All new infrastructure will be designed in accordance with the SANS standards and will be identified and designed during the Detail Design phase by the EPC Consultant.

4.7.2 Buildings

Not applicable. No additional buildings are required.

4.7.3 Earthworks

Not applicable. No additional earthworks are required.

4.7.4 Foundation, plinths and trenches

Standard foundations will be required for all new main and equipment steelwork. All new works will be done in accordance with the SANS standards [48] [49] [50]. New foundations to be considered in detail phase and selected according to the latest revision of the application guide 0.54/8829 and section 3.3.1.2 of [121]. All equipment purchased must be mechanically and electrically compatible with the design base stated in the application guide 0.54/8829 and section 3.3.1.2 of [121].

Trenches and cable trench entrances to control room are adequate for the proposed works. However, any need for additional trenches and/or trench entrance to the control room is to be designed in accordance to 0.54/390 SH 15H of the HV Yard Civil Work series and will form part of the detailed design package.

The EPC Consultant is to reference the Foundation and Trench Drawing, as provided in Appendix B, for consideration in the design of this project.

Standard Foundations, Plinths and Trench Drawings are located in the civil standard issue package [123].

4.7.5 Fencing

No additional fencing is required.

3.9.6 Roads

No road modifications or additions are required.

3.9.7 Structural Steel

It is not expected that any non-standard steelwork will be required to realise this project.

Standard steelwork will be required for new main structures and equipment and must comply with SANS standard [48]. New steelwork designs are to be used and selected according to the latest revision of the Application Guide (0.54/8829). Steelwork support designs are to be selected to interface directly to standard foundations and high voltage equipment as selected according to the Primary Plant Equipment Selection Guideline [121].

The EPC Consultant is to reference the Steelwork Marking Plan, as provided in Appendix B, for consideration in the design of this project.

Standard Steel Drawings are located in the civil standard issue package [123].

3.9.8 Drainage

It is not expected that additional sub soil drainage is required to realise this project.

4.8 DESIGN ASSESSMENT

4.8.1 Operability Assessment

Not applicable.

4.8.2 Reliability, Maintainability, Availability Assessment

Not applicable.

4.8.3 Constructability Assessment

The EPC Contractor is to supply a constructability assessment and a plan of how the scope will be executed.

4.8.4 Inspectability and Testability Assessment

Since Mercury substation consists of outdoor yards and equipment, inspection and status of the equipment, structures, foundations, conductors and the like are easily achieved. The EPC Consultant must ensure that structures and equipment are mounted at heights that will facilitate inspections of equipment (for instance monitoring SF6 gas in circuit breakers or oil level in transformers, etc.) from ground level.

4.8.5 Expandability Assessment

Future expandability of the substation, including but not limited to accessibility, must not be limited in any way.

4.8.6 Dismantling and Demolition Requirements

None.

4.9 SAFETY ASSESSMENT

4.9.1 Industrial Safety Assessment

The Health and Safety Specification have been received from the client and must be considered further explicitly in the detail design of the project.

The industrial safety and risk assessment compiled by the EPC Contractor must support Eskom's safety ideals, as well as Eskom's Value of Zero Harm.

4.9.2 Fire Safety Assessment

None.

4.10 PLAN OF IMPLEMENTATION

4.10.1 Project Outage Requirements

The following outages are envisaged:

- Outages will be required per 132kV and 400kV busbar to connect isolators
- And any other instances where clearances cannot be met, when doing construction

The preliminary outage requirements, on which the construction assessment is based, is to be discussed and confirmed with the relevant person at National Control via the Eskom Project Manager, prior to finalising the detail design for presentation to Eskom for acceptance.

All discussions and confirmations are to be documented in Detail Design Report.

4.10.2 Transportation Plan

The substation access road is designed to accommodate conventional and abnormal loads transported by road.

The transportation plan external to the substation is to be developed by the relevant stakeholder as it falls outside the scope of Substation Engineering.

4.10.3 Construction Plan

During the detail design, the EPC Consultant is to very carefully consider all risks pertinent to the project and in particular those highlighted in the Health and Safety Specification and Baseline Risk Assessments, and ensure that risk treatments and risk controls are identified, documented and communicated to Eskom. Further risks identified during the detailed phase of the design should also be documented together with additional treatments, controls and mitigation measures.

The construction plan falls outside the scope of Substation Engineering and is to be developed by the relevant stakeholder.

5. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
Sibongile Chawe	Chief Engineer: Integration Engineering
Moses Tshikomba	Senior Advisor: Transmission Project Development

6. REVISIONS

Date	Rev.	Compiler	Remarks
January 2024	1	R Ramnarain	First Issue

7. DEVELOPMENT TEAM

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

R Ramnarain

S Duma

8. ACKNOWLEDGEMENTS

None

APPENDIX A: CONCEPT DESIGN DRAWINGS/DOCUMENTATION

Document Number	Rev.	Document Title	Remarks
Mer23P13-SE-C3	0	Station Electric Diagram	First Issue
Mer23P13-SE-C4	0	Key Plan Drawing	First Issue

APPENDIX B: MERCURY MTS – AS-BUILT DRAWINGS (AS AT 10 JANUARY 2024)

Document Number	Rev.	Document Title	Remarks
Electrical Drawings			
Mer23P13-SE-C3	0	Station Electric Diagram	-
Mer23P13-SE-C4	0	Key Plan Drawing	-
0-WT-110-0	11	Foundation, Trench and Earthmat layout	-
0-WT-110-1	0	Foundation, Trench and Earthmat layout	-
0-WT-111-0	9	Steelwork Marking Plan	-
0-WT-109-2	3	Conductor and Hardware Schedule	-
0-WT-109-2A	2	Conductor and Hardware Schedule	-
0-WT-109-2B	2	Conductor and Hardware Schedule	-
0-WT-109-1A	1	Reference Drawing Schedule	-
0-WT-109-1	13	Bay Layout and Equipment Schedule	-
0-WT-109-7	2	400kV Transformer 1 Bay	-
0-WT-109-13	1	400kV Bus Coupler A	-
0-WT-109-15	1	400kV No 1 Bus Section 1	-
0-WT-109-35	0	132kV Transformer 1 Bay	-
0-WT-109-39	0	132kV Bus Coupler B	-
0-WT-109-40	0	132kV No 1 Bus Section 1	-
0-WT-902	9	Operating Diagram	-
0-WT-494-0	1	Overhead Earthwire Arrangement	-
Civil Drawings			
0-WT-114-0	2	Terrace and Road Layout	-
0-WT-148-0	2	Surface Drainage Layout	-
0-WT-149-0	1	Subsoil and Cut-off Drainage Layout	-
0-WT-167-0	1	500MVA Transformer Plinth details	-
0-WT-51-0	2	Contour Site Plan	-

APPENDIX C: MERCURY MTS – AS-BUILT DOCUMENTATION

Document Number	Rev.	Document Title	Remarks
-	-	Earth Continuity Tests	Unavailable
-	-	Earth Grid Impedance Measurement, GPR Tests and Step/Touch Potentials Measurements	Unavailable
-	-	Earthing Design Report	Unavailable
-	-	CDEGS Simulation Model	Unavailable
-	-	Soil Resistivity Tests	Unavailable

APPENDIX D: MERCURY MTS – PROJECT INPUT DOCUMENTATION

Normative References:

27] Health and Safety Specification Form for Mercury Substation

APPENDIX E: TEMPLATES

Document Number	Rev.	Document Title	Remarks
240-56364587	1	Site Visit Report Template	-
240-140073760	-	Detail Design Report Template	-
-	2023	Civil DRT Presentation Template	-
-	2023	SS and Tx DRT Presentation Template - Detail	-
240-111653940	2	Substation Engineering Document Issue Checklist	-