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Executive Summary

This document serves as a functional technical specification for any Substation: primary/power plant (Electrical and Civil Engineering) designs that are to be completed by an Eskom Transmission: Substation Engineering appointed external consultant. This functional specification describes the principles and basic requirements of a Major Transmission Substation. Any successfully appointed consultant shall apply these principles for assets that will be owned operated and maintained by Eskom Transmission.

This document covers the design methods, philosophies and considerations, which together with the standards and specifications, should be followed to produce the design requirements of substation projects as defined by Eskom's scoping of each project. The document summarizes these major technical requirements pertaining to substation design, procurement and construction aspects that needs to be included in the technical documentation for the substation design project.

1. Introduction

This specification aims to promote standardized Transmission substation designs, including the use of standardized materials and practices, thereby reducing design and construction periods, equipment stock levels and costs generally. This specification highlights important factors that must be considered during the design process and is applicable to new substations as well as substation strengthening and refurbishment projects.

2. Supporting clauses

2.1 Scope

This specification does not cover in detail each of the topics discussed, but rather highlights important factors that must be considered during the design process. Further details of each topic are documented in the referenced specifications.

2.1.1 Purpose

The purpose of this document is to assist the consultant appointed to do Transmission substation designs by documenting important factors that must be considered during the substation design process. The document is by no means exhaustive but highlights the requirements that Eskom deems important to consider as a minimum.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings SOC Limited Divisions.

2.2 Normative/informative references

Parties using this document shall apply the most recent revision of the documents listed in the following paragraphs.

2.2.1 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] 240-53113923, Specification for Substation Clamps for Tube Aluminium Conductors

[40] 240-53113927, Specification for Substation Clamps for Stranded Aluminium Conductors

[41] 240-83534936, Specification for Substation Clamps – Additional for Tubular and Stranded Conductor Clamps

[42] 240-152844641, Phase Conductor Standard for Eskom Overhead Line

[43] 240-120804300, Standard for the Labelling of Electrical Equipment within Eskom Wires Networks

[44] 240-75660336, The Standard for Design, Manufacturing, and Installation of Eskom Wires Business Equipment Labels

[45] 240-132747382, Safety Signs in Transmission Substation Buildings

[46] 240-83563472, Drawing Standard for Substations: Power Plant

[47] 240-68972308, Standard Procedure for Single Line Diagram Development

[48] 240-68972746, Standard Information Required for the Production of Substation Drawings

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

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

[51] SANS 204, Energy efficiency in buildings

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

[53] 240-83382076, Standard for operational floodlighting in substations

[54] 240-82172806, Standard for Air Conditioning in Tx Substation Buildings and Telecom Sites

[55] 240-100183119, Standard for the Substation HV Yard Fences

[56] 240-76368574, High Security Mesh Fencing

[57] 240-101811486, Standard for Crusher Plant

[58] 240-94743192, Standard for Fabrication Steelwork used in Eskom Transmission Substations

[59] 240-102393009, Standard for Substation Flood Analysis Design

[60] 240-102384426, Standard for Substation Surveys

[61] 240-108982466, Standard for HV Yard Stones in Eskom Substations

[62] 240-153000199, Substation Drainage

[63] 240-56177186, Battery room standard

[64] 240-56364535, Architectural Design and Green Building Compliance Manual

[65] 240-83382122, Emergency Lighting in Substations (Standard)

[66] South African Pavement Engineering Manual (SAPEM) ISBN 978-1-920611-00-2

[67] 240-85067224, Substation Platform and Access Road Design Standard

[68] 240-170000153, Security Lighting for Eskom Applications

[69] 240-57127953, Execution of Site Preparation and Earthworks Standard

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

[71] 240-122922610, Specification for Substation Tubular Conductors (Standard)

[72] 240-97364498, The Design philosophy for 132kV strung flexible stranded conductor busbar yards

[73] 240-98447933, The Design philosophy for 275kV strung flexible stranded conductor busbar yards

[74] 240-95242258, The Design philosophy for 400kV strung flexible stranded conductor busbar yards

[75] 240-87314141, The Design philosophy for 765kV strung flexible stranded conductor busbar yards

[76] 240-97364660, The Design Philosophy for 132kV Tubular Busbar Yards

[77] 240-98448011, The Design Philosophy for 275kV Tubular Busbar Yards

[78] 240-95242252, The Design Philosophy for 400kV Tubular Conductor Busbar Yards

[79] 240-85660414, The Design Philosophy for 765kV Tubular Conductor Busbar Yards

[80] 240-85524358, Standard for Determining Busbar Conductor Short-Circuit Forces and Phase Conductor Displacement in Outdoor Substations

[81] 240-85524376, Standard for Determining Dropper Conductor Short-Circuit Forces on Equipment in Outdoor Substations

[82] 240-68972408, Standard for Flexible and Tubular Conductor Heights and Phase Spacing

[83] 240-109644476, Guideline for the Application of Intra-Span (Flying) Insulators

[84] 240-68972898, Standard for the Choice of Single and Three Mechanism Circuit-Breakers

[85] 240-94937573, Standard for Feeder Bypassing

[86] 240-75908051, Application of Bus Couplers and Transfer Bus Couplers at Eskom Main Transmission Substations

[87] 240-75305807, Application of AIS and GIS Switchgear at Eskom Main Transmission Substations

[88] 240-68971742, Standard for Corona Studies

[89] 240-68971854, Standard for Power Frequency Electric and Magnetic Analysis in Substations

[90] 240-53113685, Design Review Procedure

[91] 240-606480018, Terms of reference for Design Review Teams Presiding over Transmission and Distribution Infrastructure Designs in Eskom

[92] 240-59083220, Substation DRT requirements additional to the DRT ToR applicable for 2021/22

[93] 240-55151946, AC Reticulation Philosophy for Substations

[94] 240-171000192, Overarching Basic design / Scope of work

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

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

[97] SANS 10162, The structural use of steel

[98] SANS 10163, The structural use of timber

[99] SANS 10164, The structural use of masonry

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

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

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

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

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

[105] 240-50807380, Specification for Gas Insulated Switchgear (GIS) and associated auxiliary Equipment

[106] 240-60725684, Specification for oil immersed HV and EHV Power Reactors

[107] 240-42587021, Specification for Air Core Reactors

[108] 240-64688878, Generic Capacitor Bank Specification

[109] Detailed Design DRT Presentation Template

[110] 240-140073760, Detailed Design report Template

[111] SANS 1936, Development of dolomite land

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

[113] 240-103414344, Eskom Corporate Identity

[114] 240-56737448 Fire Detection and Life Safety Design Standard

[115] 240-94743194, Specification for the Erection of Steelwork used in Eskom Tx and Dx

[116] 240-98161024, Standard for Rock Blasting In Substations

[117] 240-84854974, Continuity Measurement of Substation Earth Grid Systems

[118] 240-89926574, Specification for Installation of Tubular Aluminium Conductors

[119] 240-82736997, Stringing, Earthing, and Erection Specification for Transmission Substations

[120] 240-171000164, Technical Tender Evaluation Criteria for Substation Civil works

[121] 240-171000165, Technical Evaluation Standard For Stringing , Earthing and Erection at Transmission Substations

[122] 240-170001073, Technical Evaluation Standard for the Installation of Tubular Aluminium Conductors

[123] 240-171000161, Technical Evaluation Standard for Substation Stranded Conductor Clamps - EPC Contracting

[124] 240-171000162, Technical Evaluation Standard for Substation Tubular Clamps - EPC Contracting

[125] 240-170001073, Technical Evaluation Standard for Substation Tubular Conductors -EPC Contracting

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

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

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

[129] SANS 2001 Series, Construction Standards

[130] SANS 10249:2012, Masonry Walling

[131] SANS 10145:2013, Concrete Masonry Construction

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

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

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

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

[136] Eurocode 3, Design of Steel Structures

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

[138] 240-84418186, Roads Specification Manual

[139] 240-180000668, Guideline on how Contractors can select material to use to build the Substations or Infrastructure on the Self-build or Turnkey

2.2.2 Informative

[140] 32-1205, Eskom Maintenance Management Policy

[141] 32-727, Eskom Safety, Health, Environment and Quality policy

[142] 240-146353995, Substation and Facility Maintenance

[143] 240-77297024, Standard for Operating Diagrams for Eskom

[144] 240-68971972, Standard for Stranded Flexible Conductor Selection

[145] 240-68972068, Standard for Tubular Conductor Selection

[146] 240-100176272, Determination of conductor rating in Eskom

[147] 240-100907733, Guideline for the Application of Stranded Flexible Conductor Versus Round Tubular Conductors in Substation Design

[148] 240-97758043, Short Circuit Capability of Substation Portal Structures from 6.6kV to 765kV

[149] 240-55921217, Substation Engineering Product Realisation Work Instruction

[150] 240-56063877, RTV Silicone Rubber Insulator Coating and Shed Extender Applications Standard

[151] 240-56062705, RTV Silicone Rubber Insulator Coating and Shed Extender Supplier Specification

[152] 240-180000653, Engineering Instruction to install pantographs on 132kV and 88kV busbar selection upon design layouts requiring inline arrangements

[153] 240-148617190, Replace with New 132 kV Circuit-breakers rated for 50kA and above at the Substations with fault Levels 30kA and above

[154] 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)

[155] IEC 60071, Insulation Co-ordination

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

[157] SANS 60060-1

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

[159] Earthing Quality Inspection and Test Plan – Guideline

[160] Tubular Busbar Installation Quality Inspection Plan - Guideline

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

[162] Scoring – Substation Civil Works at Substations

[163] 240-128559117, Method Statements for Eskom Transmission substations – Stringing, Erection and earthing.

[164] 240-170001074, Civil design file calculations

2.3 Definitions

2.3.1 General

Definition	Description
Busbar	Low impedance conductor to which several electric circuits can be connected separately.
Corona	Luminous, audible discharge because of electrical overstressing in an insulating material, usually air that occurs when there is an excessive localized electric field gradient upon an object or conductor that causes the ionization and possible electrical breakdown of the air adjacent to this point.
Extra High Voltage	The set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range 220kV < Un ≤ 765kV
High Voltage	The set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range 44kV < Un ≤ 220kV.
Medium Voltage	The set of nominal voltage levels that lie above low voltage and below high voltage in the range 1kV < Un ≤ 44kV.
Minimum bay separation distance	The minimum distance between the centre lines of two bays next to each other exiting in the same direction.
Specific Creepage Distance (SCD)	The total creepage distance divided by the phase-to-phase system highest voltage.

Definition	Description
Tube	A hollow cylindrical aluminium conductor of specified diameter and wall thickness designed to carry current
Unified Specific Creepage Distance (USCD)	The total creepage distance divided by the phase-to-earth system highest voltage.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
AC/DC	Alternating Current/Direct Current
AIS	Air Insulated System
BAH	Breaker and a Half
CAD	Computer Aided Design
CB	Circuit Breaker
CDEGS	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis
CT	Current Transformer
CVT	Capacitive Voltage Transformer
DRT	Design Review Team
EHV	Extra High Voltage
EMVT	Electromagnetic Voltage Transformer
EPCM	Engineer, Procure, Construct and Maintain
ES	Earth Switch
FPI	Footprint Investigations
GIS	Gas Insulated System
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
ISOL	Isolator
kV	kilo Volt
LED	Light Emitting Diode
LH	Left Hand
LIL	Lightning Impulse level
LT	Line Trap
LV	Low Voltage

Abbreviation	Description
MV	Medium Voltage
MVA	Mega Volt Amperes
NECRT	Neutral Electromagnetic Coupler with Neutral Earthing Resistor and Auxiliary Transformer
PI	Post insulator
QITP	Quality Inspection test plan
RAM	Reliability, Availability, and Maintainability
RH	Right hand
RTV	Room Temperature Vulcanized
SA	Surge Arrestor
SABS	South African Bureau of Standards
SANS	South African National Standard
SCOT	Steering Committee of Technologies
SCD	Specific Creepage Distance
SLD	Single Line Diagram
TRFR	Transformer
VT	Voltage Transformer

2.5 Roles and responsibilities

Not Applicable

2.6 Process for monitoring

Not Applicable

2.7 Related/supporting documents

Not Applicable

3. Design Practice

3.1 General Requirements

3.1.1 Substation site information

The consultant is to provide a detailed description of the project, the major parameters, and what is required to deliver the project. The description should include all items as stipulated in the design report template [110].

3.1.2 Statutory requirements

The total design shall comply with South African Grid Codes [1] and additionally the requirements of the Occupational Health and Safety Act [2] and all subsequent amendments and regulations shall always be observed. All designs are also to comply with the Safety Health and Environmental Specification compiled for the associated scope of work.

3.2 Technical Design Specifications

3.2.1 General Requirements

The performed work and supplied equipment and material for the project shall meet or exceed, in regard to quality, ratings, reliability, functionality, integration to electricity network, future expandability, serviceability, maintainability, health, safety and environmental, the requirements given in the technical specification and applicable international and national standards, Eskom's standards and guidelines, prevailing legislation and best engineering practices.

It also requires that physical layout and equipment shall conform to the latest state-of-the-art design practices and that all materials used for equipment, steel structures and accessories shall be of high quality, while satisfying all functional requirements under any possible combination of environmental conditions, the objective and providing simplicity, reliability and safety while ensuring high economy and low maintenance cost. Personal safety and all required precautions and provisions necessary to make the works safe, shall be considered a paramount requirement of the design. The design and construction of the substation shall comply with the requirements of national and local legislations and by-laws.

Nothing will be supplied as free issue from Eskom and all components need to be sourced by the contractor as per the specifications stated in relevant sections.

3.2.2 Major Equipment Specifications

Major equipment for project specifics can include, but may not be limited to, the following:

- Power transformers
- Auxiliary transformers
- Circuit breakers
- Disconnectors
- Earth switches
- Current transformers
- Voltage transformers
- Surge arresters
- Power cables
- Insulators
- Shunt reactors
- Fault Limiting reactors
- Shunt Capacitor Banks
- Power Electronics devices

The technical requirements of substation primary plant including power transformers, circuit breakers, disconnectors, earth switches, current transformers, voltage transformers, surge arresters, insulators, insulated HV cables, Fault limiting reactors and Shunt capacitor banks are specified in the relevant Eskom standards and document [139].

The Consultants shall ensure that the voltage ratings for all substation network interconnection primary plant are in accordance with the specified voltages at each specific site. Any equipment with voltage rating equal to or higher than the applicable system voltage can be used, except for voltage specific equipment.

22kV rated equipment is used for both 11kV and 22kV applications, and 132kV rated equipment is used for both 88kV and 132kV applications, and similarly 275kV rated equipment is used for both 220kV and 275kV applications. Voltage specific equipment includes power and auxiliary transformers, NECRT's, VTs and surge arresters.

All plant & equipment supplied shall be new, unused, proven and of the most recent or current models as specified in [139]. All porcelain surfaced HV Equipment shall be RTV coated prior to commissioning as per [150] & [151].

All plant and equipment must be compatible with the existing design base as per section 3.3.1.2 Equipment foundation and Steelwork.

3.2.2.1 Power Transformers

The design, manufacture and supply of the main power transformers shall comply with the requirements of [16].

3.2.2.2 Auxiliary Transformers

The design, manufacture and supply of auxiliary transformers shall comply with the requirements of [17]. The application of these should be as[18] & [19].

3.2.2.3 Circuit Breakers

The design, manufacture and supply of the circuit breakers shall comply with the requirements of [20]. For all new installations control voltages and motor voltages of circuit breakers shall be 220VDC. For existing stations control voltages are to match the current installation voltage unless a total upgrade is considered. Philosophy document [84] should be applied for varying circuit breaker applications.

Engineering instructions [153] & [154] are to be applied to find the optimum solution to mitigate against overstressing of circuit breakers.

3.2.2.4 Disconnectors and earth switches

The design, manufacture and supply of the disconnectors and earth switches shall comply with the requirements of [21]. Engineering instruction [152] should be applied during the design of through connection arrangements.

For installations with fault currents greater than 16kA fixed earth switches shall be installed on disconnectors. Earth switches shall be applied at:

- Each zone on a busbar
- Either side of circuit breakers for maintenance
- Line entries

3.2.2.5 Current Transformers

The design, manufacture and supply of the current transformers shall comply with the requirements of [22] for 132kV and below and [23] for 220kV and above applications.

3.2.2.6 Voltage Transformers

The design, manufacture and supply of Inductive Voltage transformers are applied for voltages below 220kV and need to comply to [24]. For 220kV and above, capacitive voltage transformers are applied, and the design, manufacture and supply need to comply to [25].

3.2.2.7 Surge Arresters

The design, manufacture and supply of the surge arresters shall comply with the requirements of [26]. Surge arresters shall be located on bay entries into a substation and next to important equipment such as power transformers, and reactors. For power transformer applications, MV & LV surge arresters shall be mounted on the power transformer tanks or as close as possible to ensure they are within applicable protective distances per voltage level.

3.2.2.8 Power Cables

The design, manufacture and supply of HV and EHV Power Cables shall comply with the requirements and specifications as per [33], [34], [35], [36], [37], and [38].

3.2.2.9 Station Post Insulators

Station Post Insulators shall be selected such as to meet the specified environmental conditions (level and type of pollution) and to withstand the combined stresses imposed by worst case scenario short circuit and wind/ice conditions. A safety factor for sizing of insulators on mechanical loads, for maximum static loads and for combined maximum static and maximum dynamic loads shall be included for the selection of the mechanical characteristics of the insulators.

The design, manufacture and supply of the station post insulators shall comply with the requirements of [27]. Only station post insulators made of porcelain material shall be accepted.

3.2.2.10 Oil Immersed Reactors

The design, manufacture and supply of all oil immersed reactors shall comply with [106].

3.2.2.11 Air Core Reactors

The design, manufacture and supply of all Air Core Reactors shall comply with [107].

3.2.2.12 Capacitor banks

The design, manufacture and supply of the Shunt capacitor banks shall comply with [108]

3.2.2.13 Power Electronic devices

For any project specific power electronics devices communicate with the Eskom custodian for specification guidance and Eskom acceptance.

3.2.3 Substation Conductor, Hardware and Accessories

3.2.3.1 Conductors

Conductors and connectors should conform to the same electrical and mechanical strains and stresses as those of equipment. The selection of conductors should be made according to basic requirements i.e., service voltage, nominal current, short circuit current, environmental conditions, and layout of conductors. The selection of conductors should also consider corona inception for the varying applications and adhere to [88], [144], [145], [146], and [147].

Eskom has standardised on only a few conductors for use in substations. The standard conductors are listed in the table 1 below.

Table 1: Standardized conductors

Item	Description
Tubular conductor	• The design, manufacture and supply of all tubular conductor shall be in accordance with [71] and suppliers will be evaluated as per [125]. • For 132kV busbar applications: Ø200mm x 6mm wall thickness aluminium tubes and [76] apply • For 275kV applications: Ø250mm x 6mm wall thickness aluminium tubes and [77] apply • For 400kV busbar applications: Ø250mm x 6mm wall thickness aluminium tubes [78] apply • For 765kV busbar applications: Ø200mm x 6mm wall thickness aluminium tubes [79] apply • Centipede conductor shall be installed inside the tube for 2/3 of its length from either side to suppress Aeolian vibrations. • The tubular conductor shall be fixed to the end cap on one side only between supports. A Fixed – Slide - Fixed – Slide sequencing shall be applied across any tubular application. One side of the bar shall have a sliding type of clamp for expansion. • Where tubular conductor overhangs are present a sliding through clamp configuration will be applied at the support structure. • Welded Angle inserts can be used to create bends in tubes but should not be used as extensions for straight connections.
Flexible conductor	• The design, manufacture and supply of all strung flexible conductors shall be in accordance with [42]. • The design philosophies for strung flexible conductors are captured in [72] through to [75]. The standardised conductors used in Transmission stations are: • 470A (900C)– Hornet (16.3mm diameter gives 157mm2 cross sectional area), • 860A (900C)– Centipede (26.5mm diameter gives 415mm2 cross sectional area) • 1 353A (900C)– Bull (38.3mm diameter gives 865mm2 cross sectional area) • Insulated versions of the above (Tertiary Bay applications)
Shieldwire	• The design, manufacture and supply of all shieldwire shall be in accordance with [42]. • Maximum tension for shieldwire applications should be 2kN. Conductor types are: • Coastal Sites – Greased Oak (13.95mm) • Inland Sites – Hare (14.16mm)
Surge arrester connections	• Surge arrestor connections are voltage tap off points and need not be the full current rating of the circuit. Were possible these can be Tee-off connections with smaller conductor sizes (centipede) to reduce mechanical loading on the surge arrestors. • Corona inception needs to be considered per application to ensure [88] is not violated.
Earthing	• The design, manufacture and supply of earthing conductors shall be in accordance with [13] and [14]. Eskom has standardized on 10mm round copper for the main earthmat and earth tails within the substation in general and bare flat copper 50x3.15mm for buildings/plinths, along walls or at appropriate locations. See 0.54/393 series for earthing details.

3.2.3.2 Clamps

Substation clamps are critical components within a substation since they are generally connected in series with the current path. The reliability of the whole power network may be compromised by the failure of clamps if they are not properly designed, manufactured, and adequately tested to operate not only under normal operating conditions, but also a range of abnormal conditions as well.

Clamps should conform to the same electrical and mechanical strains and stresses as those of equipment. The reliability of the station will only be ensured if all components (equipment, conductors, and clamps) reply to the same requirements.

Clamps must transmit a constant current almost without any loss from one conductor to the other. Clamps must serve for many years without maintenance and to be resistant against climatic influences and physical loads (e.g., changing temperature during hundreds of on and off switchings and temperature shocks up to 200°C after short circuits). To facilitate necessary maintenance work, clamps should be easy to disassemble and reinstall.

When determining the type of current carrying clamp to be utilised, the maximum continuous load rating and short circuit currents are critical factors to consider.

The following information is applicable to Eskom's clamps requirements:

- Bolted clamps onto solid stems are generally satisfactory.
- Bolted clamps onto standard conductors are unsatisfactory. All current carrying clamps shall be the compression type.
- Compression clamps perform well on stranded conductors.

Eskom has standardized on the range of standard clamps as covered in the corresponding clamp specifications (Tubular and Stranded conductor clamps), [39],[40] & [41]. Clamps shall be designed in accordance with the above specifications. Local Suppliers Vexila (Pfisterer), McWade and Preformed Line Products South Africa (PLP) have been evaluated previous and deemed technically acceptable for application within Eskom Transmission. At tender stage commitment letters to procure from these suppliers will be deemed acceptable. Any other suppliers would need to be evaluated as per [123] and [124].

3.2.3.3 Hardware

Hardware components refer to those non-current carrying items needed to physically support the conductors associated with the electrical system. Hardware design, manufacture, testing and supply and delivery shall be according to [32]. Refer to 0.54/412 series schedules for the various items that are used in a substation.

3.2.3.4 String Insulators

For any string insulators applied as intra-span(flying) [83] should be applied.

a) Long Rod Insulators

The design, manufacture and supply of Long rods insulators shall comply with the requirements of [29] for installations 220kV and above, [30] for 66kV and 132kV, and [28] for installations below 33kV.

b) Glass Cap and Pin Insulator

The design, manufacture and supply of the glass insulators shall comply with the requirements of [31].

3.2.3.5 Labelling

3.2.3.5.1 Plant and Equipment

Labelling is a statutory requirement of the Occupational Health and Safety Act (OHS Act) No 85 of 1993. The act states that all controlling apparatus shall be permanently marked to identify the system or part of the system it is made up of.

Each piece of equipment shall be labelled, and the information shall be visible and legible from as many operating points as practicable. Labelling of all equipment in Eskom Wires substations shall be in accordance with [43]. The Design, Manufacturing and Installation of Eskom Wires Business Equipment Labels shall be in accordance with [44]. Labels are generally attached to lattice structures via J-brackets or L-brackets, see 0.54/403 and 0.54/1794.

3.2.3.5.2 Safety Signs

Labelling throughout the substation shall be applied as per [45].

3.2.3.5.3 Substation External Signage

Labelling at the entrance of the actual substation will comply to Eskom's corporate Identity Policy [113].

Figure 1 : External Freestanding Sign

External primary - freestanding sign

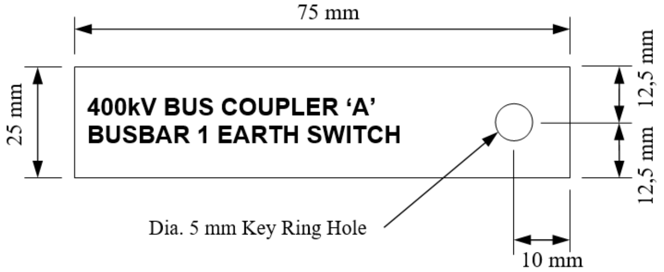
3.2.3.5.4 Key Ring Labels

The labelling of locks, for all hand operated, switchable plant is required and shall be manufactured from 1,6 mm brass plate and drilled to the dimensions detailed in the drawing below in accordance with the label requirements of the station. Plain block lettering shall be used, and the inscriptions shall be exactly as the associated plant label.

Label requirements:

- Engraved black lettering,
- 1,6 mm thick brass plate,
- 3,5 mm text height,
- 2,5 mm text width,
- 1 key ring per label

Figure 2: Brass label sample



3.2.4 Insulation and Insulation Co-ordination

3.2.4.1 General

Substation insulation co-ordination must ensure that the selection of the electric strength of equipment and its application, in relation to the voltages which can appear on the system and considering the characteristics of available protective devices, to reduce to an economically and operationally acceptable level the probability that the resulting voltage stresses imposed on the equipment will cause damage to equipment insulation or affect continuity of service. The insulation co-ordination must comply with IEC 60071, [155].

The design must identify the insulation co-ordination requirements between the power line and substation assets.

3.2.4.1.1 Direct Lightning Protection

Substations shall be protected from direct lightning strikes by adequate shielding in accordance with the requirements of the Direct Lightning Stroke Protection of Substations,[15].

3.2.4.1.2 Electrical and Working Clearances

Design and safety clearances for all nominal voltage levels shall be in accordance with Table 2 below. Equipment clearances must maintain electrical safety and maintenance requirements.

Table 2: Eskom standard electrical and working clearances

System Nominal Voltage (kV)	System Highest Voltage (kV)	Minimum Electrical Clearance		Working Clearance	
		Phase-To-Earth (mm)	Phase-To-Phase (mm)	Vertical (m)	Horizontal (m)
11	12	200	270	2,7	1,3
22	24	320	430	2,8	1,4
33	36	430	580	2,9	1,5
66	72	770	1050	3,2	1,8
88	100	840	1150	3,3	1,9
		(1000)	(1350)	(3,5)	(2,1)
132	145	1200	1650	3,7	2,3
220	245	1850	2300	4.3	2.9
275	300	2350	2950	4.8	3.4
400	420	3200	4000	5.7	4.3
765	800	5500	8000	8	6.6

Notes: Bracketed figures for 88 kV are for full insulation and are to be used only if the system is not effectively earthed. The figures given for systems of 66 kV and below assume non-effective earthing. This table is based on gapped arresters using over-voltage factors.

3.2.4.1.3 Standard insulation levels

The current standard minimum equipment insulation levels within Eskom are as stated in table 3 below.

Table 3: Standard Voltages and Rated Minimum Equipment Insulation Levels at 1 000m AMSL

Nominal System rms Voltage Un (kV)	Highest rms Voltage for Equipment Um (kV)	Rated Peak Lightning Impulse Withstand Voltage (kV)
11	12	95
22	24	150
33	36	200
66	72,5	350
88	100	450
132	145	550
220	245	825
275	300	1050
400	420	1425
765	800	2100

3.2.4.1.4 Insulation pollution performance and requirements

- All sites within 50km from the coast shall be rated as extra heavy pollution unless otherwise indicated by Eskom, and rated at minimum 31mm/kV SCD, and composite insulation.
- Inland sites shall be rated as heavy and minimum 25mm/kV SCD unless local environmental factors deem them extra heavy.
- All porcelain surfaces shall be RTV silicone rubber coated as per [150] & [151].
- There are also extreme cases such as proximity to cement plants, where even the creepage for the 'very heavy' pollution class will be insufficient. The contractor shall verify that technology specified is appropriate.
- IEC 60815, Selection and Dimensioning of High Voltage Insulators Intended for Use in Polluted Conditions [156] must also be considered.

3.2.4.1.5 Insulation Coordination System Studies

The discipline of insulation coordination covers many aspects, as mentioned above and including earthing and grounding [Section 3.2.5.4].

Only these aspects of Insulation Coordination will be assessed and evaluated within the Substation Engineering functional specification.

The consultant is to further identify all other aspects of insulation coordination as may be required by the design, and perform the necessary analysis supported by relevant and appropriate studies. These studies may include but are not limited to:

- Neutral Earthing Reactor Sizing Studies
- Shunt Reactor Neutral Surge Arrester Sizing Studies

- Transient Recovery Voltage Studies
- Temporary Overvoltage Studies
- Resonance Studies
- Surge Capacitor Sizing Studies
- Switching Studies
- Disconnector Switching Studies in the GIS
- Surge Arrester Optimal Positioning and Selection Studies
- Detailed Insulation Coordination Studies when standard clearances are not being met

Where these studies are required, the need must be highlighted to Eskom and the outcomes must be presented at the Substation DRT meeting. However, the Eskom Insulation Coordination Specialist must be consulted for input on the study that is required, as well as for verification and acceptance of the results and recommendations.

3.2.5 Electrical Design

This section gives the consultant the design requirements for the entire electrical installation of the substation. The South African grid code [1], the Standard for Implementation of Substation Layouts for Transmission Substations [6], and Standard for Independent Power Producers Connections at Main Transmission Substations [7], shall be applied at Transmission Stations. The standard information required to produce Substation Design and Drawings [48] take a designer through all aspects of designing various aspects within a Transmission substation. These three guiding documents along with [72] through to [82] should be applied to design the necessary scope. All design shall also abide by [88] and [89].

For new Transmission Stations as a minimum the following switching philosophies apply.

Table 4 : Switching Philosophies per Voltage level

Voltage (kV)	Busbar configuration
11	Double Busbar Selection
22	Double Busbar Selection
33	Double Busbar Selection
66	Double Busbar Selection
88/132	-Double Busbar Selection -Double Busbar Selection with Bypass Bar on Radial Feeds
275/400	-Breaker-and-a-Half -Double Busbar with Transfer *
765	-Breaker-and-a-Half with Reactor Transfer bar

* refer to [6] for applicability.

3.2.5.1 Single Line Diagram

The Single Line Diagram illustrates the electrical location of all major electrical equipment to be installed at a substation. The Single Line Diagram shall be done for the initial as well as for the ultimate state of the substation on conception as per [47]. In creating the SLD, [46], [48], [84], [85], [86], & [87] should be applied. For all approval phases, the successful consultant shall supply Eskom with all drawings in CAD format as per the latest Eskom compatible software package.

3.2.5.2 Basic layout

The Basic Layout covers the location of all major electrical equipment, structures, buildings, roads, etc. in the substation with emphasis on maintaining the required electrical and safety clearances for the specified voltage levels and Lightning Impulse Level (LIL), accessibility to various components of the station, reliability requirements, maintainability, constructability, etc.

The Basic Layout of the substation shall be developed for both the initial stage as well as for the ultimate stage. Basic Layout drawings shall include as a minimum:

- Key Plan / General Arrangement Plan
- Sections
- Steelwork Marking Plan
- Foundation and Trench Layout
- Earthmat Layout
- Shielding Wire Layout
- Tubular Busbar Layout

All these layouts need to abide by [46] and [48]. For all approval phases, the successful consultant shall supply Eskom with all drawings in CAD format as per the latest Eskom compatible software package.

3.2.5.3 Bay Design (Layout)

Bay layouts shall indicate the busbar support, tubular layout, equipment, equipment foundation, columns, beams, Transformer plinth and earthing details to be used for the substation as detailed in [46]. See typical layouts, 0.54/8629 and 0.54/8617 for 132kV and 400kV configurations. For all approval phases, the successful consultant shall supply Eskom with all drawings in CAD format as per the latest Eskom compatible software package.

3.2.5.4 Earthing

Earthing covers permanent, temporary, cable shield and P&C (Protection and Control) facilities earthing. All these earthing installations shall be capable of carrying the ultimate maximum earth fault current for the substation fault magnitude and duration, without causing any hazardous potentials, potential gradients, interference to other systems, or damage.

Earthing system shall include:

- Earthing of all conductive enclosures that may be touched by personnel thereby eliminating shock hazards,
- Earthing to limit voltage in the substation to definite fixed values of step and touch potentials to ensure personnel safety,
- Appropriate earthing around surge arresters and lightning protection masts to create a low resistance path to earth,

- Earthing of all metallic fences and gates around the perimeter of the substation and inside it,
- Earthing around the buildings located inside the substation

To evaluate the safety parameters (step and touch potentials) of the substation earthmat, the electrical soil characteristics of the yard is required. The soil characteristics will form an input into the substation earth grid design process. The process to be followed in measuring the electrical soil parameters is prescribed in the Soil Resistivity Testing for Substation Applications, [9].

Transmission uses HV Yard stones [61] as the upper most level within their stations and shall have a high resistive covering to increase the resistance of the current path through the body for personnel safety.

The Consultant shall conduct Continuity Measurement of Substation Earth Grid Systems to evaluate its integrity according to [117].

New and existing substations earthmat will need to be tested and confirm the design base. Testing the continuity of a substation earth grid is mandatory to establish the integrity of grid interconnections for new / additions to existing grid and is a necessity to detect any open circuit or isolated structures/equipment that should be connected to the earth grid.

The Consultant shall conduct Substation Earth Electrode Resistance Measurement in accordance with [10], to determine / verify that the substation earth grid as installed, complies with the associated design. For existing substations this gives an indication of the grid condition compared to the original design value and/or previously measured values.

The new and final earth grid design shall be done based on calculations and modelling and simulations using the software program CDEGS and according to IEEE 80 Guide for Safety in AC Substation Grounding [8].

The Consultant shall compile and submit an earthing system design report that shall incorporate the earthing studies.

3.2.5.5 Direct Lightning Stroke Protection

Direct Lightning Stroke Protection specifies the required protection of the substation against direct lightning strokes. Direct Lightning Stroke Protection will be achieved by using a rolling sphere method as prescribed in the Direct Lightning Stroke Protection of Substations, [15] .

The technique involves rolling an imaginary sphere radius at busbar level over the surface of the substation. The sphere rolls up and over (and is supported by) the lightning masts, shield wires and other grounded metal objects intended for lightning shielding. A piece of equipment is protected from a direct stroke of lightning if it remains below the curved surface of the sphere by virtue of the sphere being elevated by shield wires or other devices. Equipment that touches the sphere or penetrates its surface is not protected from direct stroke of lightning.

3.2.5.6 Floodlighting Design

Only 24m masts are considered for Floodlighting in a 400/132KV stations.

The following requirements must be adhered to in accordance with the OHS Act inside the HV yard as well as [53]:

- Average of 10 lux minimum must be maintained,
- Average of 20 lux minimum must be maintained within 5m of Transformers, and Reactors,
- Uniformity of 1:5 (minimum: average) must be maintained in the HV yard.

Simulations with RELUX are required to verify the adequacy and extent of existing and proposed new (if necessary) yard lighting

3.2.5.7 Security Lighting Design

Security lighting shall be designed and installed according to the Security lighting for Eskom applications standard, [68]. Maximum of 60W LED luminaires shall be used on a 4m high pole, these poles shall be spaced 15m apart around the inner barrier fence.

The following requirements must be adhered to.

- Average of 10 lux minimum average between the inner and outer barrier fence.
- 4 lux minimum between the inner and outer barrier fence
- Zones of security lighting to operate with energiser zones.

3.2.5.8 Busbars

This subsection provides details on the characteristics of rigid buses, stranded flexible conductors and insulators (string and longrod) to be specified by the Consultant for the entire buswork of the substation. The Consultant shall provide the calculations on which the entire buswork of the substation has been selected. The design philosophies [72] through to [79], are to be applied for the various voltage levels.

For new green field stations rigid tubular busbar configurations shall be applied at transmission stations. For existing stations which are strung with flexible stranded conductors, the existing practice can be extended. Buses, connections, and bus supports shall be designed to withstand worst case scenario of forces resulting from combination static and dynamic forces created by:

- Static pressure of a specified wind speed on tubular conductors, insulators, bus support, connectors, and conductors,
- Static pressure of a specified wind speed on tubular conductors, insulators, bus support, connectors, and conductors, all covered with a specified layer of ice (where applicable),
- Dynamic pressure of wind for above speeds with a specified gust factor,
- Dynamic forces of momentary ultimate short circuit current at installation location,
- Automatic re-closing,

The tubular rigid conductors and stranded conductors shall be sized for maximum mechanical stresses for the worst-case scenario, the conductor temperature rise during ultimate short circuit current for the predicted duration of the fault (3 seconds) and nominal continuous current for specified environmental conditions (aluminium conductors may operate continuously at 90°C). See table 3 for standardized conductor sizes for Transmission stations.

Busbar bay spacing has been standardised across Transmission sites and should be applied as per Table 5 below at all new stations:

Table 5: Standardized Tubular Bay spacing for Transmission Stations

Voltage (kV)	Bay Spacing (m)
88/132	12
275/400	20/24**
765	46

For existing stations, the bay spacing philosophy in place may be maintained.

** See maintenance access section 3.2.5.10.2 for application

3.2.5.9 Station AC Auxiliary Supply

The design of the Station AC Auxiliary Supply system shall be such as to facilitate safe, reliable, correct, and accurate operation of the substation. Design should comply the philosophy document [93]

3.2.5.10 Maintenance access to bay equipment

The manoeuvrability of maintenance vehicles is onerous in determining the layout of circuits within the station. Designs are to comply with Eskom's maintenance management policy [140] and substation and facility maintenance as well [142].

3.2.5.10.1 Operator access

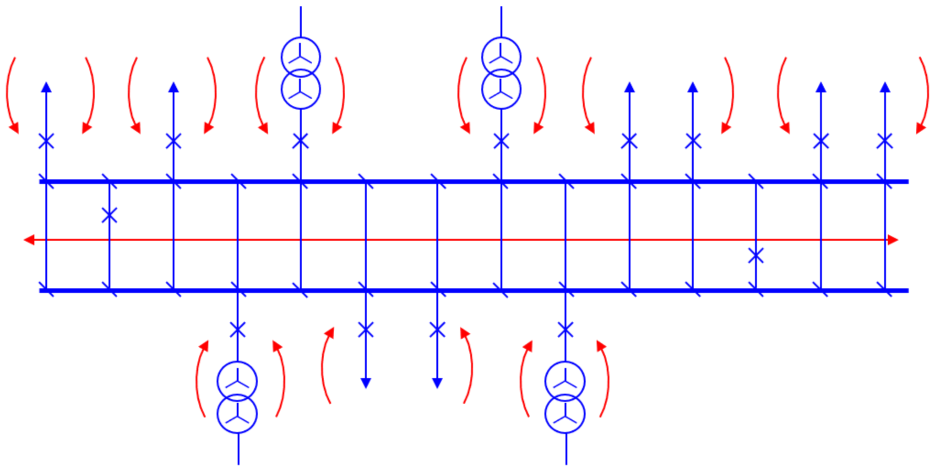
Operators need to access various pieces of equipment for operating, maintenance or visual inspection purposes throughout the substation. Where gauges or operating switches are not accessible from ground level, steps or operating platforms need to be provided for.

3.2.5.10.2 132kV System

This is more critical for voltages 132kV and below. The following points are to be considered for 132kV Layouts to allow for access to all equipment:

- Bay sequencing must be carefully evaluated during layout design to allow for the removal of equipment
- No more than two of the same circuit types exiting the busbar in the same direction are allowed next to each other.
- Optimally allow vehicle access from two sides to any circuit but as a minimum allow vehicle access on one side, see Figure 3 below.
- Allow for sufficient ramps across trenches and access gates through the yard

Figure 3: 132kV Staggered bays to facilitate maintenance



3.2.5.10.3 400kV System

In-line and Side-by-Side arrangements are both supported for 400kV BAH installations. In-Line BAH arrangements are predominantly used when the width of the substation is restricted due to the unavailability of land for the establishment of the substation. Where in-Line BAH Diameters are located next to each other, a minimum bay width of 24m must be used as shown in figure 4 below. Figures 4 & 5 are indicative of 400kV tubular busbar support foundations that are spaced 24m, centre to centre, with a H-Type busbar support cap that makes provision for the installation of two busbar support Post Insulators, 2m on either side of the busbar support foundation centre. Where a vacant space is created between diameters due to the alignment of Feeders and Transformers/Busbar Reactors etc. 20m bay widths are deemed acceptable in such In-line BAH arrangements if vehicle access is achievable, shown in Figure 4 below.

Figure 4: In-line BAH back-to-back configurations – Plan View

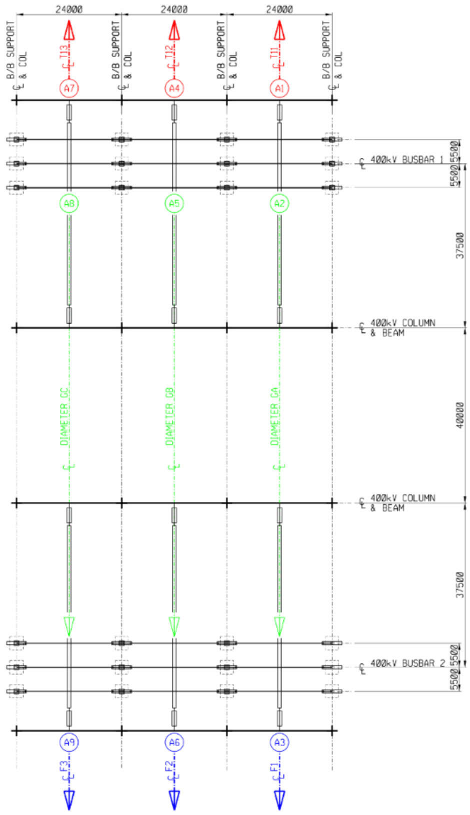
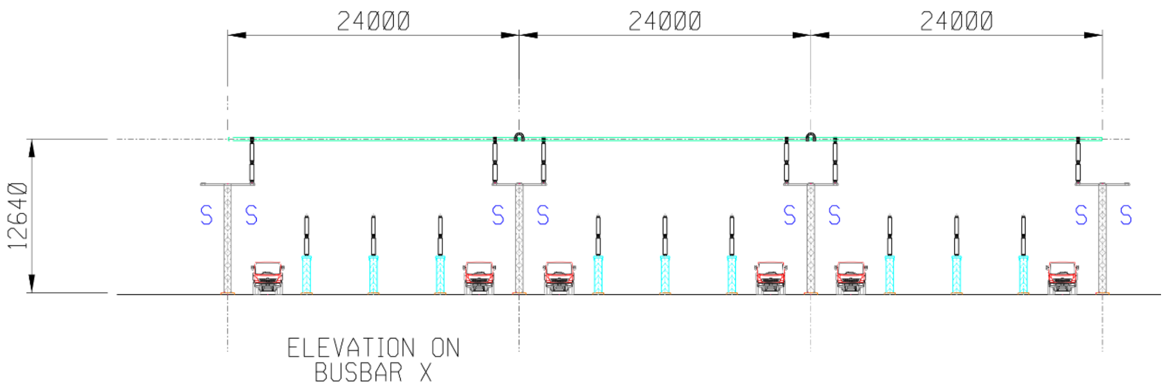


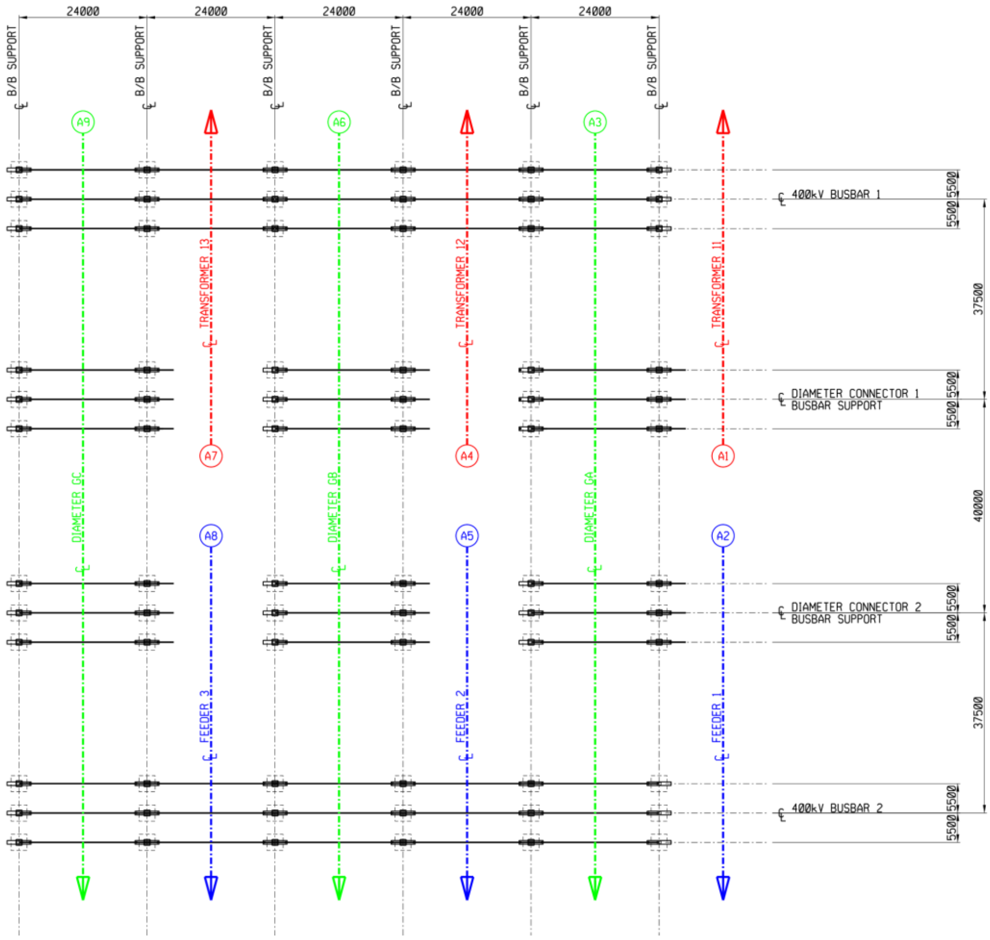
Figure 5: 24m Busbar spacing with H- Type Support Cap – Elevation



Side-by-Side BAH arrangements are preferred above In-Line BAH arrangements as the stringer level conductors and conductors under tensions (excluding the lightning shielding conductors) are omitted.

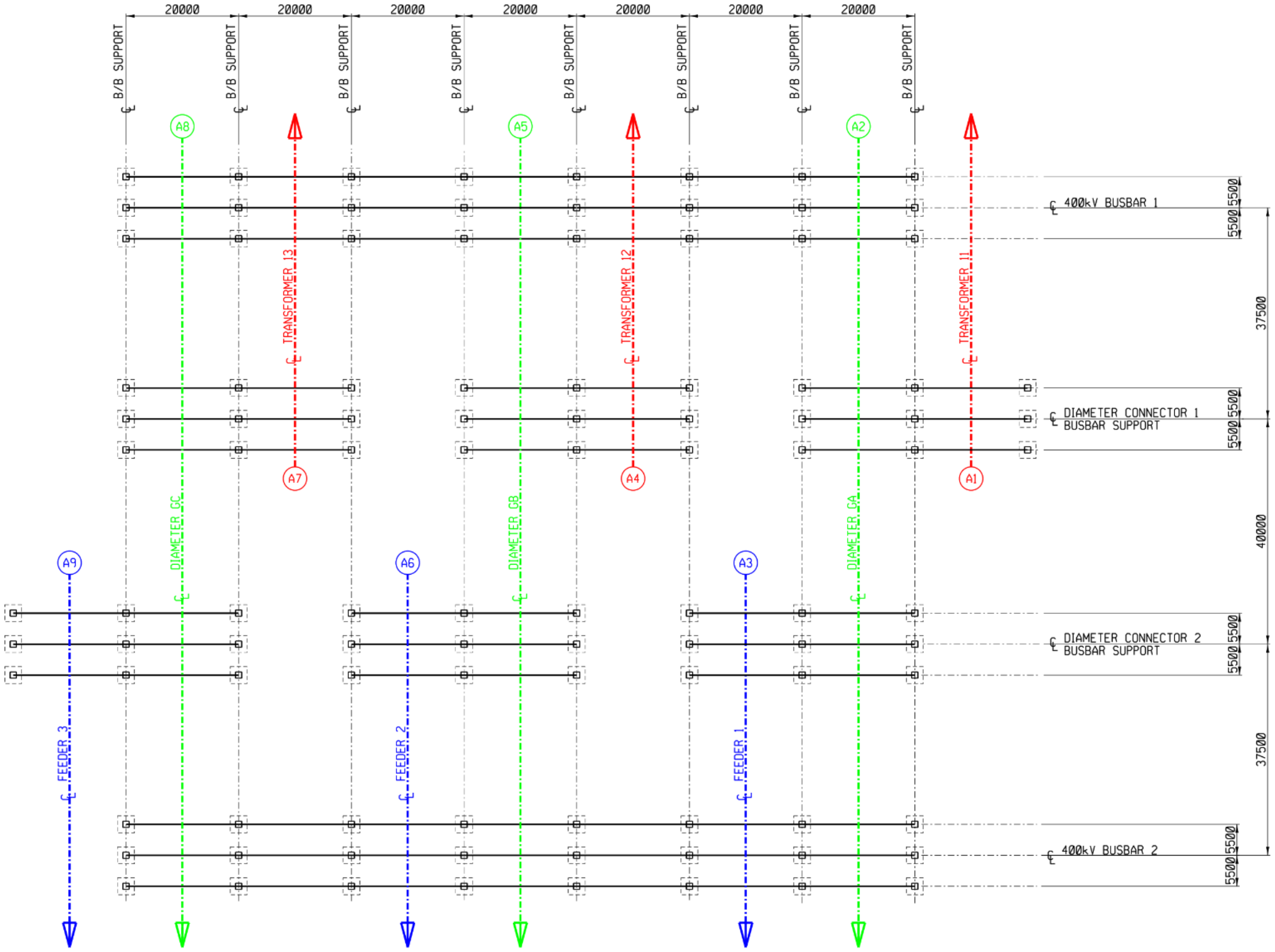
Side-by-Side, BAH arrangements with back-to-back configurations as shown in figure 6 below must be avoided as far as possible. Where such back-to-back configurations cannot be avoided, a bay width of 24m must be used as shown in figure 5 above.

Figure 6: Side-by-Side BAH back-to-back configurations



Staggered configurations for Side-by-Side BAH arrangements as shown in Figure 7 below are preferred. Where staggered Side-by-Side BAH Diameters are located next to each other, a minimum bay width of 20m can be used as shown in figure 7 below as these allow sufficient vehicle access to all pieces of plant.

Figure 7: Side-by-side BAH – staggered configurations



3.2.6 Civil/Structural Design

Civil Works deal with a few aspects namely:

- Geotechnical Investigations, special precautions should be taken regarding substations underlain with dolomite and take into cognisance that possible Footprint Investigations (FPI) may have to be conducted based on the classification and category of the site. The Council of Geoscience must be contacted for comment and review on works on such substations.
- Site development including clearing, levelling, and terrace construction.
- Relocation of existing underground services as necessary.
- Design, building and commissioning of storm sewer systems, site perimeter ditches, subgrade, rough grading, site access and station service roads.
- Stormwater drainage system of the substation area.
- Installation of temporary construction roads.
- Paving and surfacing of the substation area.
- Retaining walls.
- Design, building and commissioning of spill control systems for transformers,

- The design and building of retaining walls for substations that have different levels due to topography of the site.
- The design of the potable water reticulation system of the substation, either getting connection from the municipal or borehole.
- The design of the wastewater management system connecting either to the municipal if there is a possibility of connection or a septic or conservancy tank.

Structural Works deal with concrete foundation, footings, anchor bolts & shear, anchor & piles, outdoor steel structures and substation safety fence. Structural works also covers design of any sound barriers/enclosures around power transformers/reactors required to meet local guidelines for noise.

3.2.6.1 General

The civil infrastructure will be designed in accordance with the relevant SANS standards. In the site assessment process consideration needs to be taken of physical and topographical impacts such as potential for floods, adequate drainage, rocky terrain, uneven terrain, and soil type (from a resistivity and erosion point of view), etc. [59], [62], [67]and [69].

An on-site visual inspection of the soil condition shall be conducted. Thereafter a detailed geotechnical investigation shall be conducted. Should there be a lack of existing geotechnical information or in instances where the existing geotechnical information is deemed insufficient; a site investigation shall be conducted to determine the characteristics and variability of the subsurface geology and geohydrology. The geotechnical testing regime will also make considerations for other factors interacting with the proposed work or structure[111] and [112]. Designs for the new foundations and structures shall be finalised based on the outcome of the geotechnical investigation.

3.2.6.2 Topographical Survey

To assess whether a site is large enough, a topographical survey of the proposed site, a plot/key plan of the substation is required.

The topographical survey gives us the geographical features of the site; it also depicts the natural and man-made features that are critical to be noted for development; these could be rivers, agricultural land use, roads, hiking trails, mining activity, etc. A study of the survey will indicate whether or not there are any peaks that need be avoided so as to minimise the amount of ‘cut’ on the site. It will also indicate whether or not there are large depressions or basins that need to be avoided to minimise the amount of ‘fill’ required as well as minimise the chances of flooding the substation. The standardised survey requirements for Eskom substation design can be found in [60].

3.2.6.3 Geotechnical

The design of the substation will require geotechnical studies to be conducted to determine the underlying soil conditions looking at the soil parameters to be utilised for the design of the substation. Typical tests include foundation indicator tests, bearing capacity, soil strength parameters etc. The investigations should be conducted based on the scope and specification produced for the specific project [137] and the standard referenced in [126].

Special consideration should be taken for sites and/or substations that are constructed in dolomitic land. The site will require Dolomitic Stability Investigations to determine the suitability of the underlying dolomite as it is susceptible to dissolve when it encounters weak acidic water and causes sinkholes and subsidence above in the ground surface [137].

3.2.6.4 Earthworks

Detailed geotechnical studies shall be conducted to outline the full scope of the earthworks. The design of the earthworks shall be in accordance with SANS standard [49], [57], [67] and [69].

3.2.6.5 Roads

All roads leading into and within the substation yard shall be designed to facilitate easy access and loading for transportation and offloading of all major plant and equipment such as power transformers. Access for mobile cranes during construction as well as maintenance and replacement thereof under all weather conditions.

The design of the road shall be in accordance with SANS standard [49], [67], [66] and [138]. The road needs to be capable of carrying a maximum transformer size of 2000MVA.

3.2.6.6 Fencing

High security perimeter fencing shall be installed at all sites as specified in [55] and [56] in accordance with the security risk assessment associated with each site, as determined by Eskom Corporate Risk.

3.2.6.7 Structural Steel

The design of the steelwork shall be in accordance with [97] and [136] where applicable, and fabrication in accordance with [58]. See 0.54/8829 series for varying configurations and layouts.

The design to all structural steelwork shall include the following:

- The electromagnetic forces due to short-circuit current shall be calculated according to [134] or methods described in [135],
- If an equivalent static force is used for the electromagnetic force, the dynamic properties of the structures must be considered through an amplification factor,
- As an alternative to an equivalent static force, a direct dynamic analysis can be conducted,
- For steel support structures, the operational loads of relevant equipment must be considered,
- The non-standard components within all structures, that are not within the scope of [97], must be designed according to the [136],
- The design of all plated components is the structure can be designed using [136], Parts 5 to 7. Finite Element Methods should be used for cases where there are no closed-form solutions,
- Non-linear Finite Element Methods should be used for components that experience stresses higher then yield. In such cases advantage can be taken of the ductility of the steel, and
- Geometric Non-linearity, incorporating imperfections, must also be considered where necessary.

3.2.6.8 Foundation and Plinths

The design of the foundations and plinths shall be in accordance with SANS standard [95] and [96]. Important geotechnical aspects should be considered during design e.g., bearing capacity of the underlying soil must be determined or known and compared with the bearing pressure from the foundation. See 0.54/8829 series for varying configurations and layouts.

All transformers are to be installed with facilities to contain any oil spillage in the event of a tank failure. Bund walls shall be constructed on the concrete slab that forms part of the transformer plinths. No oil shall be allowed to spill beyond the bund wall [104]. See 0.54/8427 series for varying configurations

3.2.6.9 Cable trenches and cable trench covers

The design of the trenches shall be in accordance with SANS standard [49] and [96]. See 0.54/390 series for varying trench configurations, ramps & covers etc

3.2.6.10 Retaining Walls

The design and building of retaining walls is critical to ensure slope stability due to the variation in terrain where the substation is constructed. The retaining wall should be specified in such that it able to withstand the applied pressures and additionally it should be founded on layered engineering G material or stabilised soil to ensure that the underlying soil has adequate bearing capacity.

3.2.6.11 Buildings

The design of buildings shall be in accordance with standards [50], [51], [52], [54], [63], [64], [65], [95], [96], [97], [98], [99], [100], [101], [102], [103], [113], [114], [127] and [128]. Building that should be provided for:

- A control building to host the panels, battery banks, office, and ablution.
- A consumable store building to keep oils, paints, pesticides etc.
- A maintenance workshop and stores building
- An access control building

In the design of the buildings mentioned above, the consultant shall do a contextual study (positioning of the buildings in relation to the HV yard, entrance gate and the access road), take into consideration the positioning of glazing, shielding of glazing, use of insulation and temperature controlling equipment to use less energy, all building designs shall be approved by the local authority as per Act 103 of 1977.

The consultant should consider using cavity walls for coastal and hot regions & solid walls for interior regions. For access control standard drawings see 0.54/7515 series

3.2.6.12 Drainage

Storm water and subsoil drainage to be provided based on the finished terrace design and the overall catchment area that the substation falls in; this will include the design of cut off drains, water divergent channels and soil erosion control measures. The design of the drainage system shall be in accordance with [62], SANS standard [49] and Standard for Substation Flood Analysis Design, [59].

3.2.6.13 Fire Safety Assessment

The Consultant shall provide the details of the fire assessment performed to identify potential fire hazards and treatment by applying the philosophy as captured in [104] and [114].

3.3 Design Standardization

3.3.1 Design Standardization

Design standardization refers to methods of simplifying the product by promoting the use of standard parts and the re-use of parts and subassemblies.

3.3.1.1 Main Foundations and Steelwork

For various voltages up to and including 400kV, Transmission has standardized on a few Main column foundations along with associated column and beam steelwork. See series of application drawings SLDG 21-2 with various sheets capturing typical applications.

Design file calculations for these configurations are verified in [164]

3.3.1.2 Equipment Foundations and Steelwork

For voltages up to and including 400kV, Transmission has standardized on the different height variants of small, medium, and large equipment supports (0.54: 10248, 4358 & 4368) as far as possible for varying applications across HV plant equipment. See application drawings 0.54/ 8829 listing the various types of equipment, their foundations, steelwork and associated top caps. Also see typical bay layouts for 132kV and 400kV, 0.54/8629 and 0.54/8617 detailing these further and applying them for specific scenarios. Table 6 below list the most widely used combinations of foundations, steelwork, and top caps.

Design file calculations for these configurations are verified in [164].

Table 6 : Typical Equipment Foundation, steelwork, and Top cap combinations

<table>
<tr><th>Equipment</th><th>Foundation (0.54)</th><th>Steelwork (0.54)</th><th>Top Cap (0.54)</th></tr>
<tr><td>132kV PI</td><td rowspan="24">4358</td><td>303</td><td>3512</td></tr>
<tr><td>132kV CB</td><td>301</td><td>307</td></tr>
<tr><td>132kV LT</td><td>302</td><td>306 or 307</td></tr>
<tr><td>132k Pantographs***</td><td>313, 10248***</td><td>306 or 307</td></tr>
<tr><td>132kV EMVT</td><td rowspan="20">302</td><td>307 or</td></tr>
<tr><td>132kV SA ****</td><td>306 ****</td></tr>
<tr><td>132kV Isol, 0ES</td><td>10102</td></tr>
<tr><td>132kV Isol, 2ES</td><td>10103</td></tr>
<tr><td>132kV Isol, LH</td><td>10104</td></tr>
<tr><td>132kV Isol, RH</td><td>10105</td></tr>
<tr><td>132kV ES</td><td>10101</td></tr>
<tr><td>220kV Isol</td><td rowspan="4">306, 10110</td></tr>
<tr><td>220kV ES</td></tr>
<tr><td>275kV Isol (4.3m)</td></tr>
<tr><td>275kV ES (4.3m)</td></tr>
<tr><td>275kV Isol (6.7m)</td><td rowspan="2">306, 10111</td></tr>
<tr><td>275kV ES(6.7m)</td></tr>
<tr><td>275kV CB</td><td>306</td></tr>
<tr><td>400kV Isol, (5.5m)</td><td rowspan="2">306,10112</td></tr>
<tr><td>400kV ES, (5.5m)</td></tr>
<tr><td>400kV Isol, (6.5m)</td><td rowspan="2">306, 10108</td></tr>
<tr><td>400kV ES, (6.5m)</td></tr>
<tr><td>400kV Isol, (7.01m)</td><td rowspan="2">306, 10109</td></tr>
<tr><td>400kV ES, (7,01m)</td></tr>
</table>

400kV CVT			307
400kV SA			306 or 307, 6603
400kV CB			306
400kV CT	4368	309	311
400kV LT			4337

*** For Pantographs varying heights of steelwork may be required depending on busbar height and procured product.

**** For 132kV and below Surge arrestors need not have their own support and foundation these can be applied on power transformer or added to adjacent equipment via top cap adaptors that can accommodate both sets of equipment. See 0.54/8739

3.3.1.3 Bay spacing

As stated in 3.2.2, 22kV rated equipment is used for both 11kV and 22kV applications, 132kV rated equipment is used for both 88kV and 132kV applications, and similarly 275kV rated equipment is to be used for both 220kV and 275kV applications. Applying this this together with Transmissions vision to phase out 88, 220 & 275kV Voltages, any new substation requiring these voltages are to be designed at a voltage level up considering insulation levels. 88kV applications are spaced at 132kV and 275kV application are spaced at 400kV insulation levels for any new builds / green fields. This is upfront planning for migrating to standardize the Transmission system at predominantly 132, 400 & 765kV Voltages.

Table 7 : Bay spacing per Voltage level

Voltage (kV)	Bay Spacing (m)
88/132	12
275/400	20/24
765	46

For existing stations, the philosophy in place will be extended

3.4 Design Reviews

The design review should ensure that the most efficient design solution is selected and should abide by [90], [91] and [92]. 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 the design to operations (Grid Owner and National Control) requirements.
- Compliance of designs to design standards, philosophies, practices, and codes.
- Compliance of design to internally issued technical instructions, engineering instructions and technical bulletins.
- Demonstration of sound engineering thinking where a unique solution must be provided (design approach, rationale, assumptions, modelling, calculations, simulations).

- Where deviations from design standards and philosophies, and/or new design standards are proposed, the design review of the proposed deviations or new design must follow the SCOT process, prior to the project review process. This will ensure appropriate technical governance.
- Review, challenge, and approval of the technical designs at the various project stages. These are documented in [94]
- Practicality of the implementation of the design solution.
- Safety in design (design is safe to operate and maintain).
- The design has considered and incorporated all aspects of constructability, procurement, operability, maintainability, sustainability, reliability, availability, testability, expandability, disposability, inspectability 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.

All design must be reviewed for acceptance by Eskom and only when a design has been accepted by Eskom, will the design proceed to the next stage and start procurement of equipment.

Design accountability remains with the contractor, notwithstanding the support or acceptance by Eskom.

The requirements for the various Design review committees are documented in [94]. All design information must be captured in [106] and constitute part of the package that is submitted to Eskom for review. All designs are to be presented at Substation DRT applying the template as in [109].

3.5 Construction Requirements

The Consultant shall comply with all the requirements stipulated in the OHS Act of 1993 - Construction Regulations, 2014, [3]. The requirement of the Operating Regulations for High Voltage Systems [5] shall apply to all construction on the high-voltage apparatus of Eskom. The purpose of the Operating Regulations for High Voltage Systems is to ensure the safety of all persons and to safeguard the apparatus and ensure continuity of supply. These regulations are an extension of and must be read in conjunction with the Occupational Health and Safety Act (Act 85 of 1993) [2] as amended and the regulations made there under.

All construction is to be carried out in accordance with Eskom's Safety, Health Environmental and Quality Specification, [141]. All the necessary safety procedures must be strictly adhered to where construction is to be required in close proximity to other energized electrical equipment.

The consultant is mandated to carry out the necessary inspections at appropriate stages to verify that the construction of the relevant work is carried out in accordance with the design. Typical Method statements [163], and typical quality inspection plans provided in [158], [159] and [160].

3.5.1 Civil Requirements

Construction should be done in accordance to [49], [50], [55], [57], [58], [61], [115], [116], [129], [130], [131], [132] and [133]. Potential bidders should comply with technical returnable as stated in [120] and will be evaluated as per [120].

3.5.2 Electrical requirements

Construction should be done in accordance to [117], [118] and [119]. All substation earthing installations are to be carried out in accordance with the applicable sheet of Drawing 0.54/393 and the proposed project specific Earthmat Layout drawing (Where applicable), Bay Layout Earthing and Transformer Plinth Earthing drawings. Potential bidders should comply with technical returnable(s) as stated in [119] and will be evaluated against [121]. Scoring will be as per [161].

3.5.3 Working in live Substations

All personnel must always comply with the Operating Regulations for High Voltage Systems [5] as set out by Eskom when working on, or in the vicinity of electrical apparatus that is live or is capable of being made live from any source of supply.

Eskom reserves the right to evict any personnel from the site at any time should their presence on-site be considered to constitute a hazard.

3.5.4 Quality Management

3.5.4.1 Workmanship and Materials

Work must be done by appropriately qualified, competent Consultant in an entirely sound, secure, neat, efficient, and professional manner, complying with the relevant Eskom quality requirements. Where materials or work methods are included in the Eskom's specification, the materials and workmanship used must not be inferior to those in the relevant Eskom Standard. Quality Inspection plans are to be submitted to Eskom for acceptance. Baseline QITP's, [158], [159], [160] are supplied as a guide and consultants submissions should cover these as a minimum. These should typically include hold points on first off installations, crimps, cuts, etc

The verifying and hold points specified in this section are intended to provide assurance to Eskom that the prevailing Eskom Standards and specifications are adhered-to during project execution. The verifying and hold points provide a mechanism for Eskom to inspect and test the works during the construction phase. This has the benefit of ensuring that any non-conformances are resolved as early as possible in the construction phase.

Unless otherwise specified, all materials used must be entirely suitable for the intended application, whether stated or implied, and be free from defects. Where materials bearing the SABS (South African Bureau of Standards) mark are available, these materials must be the minimum standard for use. All manufactured materials must be used strictly in accordance with the manufacturer's instructions and recommendations.

3.6 Commissioning and Handover

The requirements for the various Quality Control and Handover process stages for a substation project from the inception of construction to commissioning and final handover are detailed in [70], Inspection Sheets must be completed for all the Substation Equipment that is to be taken over by the Asset Owner. An Operating diagram must be compiled for all the primary plant that is proposed to be commissioned in accordance with [46] and [143], prior to commissioning.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
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5. Revisions

Date	Rev	Compiler	Remarks
July 2023	1	M Peffer	First Issue.

6. Development team

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

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7. Acknowledgements

Not applicable.