Eskom	**Standard**	**Distribution**

Title: **DEVELOPMENT OF FUNCTIONAL SPECIFICATION FOR DISTRIBUTION STATCOM**

Unique Identifier:	**240-171000117**
Alternative Reference Number:	**n/a**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**1**
Total Pages:	**60**
Next Review Date:	**March 2028**
Disclosure Classification:	**Controlled Disclosure**

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Date: 30/03/2023

PCM Reference: **<xxxxxx>**

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Executive Summary

This document presents the technical and functional specification, design requirements, and parameters for a Distribution Static Synchronous Compensator (DSTATCOM) to be used on the 22 kV distribution feeder. The DSTATCOM is designed to offer reactive power compensation, voltage regulation, improve power quality, reduce feeder losses, enhance system stability, and enable renewable PV integration.

The DSTATCOM technology has several control modes, and the control system plays a critical role in selecting and switching between different control modes based on specific distribution network and load conditions. The DSTATCOM technology is a viable solution for addressing power quality issues and improving the reliability and efficiency of distribution networks. A hybrid DSTATCOM with voltage regulation, harmonic mitigation, and communication capabilities can help maintain power quality and stability, ensuring proper functioning of electrical equipment and devices.

The document also includes minimum required system parameters such as efficiency, response time, and fault ride-through capability, for optimal design of protection system, control system & control algorithms, and communication interfaces for remote monitoring and control of the DSTATCOM solution. Overall, the DSTATCOM technology is a promising solution to improve the power quality of distribution systems. The protection, control, and cooling systems should be carefully designed and implemented to ensure optimal performance.

The successful bidder will be required to supply a Full Turnkey solution from studies, design, manufacturing to commissioning of a ±1 MVAr 22 kV DSTATCOM at Disselfontein Zoetgat 22 kV feeder, the installation will be on pole number DZO-172. This location is at GPS 29°35'04.4"S 24°03'01.0"E near Hopetown in Northern Cape province. The feeder has 5 small-scale embedded generation (SSEG) renewable integrated projects, it is supplied from Disselfontein substation and has a 22km long backbone using Hare and Mink conductors, the substation is close to Douglas town. The feeder has a peak load of 7.78 MVA at a power factor of 0.88, and a low load of 1 MVA during off peak period and when the SSEG are at maximum outputs.

This Technical specification is intended for once-off use on the Disselfontein Zoetgat 22 kV feeder to meet the distribution network voltage challenges as defined in this standard. The specification can be used for other Distribution projects, but careful considerations must be made to customize this to meet each projects' specific requirements while meeting safety and regulatory standards. The expected service life of the required DSTATCOM is 30 years.

1. Introduction

This specification is based on the findings and response from Request for Information (RFI) number ERIC3114 and the Eskom RT&D Project number RES/SR/20/1957256 for "A Dynamic Solution that Addresses Threats to Distribution Voltage". This specification outlines the minimum Distribution Group's requirements for ±1 MVAr (1 MVAr capacitive, and 1 MVAr inductive) 22 kV Distribution Static Synchronous Compensator (DSTATCOM) required to provide Volt/Var Optimisation and Control DSTATCOM on a full Turnkey EPC project contract.

The RFI procurement process evaluated Distribution STATCOM technologies that are suitable for addressing threats to distribution voltage and the required technology solution was to regulate voltage within acceptable limits, allow increased penetration levels of Photovoltaic (PV) Distributed Generation (DG) plants, and provide VAR support by injecting or absorbing reactive power into the network. The recommended solution from the RFI and RT&D study was a Volt/Var Optimisation and Control (VVO/VVC) distribution voltage regulation method and technology. It was also found that the VVO/VVC functions required to mitigate the threats to the distribution voltage, its renewable or other distributed energy sources integration can be provided by Distribution Static Synchronous Compensators (DSTATCOM or D-STATCOM) technology. The below listed DSTATCOM equipment were the recommended technologies to refer to for the development of a generic specification required to implement on this project as a pilot;

a) AMSC D-VAR

b) AMSC D-VAR VVO

c) ABB VArPro STATCOM

d) Nidec Silcovar-H STATCOM, and

e) RXHK Maxivar STATCOM.

This document provides a technical and functional standard specification developed based on the findings and response from the RFI number ERIC3114. This specification outlines the minimum requirements, system parameters, protection systems, communication interfaces, efficiency, voltage regulation & control range, cooling systems, fault ride-through capability, control strategy, condition monitoring & online diagnostics, control modes, power factor correction, harmonic suppression, RAM performance & guarantees, lifespan, size & weight, mechanical and environmental parameters. The expected service life of the DSTATCOM is 30 years.

2. Supporting clauses

2.1 Scope

This Specification is for the design, studies, engineering, software provision, material procurement, manufacturing, quality management, factory inspection, testing, transport, delivery to site, insurances, construction, installation, site inspection, testing, commissioning, training, RAM calculations and guarantees, performance verification, warranty and all associated work and services relating to the installation of a ±1 MVAr Distribution Static Synchronous Compensator (DSTATCOM) at Pole number DZO-172 on the Disselfontein Zoetgat 22 kV feeder. The following equipment forming part of the DSTATCOM will be supplied and installed by the supplier to achieve the required functional requirements of the DSTATCOM based on application and requirements, some may not be required while others not on this list may also be included as per design.

a) Power electronics converter

b) DC Link capacitor

c) Protection and Control systems

d) Communication and Tele-control interface

e) Cooling system and air-conditioning

f) Harmonic filter(s)

g) Auxiliary AC and DC power supply

h) Energy Storage System

i) DSTATCOM Transformer

j) Instrument Transformers (CT and VT)

k) MV Breakers/Switchgears, Disconnector, Earthing, Isolators, Cables, Insulators, and Surge Arrestors

l) GPS with an antenna

Details of above components and other important aspects of the DSTATCOM system will be covered in relevant sections of this specification or standard.

2.1.1 Purpose

The aim of this specification is to define the Eskom requirements for the DSTATCOM to be installed at Disselfontein Zoetgat 22 kV feeder.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited, Distribution Divisions

2.2 Normative/informative references

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

2.2.1 Normative

Normative references are documents that are indispensable for the application of this document, i.e. documents to be used together with this document.

[1] ISO 9001, Quality Management Systems.

[2] IEC 61000-4-7 Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques

[3] IEEE 519 Standard for Harmonic Control in Electric Power Systems

[4] SANS 61089 Round wire concentric lay overhead electrical stranded conductors

[5] ANSI C57.12.28 IEEE Standard for Pad-Mounted Equipment - Enclosure Integrity

[6] ISO 9000 International standard for a quality management system (“QMS”)

[7] SANS 780 Distribution transformers

[8] SANS 60076-* Power Transformers (*All parts), SANS 60076-11, Dry Type Distribution Transformers

[9] NRS 079 Distribution standard for the interconnection of embedded generation

[10] SANS 62529 Degrees of protection provided by enclosures

[11] NRS-048-2 and 048-6 Electricity Supply – Quality of Supply

[12] IEEE 1052 IEEE Guide for Specification of Transmission Static Synchronous Compensator (STATCOM) Systems

[13] SANS 1029, Mini-substations for rated AC voltages up to and including 24 kV

[14] SANS 1874 Switchgear — Metal-enclosed ring main units for rated AC voltages above 1 kV and up to and including 36 kV

[15] Act 107 of 1995 National Environmental Management Act

[16] Act 85 of 1993 Occupational Health and Safety Act & Regulations

[17] South African Grid Code – All parts, latest revision

[18] SANS / IEC 61850 Communication networks and systems for power utility automation

[19] SANS 876 Cable terminations and live conductors within air-filled enclosures (insulation coordination) for rated AC voltages from 7,2 kV and up to and including 36 kV

[20] 36-1126 Specification for corrosion protection of plant

[21] 240-171000118 Distribution STATCOM Evaluation Criteria

[22] RES/SR/20/1957256 Outcomes from the Request For Information (RFI) process

[23] 240-119185951 Standard guideline for Trial or Pilot sites

[24] 240-56030635 General Information and Requirements for Medium-Voltage Cable System

[25] 240-71630971: Dx Telecontrol: User Requirements Specification for GSM-Based Communications

[26] 240-97690165 (DSP 34-2123): Specification for telecontrol requirements for ring main units

2.2.2 Informative

[27] 240-71084644 Pole mounted Auto Reclosers standard – part 1: General and protection requirements

[28] 240-76628305 Specification for pole-mounted auto-reclosers, part 2: Telecontrol Requirements

[29] 240-59089329, Eskom's DNP3 Implementation Standard

[30] 240-55410927 Cyber security standard for operational technology (OT)

[31] 240-64038621, Remote Device Communication Standard for Data Retrieval and Remote Access

[32] 240-55410927, Cyber Security Standard for Operational Technology.

[33] 240-71084644, Pole Mounted Auto Reclosers general and protection requirements standard.

[34] 240-62420246 Network planning proposal

[35] TPC41-141: Commissioning of new substation plant documentation and check sheets

[36] ESP 32-846: Operating Regulations for High Voltage Systems (ORHVS)

2.3 Definitions

2.3.1 General

Definition	Description
British Thermal Unit (BTU)	British Thermal Unit. A measurement of how much energy is required to raise the temperature of one pound of water by one degree. It is used on the ratings and size of the Air-conditioners
Forced Interruption	Interruption that occurs when a component is taken out of service immediately, either automatically or as soon as switching operations can be performed, as a direct result of emergency conditions, or an interruption that is caused by improper operation of equipment or human error
Harmonic	A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency
Island network	Network that is operated without connection to the main grid
Life Cycle	Stages involved in the management of an asset, from conception to disposal
Local Control	Control of an operation at a point on or adjacent to the controlled switching device.
Medium voltage	A set of nominal network voltage levels that lie above low voltage and below high voltage in the range 1 kV < Un ≤ 33 kV AC

Definition	Description
Pilot site	An assessment of a technology, methodology and/or prototype where no standard exists and it is a completely new technology that can improve the system performance or operations – i.e. research-based projects, or manufacturer driven technology
Planned interruption	Interruption that occurs when a component is deliberately taken out of service (by the utility or its agent) at a selected time, usually for the purposes of construction, preventative maintenance, or repair
Remote Control	Control of an operation at a point distant from the controlled switching device.
Root mean square / RMS	The square root of the arithmetic mean of the squares of the values. It is used for measurements on AC waveforms.
Trial site	An assessment of a proposed change in technology and/or methodology where a standard exists and could lead to improvement of the existing technology and/or methodology – i.e. operational type changes etc. (developing in-house solutions)
V/I characteristic	Voltage and Current characteristic
Vref	Reference voltage point where DSTATCOM output is zero MVAR

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
AI	Artificial Intelligence
AR	Augmented Reality
BB	Busbar(s)
BIL	Basic insulation level
BTU	British Thermal Unit. Size used on ratings of Air-conditioners
BME	Bandwidth management equipment
CSC	Current Source Converter
CSI	Current Source Inverter
CT	Current Transformer
DSTATCOM (D-STATCOM)	Distribution Static synchronous compensator
D-VAR (DVAR)	Dynamic Volt-Amp Reactive
DG	Distributed Generation
EG / SSEG	Embedded Generation / Small-scale embedded generation
FACTS	Flexible AC Transmission System
FAT	Factory Acceptance Test
Fdr	Feeder, 22 kV Zoetgat distribution line from Disselfontein Rural substation
GPS	Global Positioning System

Abbreviation	Description
GOOSE	Generic Object Oriented Substation Event, it is an IEC61850 protocol.
HMI	Human Machine Interface
IED	Intelligent Electronic Device
IGBT	Insulated gate bipolar transistor
IGCT	Insulated gate-commutated thyristor
IP	International (Ingress) Protection ([1])
IP	Internet Protocol ([2])
IRTU	Integrated Remote Terminal Unit
ISO	International Organization for Standards
IT	Information Technology([1])
IT	Instrument Transformers ([2]). Current and Voltage transformers
MV	Medium voltage
MVA	Mega Voltage-Ampere
LCMP	Life Cycle Management Plan
LVRT	Low Voltage Ride-through
MVAR	Mega Voltage-Ampere Reactive
NPS / PPS	Negative phase sequence / Positive phase sequence
OEM	Original Equipment Manufacturer
OVRT	Overvoltage (high voltage) ride-through
OT	Operational technology
ORHVS	Operating Regulations for High Voltage Systems
PBC	Polychlorinated Biphenyl
PCC	Point of common coupling
PF	Power Factor
POC	Point of Connection
PTM&C	Protection, Telecotrol/Telecommunication, SCADA, Metering, and DC
PWM	Pulse width modulation
QOS	Quality of Supply
RAM	Reliability, availability, and maintainability
RFI	Request for Information
RMS	Root mean square.
RT&D	Eskom Research, Testing, and Development
RTU	Remote Terminal Unit
SANS	South African National Standards
SCADA	Supervisory Control And Data Acquisition

Abbreviation	Description
SER	Sequential Event Recorder
SME	Subject matter expert
STATCOM	Static synchronous compensator
TFR	Transient Fault recorder
THD	Total harmonic distortion
UHF	Ultra-high frequency
USB	Universal Serial Bus
Vref	Reference voltage point where DSTATCOM output is zero MVAR
VSC	Voltage Source Converter
VSI	Voltage Source Inverter
VT	Voltage Transformer
VVC	Volt/Var Control
VVO	Volt/Var Optimisation

2.5 Roles and responsibilities

Transmission Power Electronics will ensure that this document remains current, Distribution division will implement this document to the pilot project on the selected site.

All personnel involved in the procurement of the products specified in this standard shall ensure that the product supplied comply with this standard.

The Project Manager, working with Eskom RT&D, will co-ordinate the acquisition of land and capturing the site data for the selected pilot site and record all site information as per 240-119185951.

2.6 Process for monitoring

Power Electronics Care Group shall monitor and maintain this standard and the evaluation criteria to ensure that they remain current.

2.7 Related/supporting documents

Not applicable.

3. Administrative responsibilities

3.1 Work to be done by The Contractor

The Contractor, on an EPC Full Lump Sum Turnkey contract, will provide the following as part of the contract of tender for the Employer;

a) Engineering design of the DSTATCOM system and all its components

b) Do studies and submit reports with the bid submission for all simulations, modelling, electrical studies for the verification of DSTATCOM ratings, functionality, protection, control, cooling, and the overall system performance.

c) Transport; packaging; loading, and safe/secure delivery and offloading of all components, material, equipment, and spares to site.

d) Provide a suitable storage of all equipment to be used in the scope of supply and construction for this project.

e) Erection and installation of all material, equipment, components and the DSTATCOM system. Work includes the design and implementation of earthing and earth mat / grid system.

f) Type, Routine, Special, Factory, and Site Testing of plant and material of the DSTATCOM system. FAT testing will be done on all protection and control cards and related equipment to try and ensure better field performance and lower failure rates. This will include the Type & Endurance testing on these cards before acceptance and on card with high failure rates to be done by the OEM.

g) Integration of the DSTATCOM into the 22 kV feeder, including supply of the step-down transformer control, protection, and interlocking systems if required as per supplier's design.

h) Labels shall be supplied and installed by the contractor, they shall meet the minimum requirements below;

    1) Labels shall be in English

    2) They shall be indelibly and permanently marked, and securely attached to equipment

    3) Warning and danger signs/labels shall be RED on a WHITE background.

i) Lightning protection, earthing, civil works, and supporting structures as required will all be done by the contractor.

j) Name plates for all materials and equipment will be supplied and installed by the contractor as per applicable standards indicating the following at a minimum; They shall be clearly, legibly, and indelibly marked on corrosion-resistant rating plates.

    1) Manufacturer's name

    2) Manufacturer's type number

    3) Manufacturer's serial number

    4) Year manufactured

    5) Equipment rating(s), as applicable

    6) Rated voltage, frequency, power factor, altitude, etc

    7) Short-time withstand current, and time

    8) Type of converter used

k) Development and implementation of a complete external device control program, hardware, and software as well as integration to the Communication interfaces between the DSTATCOM and the Employer's control centre.

l) Commissioning of the complete DSTATCOM as a system.

m) Training to be provided to the Employer's technical team (including Engineers, Maintenance & Operating staff), training shall be developed in two levels with scope suitable for engineers and operational teams responsible for testing, configuration, and diagnostics.

n) Performance verification and field acceptance testing, RAM, studies, and guarantees. The RAM period is 2 years from the date of commercial operation.

o) Documentation, including maintenance manuals, drawings, settings, and configuration for the DSTATCOM system and its components.

p) Maintenance and emergency assistance during the guarantee period, the guarantee period shall be 5 years from the date of commercial operation of the DSTATCOM. The Contractor shall be responsible to correct all defects during the 5 years defect liability period.

3.2 Work to be done by The Employer

a) The Employer will provide a Project Manager (PM) who will serve as the Employer leading all project activities. The contractor will report to the PM at all times.

b) The Employer shall provide the site for the installation of the DSTATCOM.

c) The Employer will provide the 22 kV connection point at Pole DZO172 where all terminations will be made to the DSTATCOM system. All material to connect the DSTATCOM will be for the Contractor.

d) Eskom, the employer will supply the design drawing for the existing feeder pole as part of the tender enquiry documents. Annex D

e) The Employer will provide a storage site where all spares, test equipment, and special tools will be stored after delivery on completion of the project construction work and commissioning.

f) The Employer will supply all Telecontrol interface equipment, install communication and configure database and RTU/IRTU equipment for the DSTATCOM.

g) The employer will supply Quality of supply data recorded over two (2) weeks (Harmonic, Unbalance, Voltage regulation, and Flicker data) to the bidders for the assessment of background harmonics and unbalance, which will be used as a base for the design of the DSTATCOM.

h) The Employer will supply, install, configure, and commission the metering equipment at the DSTATCOM point. This includes the meter, modem, and antenna as required.

3.3 Kick-off, base design, and handover

3.3.1 Basic Mandatory Requirements (BMR) for Tendering

a) There will be a Compulsory Site Clarification project visit at Pole number DZO-172 on Disselfontein Zoetgat 22 kV feeder (GPS 29°35'04.4"S 24°03'01.0"E) on a date to be published with the tender enquiry, this is a mandatory requirement for tendering and bidders who do not attend this will not be evaluated further on technical requirements.

b) Bidders will supply single line drawings for the DSTATCOM and provide a list of all material and equipment that will be required to form part of the system as per their design, this will include all equipment and material required to terminate the DSTATCOM onto the existing 22 kV Feeder. All drawings, except for the 22 kV feeder & pole, will be done and supplied by the bidder as preliminary drawings for all equipment, material, and system design. The final drawings will be done during the design review and submitted to the Employer for review and approval.

c) All bidders must complete the applicable section of this standard, and complete the A & B schedule in full as the tender returnable. The Schedule A & B for the DSTATCOM system is in Annex A of this standard in English.

d) The supplier must provide a list of Reference installations across renewable applications, utilities, and industrial applications for similar projects containing details of equipment ratings and countries where these projects were done, including the date of completion which should not be older than 10 years.

e) All equipment, material and subsystems required to complete the works in this specification shall be submitted with bid documents and the required tests on these shall be done as per applicable IEEE, IEC, SANS, or Employer standards.

f) All deviations must be stated and listed as per Annex E of the standard. Each deviation will be assessed on risk and merit for acceptability. Copies of the same annexure can be used if more deviations are to be recorded. The bidder must state if there are no deviations.

3.3.2 Tender bid submission

The bidders shall submit the bid tender price for a 22 kV DSTATCOM system which is subject to the contractor's optimum design for the distribution voltage challenges, quality of supply, and renewable energy integration per specification in this standard. Standard 240-171000118 will be used for evaluation of the bids.

3.3.3 Kick-off meeting

a) A Kick-Off Meeting will be held in The Employer's Offices shortly after award of the Contract.

b) This meeting will cover Project implementation, the Scope of work, and Schedule. This will give The Contractor an opportunity to discuss all matters related to carrying out their responsibilities.

3.3.4 Base Design and Design Review Phase

a) The base design phase of the Project is a sixteen (12) weeks period of preliminary engineering following the kick-off meeting.

b) The purpose of the base design phase is to completely carry out system design studies / preliminary engineering to define the main ratings of all the equipment and to satisfy The Employer that all requirements are being incorporated.

c) Information developed during the base design shall be used as a guide throughout the Project and shall be considered binding on both parties, unless operational difficulties or design flaws observed during the detailed design review are noted and mandate change.

d) Coordination meetings will be conducted with the design team of The Contractor on a regular basis until the design is complete.

e) Design Calculations, Design Drawings, other documents, civil, electrical, communication, protection, Cooling system, SCADA, Control, and line drawings. These documents and reports shall be available in a readable *.pdf format and drawings must be in *.pdf as well as CAD/MicroStation *.dgn format.

f) The base design submittal shall be complete, containing drawings and calculations as required for this project solution.

g) Base design shall include drawings required to define the project. The Contractor will submit their project scope of work and project milestones which shall be subject to review, modification, comment, and/or approval by The Employer.

h) The Contractor shall submit report with list of all protection and control signals for Protection, Control, for all Digital and Analogue indications, Status, Controls, and Alarms.

i) After completing the Base Design, The Contractor shall present the Base Design Package for technical review along with the Drawing Control Sheet at the design review meeting which will be held at the Employer's selected venue.

j) The Contractor will await final approval of the design by the Employer before any procurement of material and/or equipment required for this project. Procurement undertaken before final approval of the Base Design shall be done at risk and at full cost to The Contractor if rejected by The Employer.

k) Project Interface Design Review

    1) The Contractor shall allow for the following interaction to take place with The Employer. It is expected that a monthly meeting will be held to facilitate this interaction.

    2) Scheduled project review meetings shall include review of project management, schedule, cost, technical design, testing (Type, Routine, Special, FAT, and Site Acceptance Tests), Master Test Plan (MTP), and quality assurance planning deliverables

    3) Interface meetings shall include subject matter experts and will be co-ordinated through the Employer.

l) The Contractor scope of supply as agreed from design review shall include all these activities in their accepted Programme of work, including Preliminary one and any subsequent revised submissions.

3.3.5 Testing Responsibilities

a) The Contractor shall perform all testing except for the performance verification and acceptance tests and the extended verification and acceptance tests, which will be conducted by The Employer.

b) All tests that require the connection of the DSTATCOM to Eskom's distribution feeder shall be done under the supervision of The Employer and in accordance with the safety requirements and Operating Regulations for High-Voltage Systems and Eskom's life saving rules.

c) Energised system testing shall be kept to a minimum.

d) The Contractor shall provide energisation procedures as part of the Commissioning Test Plan.

3.3.6 Life Cycle Management Plans

a) To ensure that value is realised from DSTATCOM, a Life Cycle Management Plan (LCMP) model is required to ensure that all the asset management activities to be undertaken throughout the life of the DSTATCOM equipment are focused on, to provide means to enable the achievement of asset management objectives.

b) The LCMP stages cover the contract kick-off, Base design, and all activities up to the asset handover to ensure that the product offered complies with all operational and functional performance as required. A kick-off meeting is to be held at Eskom's premises shortly after the contract award. The Base design (studies, design drawings, calculations, prelim engineering, equipment ratings, etc.) will be done and presented to the Employer for review and acceptance by subject matter experts (SME).

c) The key milestones for each scope of works are to be listed for the execution of the project. The contractor will then develop an LCMP with focus on the operational lifecycle, maintenance requirements, and life extension initiatives.

d) The contractor shall provide the Employer with a detailed LCMP document detailing the asset optimisation interventions, maintenance, and other steps to be taken during the operational life of the asset from commissioning stage to asset retirement.

3.3.7 Project Completion and handover

In addition to the Conditions of Contract, the following shall apply. Completion of the Contract shall occur when all of the following activities, as a minimum, have been successfully completed and approved by The Employer:

a) The complete DSTATCOM system as specified has been installed, tested, and commissioned as described in this specification and/or design review agreement.

b) As part of Commissioning tests, the Contractor shall comply with Eskom's requirements for commissioning as described in standard TPC41-141. The plant shall not be handed or taken over unless this standard is complied with, in all respects.

c) The DSTATCOM has successfully passed all The Employer's Performance Verification and Acceptance Tests.

d) All contract spares have been delivered to the site, and all spare electronic cards/modules have been correctly tested and calibrated on site.

e) The test equipment has been delivered to the site, and has been correctly calibrated and configured.

f) The special tools have been delivered to the site.

g) The reviewed copies of the complete documentation and drawings have been delivered to Eskom.

h) Training of the personnel of The Employer has been completed as defined in this specification.

4. Technical and Functional specification of the DSTATCOM

The DSTATCOM is made up of Power electronic converter, DC link capacitor, protection & control systems, and the cooling system. Additionally, there may also be isolators, switchgears, insulators, surge arrestors, links, smoothing reactors, filters, and a step-up or step-down transformer, auxiliary AC & DC systems, and fixed capacitor & reactors depending on the application.

Figure 1 shows a generic DSTATCOM single line diagram. The high level components of the DSTATCOM are as per section 4.1 to 4.7 of this standard, and 4.8 details some expectations and requirements for installation of the DSTATCOM.

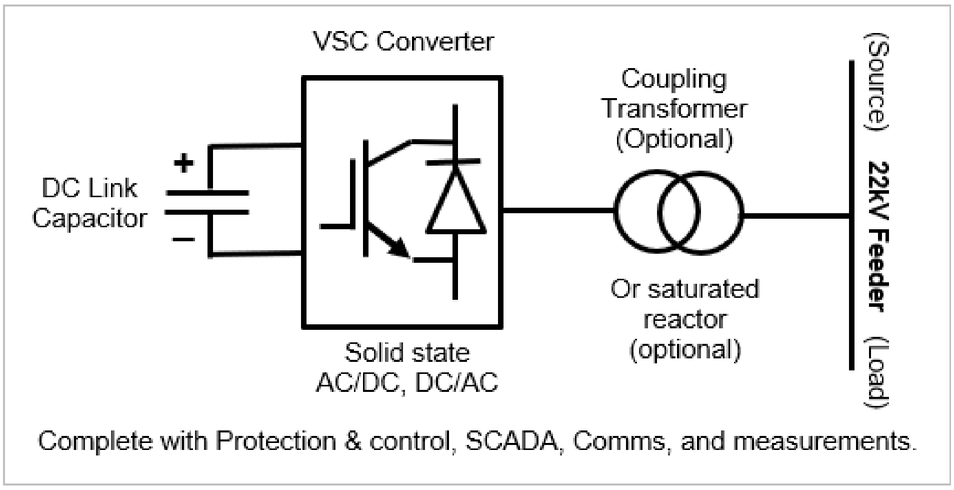

Figure 1: DSTATCOM single line diagram, generic

4.1 Power Electronics converter

The power electronic converter can be either a Voltage Source Converter (VSC) or a Current Source Converter (CSC) depending on the specific application requirements and design. The converter is connected in shunt/parallel with the distribution network and is capable of injecting or absorbing reactive power to regulate voltage and improve power quality.

The DC link capacitor provides energy storage for the converter and ensures a smooth output voltage. The control system, its algorithms, and communication interfaces are used to regulate and control the converter output and ensure stable operation of the power electronic converter. The DSTATCOM can include protective devices with protection functions such as overcurrent, overvoltage, undervoltage, and temperature protection to ensure safe and reliable operation of the voltage or current source converter.

The DSTATCOM technology is based on either the VSC or CSC and these have different functionalities and designs. The table below compares and contrasts the VSC and CSC as used in DSTATCOM technology.

Table 1: Voltage and Current Source Converters (VSC and CSC) comparison

Parameter	Voltage Source Converter (VSC)	Current Source Converter (CSC)
Also referred to as	Voltage Source inverter (VSI)	Current Source inverter (CSI)
Applications	Used on wide range of applications	Limited to specific applications
Control strategy	PWM-based	Current-fed
Efficiency	Higher efficiency at full load	Lower efficiency at full load
Grid interconnection	Requires a DC link capacitor	Directly connected to the grid

Parameter	Voltage Source Converter (VSC)	Current Source Converter (CSC)
Harmonics	Can be reduced using advanced control algorithms	Higher harmonic content and can require a filter
Output voltage regulation	Fast response time, high accuracy	Slow response time, low accuracy
Power factor correction	Can achieve unity PF	Requires external PF correction
Size and weight	Compact and lightweight	Larger and heavier
Voltage step size	Can be very small (microseconds)	Larger step size (milliseconds)

The above table shows that VSC and CSC have some key differences in their control strategies, power factor correction, output voltage regulation, harmonics, efficiency, protection systems, grid interconnection, cooling systems, voltage step size, size and weight. VSCs use PWM-based control algorithms to achieve high accuracy and fast response time in voltage regulation, while CSCs are current-fed and require external power factor correction. The Voltage Source Converter (VSC/VSI) is more efficient and can reduce harmonics more effectively, the requirement on this project is a DSTATCOM that uses VSC technology. The VSC using Multi-level voltage source converter topology is largely used on Transmission STATCOM's operating at higher power and high switching frequencies to provide smoother output waveform.

There are two types of DSTATCOMs: Grid-Forming DSTATCOMs and Grid-Following DSTATCOMs and as an added advantage, it is also possible to have a Hybrid (Multi-mode) DSTATCOM system that combines both Grid-Following and Grid-Forming technologies.

4.1.1 Grid-Forming vs Grid-Following DSTATCOM

A Grid-Following DSTATCOM is a power electronics-based device typically used to mitigate voltage sag, voltage swell, flicker, and other power quality issues. This device is dependent on the availability of the network supply. A Grid-Following DSTATCOM operates in parallel with the grid and is designed to follow the grid voltage and frequency to compensate for reactive power and to maintain a stable voltage level. In a Grid-Following DSTATCOM, the device operates as a current source and follows the voltage level and frequency of the distribution network. The outputs from the DSTATCOM include reactive power compensation, voltage support, or power factor correction, which are driven by the Active Power Control (APC) of the DSTATCOM. The APC feature is used to regulate the active power output of the DSTATCOM to maintain the power factor of the system.

A Grid-Forming DSTATCOM is an advanced power electronic device used to improve the quality of power supply. It can operate in both grid-connected and islanded mode, meaning that it can maintain power quality and forms its own microgrid and supply power to loads independently of the distribution network even when the grid is unavailable. In a Grid-Forming DSTATCOM, the device operates as a voltage source and controls the voltage and frequency of the power system. The APC feature is used to regulate the active power output of the DSTATCOM to maintain the voltage level within the desired range, the DSTATCOM outputs include Voltage magnitude, Current phase angle and Frequency.

4.1.1.1 Main components of a Grid-Following DSTATCOM

a) Voltage Source Inverter (VSI): The VSI converter converts the DC voltage supplied by a DC capacitor into an AC voltage that is synchronized with the grid voltage. The VSI is responsible for generating the compensating current required to mitigate voltage fluctuations and improve power quality.

b) DC Capacitor: The DC capacitor is used to store and supply DC voltage to the VSI. It acts as a buffer between the input and output of the VSI.

c) Control System: The control system is responsible for monitoring the grid voltage and current, generating the reference compensating current, and regulating the DC voltage across the capacitor. The control system is designed to maintain a constant voltage across the capacitor, which is necessary to ensure proper operation of the VSI.

d) Transformer: The transformer is used to step-down the voltage of the grid voltage to a level that can be used by the VSI and to step up the DSTATCOM AC voltage to match the network voltage. It is also used to provide isolation between the DSTATCOM and the grid.

e) Harmonic Filters: Filters are used to suppress the background harmonics and the harmonics generated by the DSTATCOM and ensure that the THD on the network is below the limits specified in this specification and other standards. Typically, both L-C filters and active filters are used to filter out the harmonics.

f) Monitoring and Protection System: The monitoring and protection system is responsible for monitoring the operation of the DSTATCOM and protecting it from faults and abnormal conditions. It includes sensors for measuring voltage, current, and temperature, as well as protection relays for detecting faults and abnormal conditions on the DSTATCOM and the distribution network.

A Grid-Following DSTATCOM does not require a power source or energy storage system, as it operates in parallel with the network and follows the voltage and frequency of the network. It does, however, require protection devices to ensure the stability and security of the network.

4.1.1.2 Main components of a Grid-Forming DSTATCOM

a) Power Electronics Converter: It is responsible for the conversion of AC power to DC power and vice versa. In a Grid-forming DSTATCOM, the converter can operate in both voltage control and frequency control modes to maintain grid or network stability.

b) Energy Storage System (ESS) or Power Source: The ESS is used to store energy during low demand and supply it during peak demand. A Grid-Forming DSTATCOM needs to have its own power source to operate in island mode. The energy storage system or power source can be in the form of batteries (Battery Energy Storage System - BESS) or supercapacitors.

c) Control System: It is responsible for the overall control of the DSTATCOM, including voltage and frequency regulation, power flow control, and fault detection and protection. The control system uses advanced algorithms to ensure the operation of the DSTATCOM. It needs to be able to monitor and control the voltage and frequency of the microgrid it forms.

d) Grid Synchronization Unit: It is used to synchronize the DSTATCOM with the network and maintain network stability. The grid synchronization unit ensures that the DSTATCOM generates power that is in phase with the grid and meets the grid voltage and frequency requirements.

e) DC Link: It connects the converter and the energy storage system and acts as a buffer to regulate the power flow between them, the DSTATCOM uses DC capacitors for this purpose at this operational level of the DSTATCOM.

f) Protection System: It is responsible for detecting and protecting the DSTATCOM and the network from faults and abnormal conditions. The protection system uses various sensors, fuses, Intelligent electronic devices (IED) and relays to monitor the DSTATCOM and disconnect it from the network in case of a fault to ensure the system remains stable and secure.

Together, these components make up a Grid-Forming DSTATCOM that can provide a stable, reliable and ensure uninterrupted power supply to critical loads, without a battery or energy storage device, it is not possible to operate a Grid-Forming DSTATCOM in this mode.

4.1.2 Control and operating modes: Grid-Forming vs. Grid-Following DSTATCOMs

Table 2: Control and operating modes in Grid-Forming vs Grid-Following DSTATCOM

Control/Operating Mode	Grid-Forming DSTATCOM	Grid-Following DSTATCOM
Black Start Capability, Microgrid Operation, Operation during Islanding as a standalone power source	Yes	No
Frequency Regulation	Yes	No
Inertia Support, DSTATCOM can provide grid inertia support and fault current	Yes	No
Power Factor Control, Independent control of PF	Yes	No, dependent on grid
Voltage Source Converter (Inverter operation)	As a voltage source	As a current source

4.1.3 Common Operating modes between Grid-Following and Grid-Forming DSTATCOMs

Table 3: Common Operating modes between Grid-Forming and Grid-Following DSTATCOM

Control/Operating Mode	Comments, applicable to both modes
Active Power Control (APC)	Yes, (APC feature is used differently based on application and control objectives)
Fault Current Limitation	Yes
Harmonic Mitigation	Yes
Integration with Renewable Energy Sources	Yes, (Embedded, distributed Solar PV and wind)
Reactive Power Compensation	Yes
Unbalance Mitigation	Yes
Voltage Regulation	Yes
Voltage Sag Correction	Yes
Voltage Swell Correction	Yes

Analysis of the above two tables show that the reactive power support and voltage mitigation on the distribution network can be achieved by using a Grid-Following DSTATCOM as it meets the required technology solution for the challenges defined. The APC control function is used to regulate the active power flow in the AC network by regulating Power factor on Grid-Following mode, and regulating the Voltage magnitude and frequency in Grid-Forming DSTATCOM mode.

4.1.4 Pros and Cons of Grid-Forming and Grid-Following DSTATCOMS

The advantages and disadvantages of using a Grid-Following DSTATCOM vs a Grid-Forming DSTATCOM on distribution networks.

Table 4: Pros and Cons between Grid-Forming and Grid-Following DSTATCOM

Grid-Following DSTATCOM	Grid-Forming DSTATCOM
Pros:	**Pros:**
1. Can be easily integrated into an existing grid without significant changes.	1. Can operate in islanded mode, providing power to critical loads during grid outages.
2. Can provide reactive power compensation and voltage regulation to improve power quality.	2. Can help to reduce the impact of voltage fluctuations caused by intermittent renewable energy sources.
3. Can reduce the risk of equipment damage and downtime due to power quality issues.	3. Can help to increase the reliability and resilience of the distribution network.
Cons:	**Cons:**
1. Does not provide active power support, which limits its ability to manage the active power flow on the grid.	1. Requires a more complex control system to manage the active power flow and ensure synchronization with the grid.
2. May require additional equipment, such as a synchronous condenser, for inertia to maintain stability on the grid.	2. May require significant changes to the existing grid infrastructure, including the addition of protection and control systems.
3. It may not be able to provide power during network outages.	3. May require additional maintenance and operational costs due to the complexity of the control system and equipment.

The key difference between Grid-Forming DSTATCOM and Grid-Following DSTATCOM lies in the way their voltage source converters operate. A Grid-Forming DSTATCOM inverter operates as a voltage source, while it operates as a current source in a Grid-Following DSTATCOM. This difference in operation affects their ability to regulate frequency and provide grid inertia support.

4.1.5 Control and operating modes of a Grid-Forming DSTATCOM technology

A Grid-Forming DSTATCOM can operate in different modes to control the voltage, frequency, and power flow. Some of the control and operating modes of a Grid-Forming DSTATCOM are:

a) Voltage regulation mode: In this mode, the DSTATCOM controls the voltage of the electrical grid by injecting or absorbing reactive power. The DSTATCOM senses the grid voltage and generates a voltage reference signal to maintain the desired voltage level.

b) Frequency regulation mode: In this mode, the DSTATCOM controls the frequency of the electrical grid by injecting or absorbing active power. The DSTATCOM senses the grid frequency and generates a frequency reference signal to maintain the desired frequency level.

c) Power factor correction mode: In this mode, the DSTATCOM corrects the power factor of the electrical grid by injecting or absorbing reactive power. The DSTATCOM senses the power factor of the grid and generates a reactive power reference signal to maintain the desired power factor level.

d) Islanding mode: In this mode, the DSTATCOM operates as a Grid-Forming source to supply power to a local load in the event of a grid outage. The DSTATCOM generates a voltage and frequency reference signal to maintain the required power supply to the local load.

e) Voltage unbalance correction mode: In this mode, the DSTATCOM senses and corrects the voltage unbalance in the electrical grid by injecting or absorbing negative or zero-sequence currents, and generates a reference signal to maintain the desired voltage balance level.

f) Harmonic mitigation mode: In this mode, the DSTATCOM mitigates the harmonic distortion in the electrical grid by injecting or absorbing harmonic currents. The DSTATCOM senses the harmonic distortion and generates a counter/negative harmonic signal to reduce the distortion.

g) Load balancing mode: In this mode, the DSTATCOM balances the load in the electrical grid by injecting or absorbing active or reactive power.

These are some of the control and operating modes of a Grid-Forming DSTATCOM, and the device can be programmed to operate in different modes based on the specific requirements of the network.

4.1.6 Control and operating modes of a Grid-Following DSTATCOM technology

The Control and operating modes of a Grid-Following DSTATCOM when used to compensate for reactive power, unbalance, and harmonic distortions in the power system allow for the system to operate in different control and operating modes, which are listed below:

a) Reactive Power Control Mode: In this mode, the DSTATCOM regulates the reactive power in the system by injecting or absorbing reactive power as required.

b) Voltage Control Mode: In this mode, the DSTATCOM regulates the voltage at the point of common coupling (PCC) by injecting or absorbing reactive power.

c) Harmonic Control Mode: In this mode, the DSTATCOM mitigates harmonic distortions in the power system by injecting an equal and opposite harmonic current.

d) Unbalance Control Mode: In this mode, the DSTATCOM mitigates the negative and zero-sequence components in the system by injecting an equal and opposite unbalanced current.

e) Power Factor Correction Mode: In this mode, the DSTATCOM regulates the power factor of the system by injecting or absorbing reactive power.

f) Islanding Mode: In this mode, the DSTATCOM operates in an isolated mode and supplies power to the load in the event of a power outage.

g) Grid-Following Mode: In this mode, the DSTATCOM follows the grid voltage and current waveforms and regulates the voltage and current at the PCC.

h) Current Control Mode: In this mode, the DSTATCOM regulates the current in the system by injecting an equal and opposite current.

i) Frequency Control Mode: In this mode, the DSTATCOM regulates the frequency of the system by injecting or absorbing active power.

These control and operating modes enable the DSTATCOM to provide a wide range of services to the power system, including voltage and reactive power support, harmonic and unbalance mitigation, power factor correction, and islanding operation.

4.1.7 Hybrid or Multi-mode (combination of Grid-Forming & Grid-Following) DSTATCOMs

The Multi-mode or Hybrid DSTATCOM technology has more operating modes and control functions as it combines two distinct operating systems from Grid-Following and Grid-Forming DSTATCOM. A Multi-mode DSTATCOM is a power electronics device that can provide various power quality and network grid support functions, making it a more versatile and flexible solution for distribution networks. For example, the system can operate in Grid-Following mode to provide reactive power compensation and voltage regulation during normal grid conditions, and switch to Grid-Forming mode to provide active and reactive power support during grid outages or in islanded mode.

The control system of a hybrid DSTATCOM plays a critical role in ensuring smooth and seamless switching between different modes of operation. The control system must be able to monitor the grid conditions and switch the system between grid-following and grid-forming modes as required. The control system must also ensure synchronization with the distribution network and maintain stable operation during mode switching.

The design of a DSTATCOM required on this specification is a Grid-Following technology, however, as an equivalent alternative, bidders can supply a Hybrid DSTATCOM with both the functionality of a Grid-Forming and a Grid-Following DSTATCOM with an option to operate it with and/or /without an ESS.

4.1.7.1 Different control and operating modes of a Hybrid DSTATCOM

a) Grid-Following Mode: In this mode, the hybrid DSTATCOM follows the voltage and frequency of the grid. The system provides reactive power compensation and voltage regulation to improve power quality and maintain grid stability.

b) Grid-Forming Mode: In this mode, the DSTATCOM operates in standalone mode and provides both active and reactive power support to the load. This mode is typically used in islanded microgrids or during grid outages to maintain power supply to critical loads.

c) Load Following Mode: In this mode, the hybrid DSTATCOM follows the load demand and adjusts the power output accordingly. This mode is useful where the load demand is highly variable and requires precise control of the power output.

d) Energy Storage Mode: In this mode, the DSTATCOM is integrated with an energy storage system such as a battery or supercapacitor. The energy storage system is used to store excess energy during low load demand periods and discharge it during high load demand (peak) periods, improving the overall efficiency of the system.

e) Fault Ride-Through Mode: In this mode, the hybrid DSTATCOM can ride through faults on the grid without tripping or disconnecting from the grid. This mode is useful in improving the reliability and resilience of the grid during fault conditions. Availability and functionality of this mode on Distribution applications may be limited compared to Transmission applications.

f) Active Harmonic Filtering Mode: In this mode, the hybrid DSTATCOM can filter out harmonics and other distortions from the grid, improving the overall power quality and reducing equipment damage. Active or Advance harmonic filtering on DSTATCOM used on distribution applications is not common, this mode is common in Transmission systems where Harmonics can be of high magnitude.

g) Sub-synchronous resonance (SSR) damping mode: This mode is applicable on Transmission STATCOM's and is not a compulsory requirement on this DSTATCOM technology.

The control system of a hybrid DSTATCOM must ensure network synchronization and maintain stable operation during mode switching. The required DSTACOM should have the following Control modes as a minimum; Volt/VAR, Feeder VAR, Power Factor correction mode, and to allow renewable energy integration.

4.1.7.2 Protection functions used on hybrid DSTATCOM technology

Hybrid DSTATCOMs require protection functions to ensure their safe and reliable operation. The Grid-Following DSTATCOM may be a more straightforward solution for improving power quality and reducing equipment downtime, while a Grid-Forming DSTATCOM may be more suitable for increasing the resilience and reliability of the distribution network and supporting critical loads during grid outages. Here are some of the applicable and recommended protection functions used on a Hybrid DSTATCOM technology:

a) Overvoltage Protection: This function protects the DSTATCOM against excessive voltage levels that may occur in the system.

b) Undervoltage Protection: This function protects the DSTATCOM against low voltage levels that may occur in the system.

c) Overcurrent Protection: This function protects the DSTATCOM against excessive current levels that may occur in the system.

d) Overtemperature Protection: This function protects the DSTATCOM against high temperature levels that may occur due to excessive loads or other causes.

e) DC Link Protection: This function protects the DC link capacitor against overvoltage and overcurrent conditions.

f) Short Circuit Protection: This function protects the DSTATCOM against short circuits that may occur in the system.

g) Ground Fault Protection: This function protects the DSTATCOM against ground faults that may occur in the system.

h) Communication Failure Protection: This function protects the DSTATCOM against communication failures that may occur between the device and the control system.

i) Power Quality Protection: This function protects the DSTATCOM against power quality disturbances such as voltage sags, swells, unbalance, and transients.

j) Grid Fault Protection: This function protects the DSTATCOM against grid faults such as voltage dips, frequency deviations, and other disturbances that may occur in the distribution network.

k) Differential overcurrent and earth fault protection: This function is for faults within a specific area of the DSTATCOM, equipment or sub-systems.

l) Thermal protection, cooling system protection, and Valve protection functions

These protection functions are essential for ensuring the safe and reliable operation of the DSTATCOM and should be included in the device's design and implementation. Other additional protection functions applicable to be indicated during bid stage and to be finalized at base design.

4.2 Protection and Control function optimisation in a DSTATCOM application

Most faults can be detected on the converter and/or DC link levels using the control system and some faults can be detected and cleared faster than when using the protection system. The control system monitors various parameters such as voltage, current, and power factor to determine the operation of the DSTATCOM and to detect any anomalies that may indicate a fault or disturbance in the system. The control system can then respond by adjusting the output of the DSTATCOM to compensate for the disturbance or by triggering protection functions to mitigate the fault. Mitigation can be breaker tripping, closing, and/or protection blocking.

The protection system is specifically designed to quickly detect and respond to faults in the system to prevent damage to the DSTATCOM, the distribution network, and to ensure safety of employees and the public to prevent death and injuries when faults occur. Protection systems are typically implemented using hardware-based solutions that operate independently of the control system and can detect faults in a matter of milliseconds. The most recent protection solutions include IED relays that also use digital, analogues, and other forms communication protocols such as GOOSE messaging on IEC61850.

Therefore, while the control system can provide some fault detection capabilities, it is critical to have a well-designed and implemented protection system to ensure that faults are detected and mitigated quickly and effectively to prevent damage to the DSTATCOM, network, peoples' safety, and protection to the environment. The bidder should submit a report with details of protection functions implemented on their design to Eskom with the bid documents, and later for review and acceptance during design review stage.

4.3 Control systems used in a DSTATCOM system

Open-loop and closed-loop control systems are two different approaches to controlling the output of a DSTATCOM. The Figure below shows the DSTACOM time response characteristics used when defining some of the control performance parameters, and the control systems are used on VSC to achieve the requirements.

Open-loop control is a method where the control system uses a predetermined set of control signals to adjust the output of the DSTATCOM without taking feedback from the system being controlled. This method is generally less accurate and less responsive than closed-loop control, as it does not account for any changes in the system being controlled. In an open-loop control system for a DSTATCOM, the control signals may be based on a simple mathematical model of the system, but they do not consider any feedback or input from the system being controlled.

Closed-loop control adjusts the output of the DSTATCOM based on feedback from the system being controlled and uses the error function to adjust the output. In a closed-loop control system for a DSTATCOM, the control system continuously monitors the system being controlled and adjusts the output of the DSTATCOM based on the feedback received. This method is more accurate and more responsive than open-loop control, as it accounts for any changes in the system being controlled. The closed-loop control (CLC) system of a DSTATCOM typically uses a voltage or current feedback signal to adjust the output of the DSTATCOM to maintain a predetermined set point. The feedback signal is compared to the set point, and any difference between the two is used to adjust the output of the DSTATCOM to bring the system back to the set point.

The DSTATCOM required on this project must, use both the open loop and closed loop control systems and optimise the control system with applicable Control functions and algorithms. Recent control systems used on DTATDCOM operate in the digital space and they run on fully programmable computer control systems. The response and settling time characteristic of the DSTATCOM control with overshoot is as per Figure 2. The maximum overshoot should not exceed 10% of the targeted / ordered change.

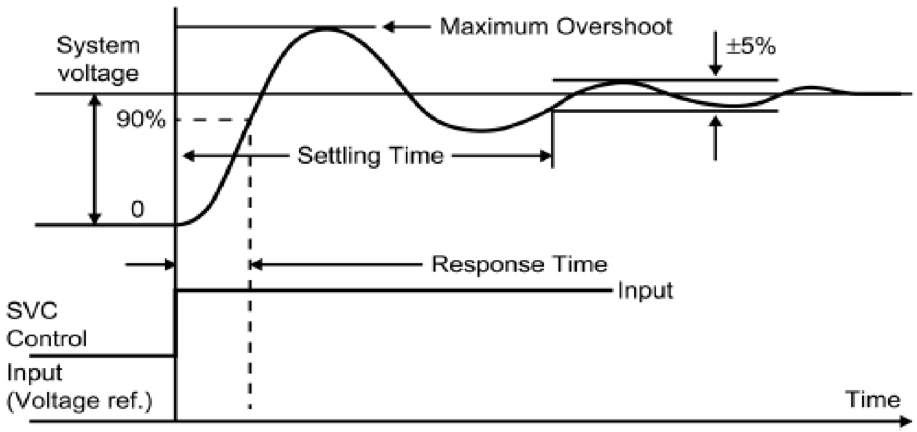

Figure 2: Response and Settling Time characteristics of the DSTATCOM, IEEE

The nominal frequency of the system is 50Hz and the DSTACTOM must be operable between the limits stated on the table below. These operational limits are to be adhered to by the asset owner and system operator.

Table 5: Frequency Limits of the distribution network system and the DSTATCOM

Operational parameter for Network and DSTATCOM	Unit	Value or limit
Nominal frequency	Hz	50
Maximum steady state frequency variation	Hz	0.15
Minimum steady state frequency variation	Hz	0.15
Minimum system frequency	Hz	47.5
Duration for Minimum system frequency	s	60
Maximum system frequency	Hz	51
Duration for Maximum system frequency	s	15
Maximum guaranteed frequency performance	Hz	50.5
Minimum guaranteed frequency performance	Hz	49.5

The design, construction, and control of the DSTACTOM must meet the performance as specified on the above table and the system shall be able to operate continuously within the limits as per this standard.

The voltage-current (V/I) characteristic curve of the DSTATCOM is given by the Figure below as defined in IEEE guideline standard as for Static Synchronous Compensators.

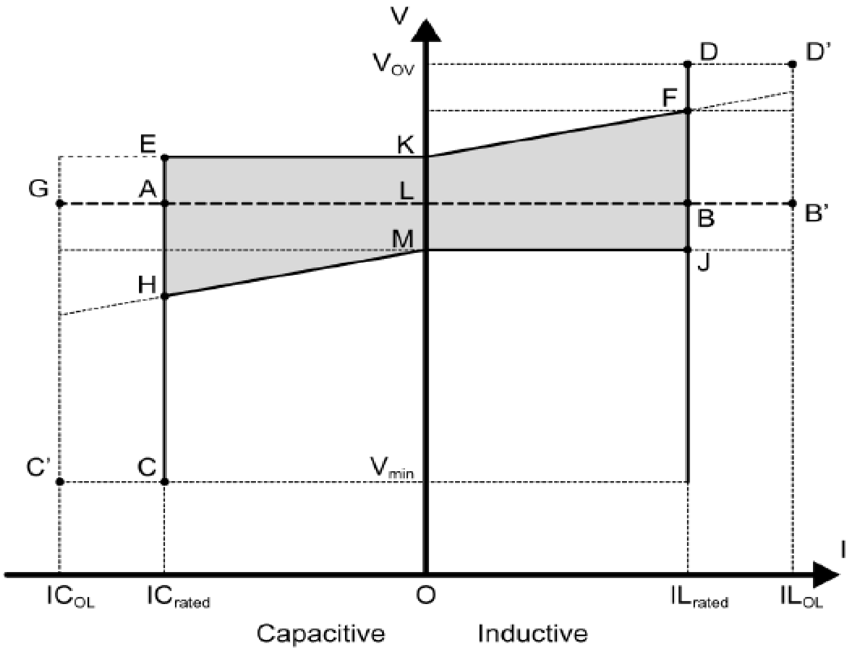

Figure 3: DSTATCOM V/I Curve of the DSTATCOM's VSC converter, IEEE 1052-2018

4.3.1 Control Algorithms used in a DSTATCOM technology

The DSTATCOM devices used in power systems rely on control algorithms to operate. There are several control algorithms that can be used in DSTATCOM applications to regulate the voltage, current, frequency, active, and reactive power. Some of the most common control algorithms are:

a) Adaptive Control: Adaptive Control is a control algorithm that adjusts the system parameters according to the changing system conditions. It is used to improve the system performance under varying load conditions.

b) Direct Power Control: This is a control algorithm that directly controls the active and reactive power components of the load. It is simple and fast, but may not provide as precise control as other algorithms.

c) Fuzzy Logic Control: Fuzzy Logic Control (FLC) is a non-linear control algorithm that uses linguistic variables (or fuzzy sets and rules) to describe the system behaviour to adjust the DSTATCOM output, It is used when the system parameters are not well-defined or when there are uncertainties in the system.

d) Hysteresis Current Control: This is a control algorithm that uses a hysteresis band to adjust the output of the DSTATCOM. It is simple and easy to implement, but may not provide as precise control as other algorithms.

e) Instantaneous Reactive Power (p-q Theory): This is a control algorithm that uses the instantaneous reactive power theory to control the output of the DSTATCOM. It is based on the idea of separating the active and reactive power components of the load and compensating for the reactive power component.

f) Model Predictive Control: This is a control algorithm that uses a mathematical model of the system to predict future behaviour and adjust the output of the DSTATCOM accordingly. It is used to handle constraints and optimize the system performance by minimizing a cost function over a finite time horizon, making it useful in high-performance applications.

g) Neural Network Control: This is a control algorithm that uses neural networks to adjust the output of the DSTATCOM. It can learn from past data and adapt to changing system conditions, making it useful in complex and dynamic systems.

h) PI Control: Proportional-Integral (PI) control is a commonly used control algorithm for DSTATCOM. It is a feedback control algorithm that uses the error between the reference and the actual value of the system variable (i.e. voltage and/or current), as well as the integral of the error signal over time to adjust the output of the compensator.

i) PR Control: Proportional-Resonant (PR) control is another control algorithm used to suppress the resonant oscillations that can occur in the system due to the interaction between the inductive and capacitive elements.

j) Sliding Mode Control: Sliding Mode Control (SMC) is a robust control algorithm that is used in DSTATCOM to regulate the system under uncertain conditions or disturbances. SMC uses a switching function to make the system follow a desired sliding surface to adjust the output of the DSTATCOM.

The above are some of the control algorithms used in hybrid DSTATCOM applications. The choice of the control algorithm is left to the OEM to design and meet the expected system and functional requirements, taking into consideration the complexity and performance requirements. The preliminary list of Control algorithms to be supplied with bid tender documents.

4.4 Comprehensive DSTATCOM P&C solution and design application

The following are important for the functioning of the DSTATCOM, and the bidder/supplier is required to indicate which of these are available (Y/N) on the design offered as per their solution. This covers the Protection & Control (P&C), Protection functions, Control Operating modes, and Control algorithms used.

Table 6: Protection and Control solution implementation on the DSTATCOM

Requirement	P&C, function, mode, algorithm, etc	Available	Comments
Control and operating modes of a DSTATCOM (As per OEM's design)	Active Power Control (APC)		
	Current Control Mode		
	Frequency Control/regulation Mode		
	Grid-Following Mode		
	Grid-Forming Mode		
	Harmonic Control Mode		
	Islanding Mode		
	Load balancing mode		
	Power Factor Correction Mode		
	Reactive Power Control Mode		
	Unbalance Control Mode		
	Voltage Control/regulation Mode		
	Voltage unbalance correction mode		

Requirement	P&C, function, mode, algorithm, etc	Available	Comments
Control Algorithms (As per OEM's design)	Adaptive Control		
	Direct Power Control		
	Fuzzy Logic Control (FLC)		
	Hysteresis Current Control		
	Instantaneous Reactive Power Theory (p-q Theory)		
	Model Predictive Control (MPC)		
	Neural Network Control		
	Proportional-Integral (PI) Control		
	Proportional-Resonant (PR) Control		
	Sliding Mode Control (SMC)		
Protection functions on Hybrid DSTATCOM (As per OEM's design, etc.)	Communication Failure Protection		
	DC Link Protection		
	Differential Protection		
	Ground/Earth Fault Protection		
	Overcurrent Protection		
	Overtemperature / Thermal Protection		
	Overvoltage Protection		
	Power Quality Protection		
	Short Circuit Protection		
	Undervoltage Protection		

The bidder is required to indicate the operating, or control modes and algorithms implemented in their design solution and to indicate how these will be tested for acceptance. Any other operating modes, control algorithms, protection functions not listed above should be indicated in the bid submission reports if applicable on the design on offer.

4.5 Communication systems and Tele-control requirements for the DSTATCOM

The DSTATCOM must be controllable both locally and remotely from the Eskom distribution and regional control centres and the SCADA RTU/IRTU interface should have communication links to the control centres. Local engineering access and HMI should be part of the design and the control system of the DSTATCOM, and the SCADA interface should have local ethernet, RS232/RS485, and/or USB ports for configuration and diagnostics via a dedicated service port (USB, RS232, Serial Port, or RJ45 Ethernet), and communication interface as per this standard.

Communication links from the DSTATCOM site can be via Microwave links, Wireless Radio interface (UHF Radio & Modem), Bandwidth management (BME) links, or fibre communication link. A redundant communication system is required and the design of this will be agreed to with the winning bidder at design review stage. The DSTATCOM must be installed with a Global Positioning System (GPS) clock with antenna and external antenna connectors for communication interface on control cabinets shall be fitted in accordance with the requirements in 240-71084644.

The preferred communication between DSTATCOM's Control system is by using a standard 48.5 m height tower for MTN and the Eskom Radio sites with a recommended Trio UHF Radio. The requirements are the RTU, Radio, Router, Cables & glands, Engineering Port to MTN T1245 with a 3 m high Candlestick (OMNI A0121) antenna and LMR 195 cable. Then install the SCADA Port to Klipfontein Eskom/Telkom Radio Site (Eskom RS) with a 5 m height Corner Reflector antenna and LMR 400 cable. The scope of supply, construction, installation, and commissioning of Telecontrol requirements in section (4.5 in full) is for Eskom, the Employer.

4.5.1 Communication medium and Telecontrol Scope

The scope of work in section 4.5 & 4.5.1 in full shall be **for Eskom**, with budget allocated for the following;

a) MTN Standard 48.5 m tower height assumed for MTN and Vodacom. Eskom Radio sites are assumed to be Trio.

b) The Employer, Eskom, will supply the RTU, Radio, Router, Coaxial & Power cables, Antennas & brackets, RF connectors, IDF and associated cables & cable glands, pipes, and poles / tower.

c) Install the Engineering Port to MTN T1245 with a 3 m high Candlestick (OMNI A0121) antenna and LMR 195 cable. Tower direction is 147º True North.

d) Install the SCADA Port to Klipfontein Telkom RS with a 5 m height Corner Reflector antenna and LMR 400 cable. Point the antenna in direction 338º True North.

e) Eskom Telecontrol to build and configure the Database of the Telecontrol/SCADA points for the unit.

Point (a) is the Eskom's design assumptions used for the communication path loss profile and the Multipath fading method (Vigants – Barnett) was used for the study. The figure below shows the Communication link path profile for the DSTATCOM point as per GPS co-ordinates 29°35'04.4"S, 24°03'01.0"E and the MTN and Eskom/Telkom Radio site towers.

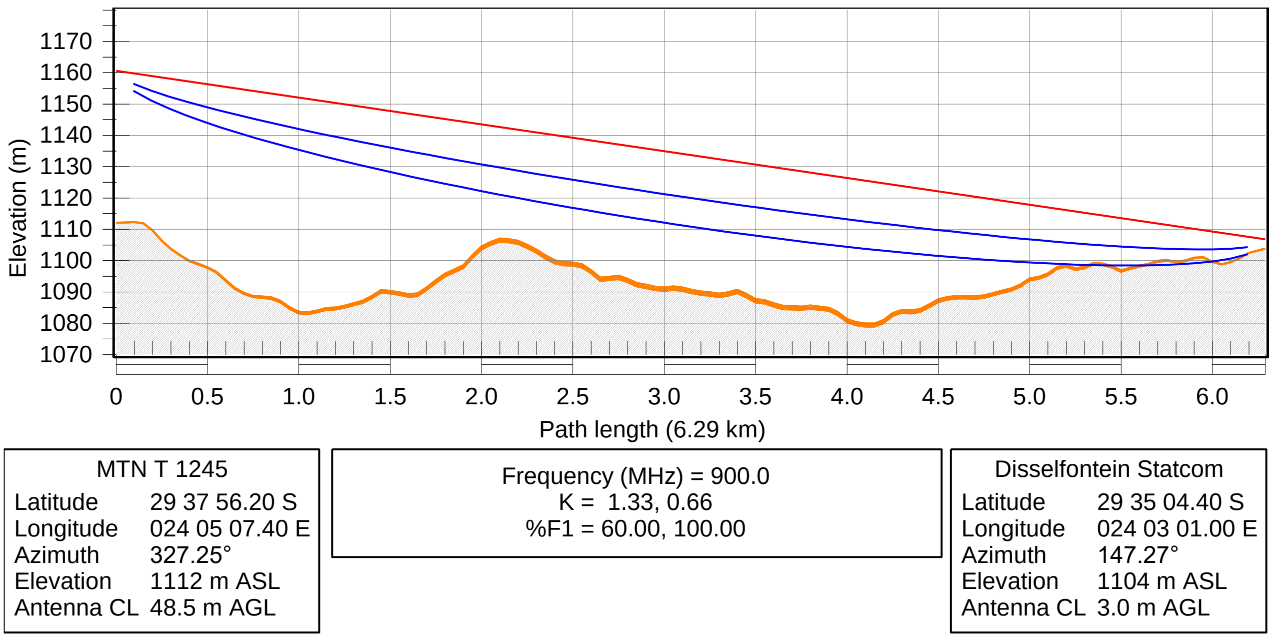

Figure 4: Path Loss Profile for MTN Tower T1245 from the DSTATCOM

The profile in the figure below is for the path profile for the link between the DSTATCOM and the Eskom / Telkom Radio Site (Eskom RS).

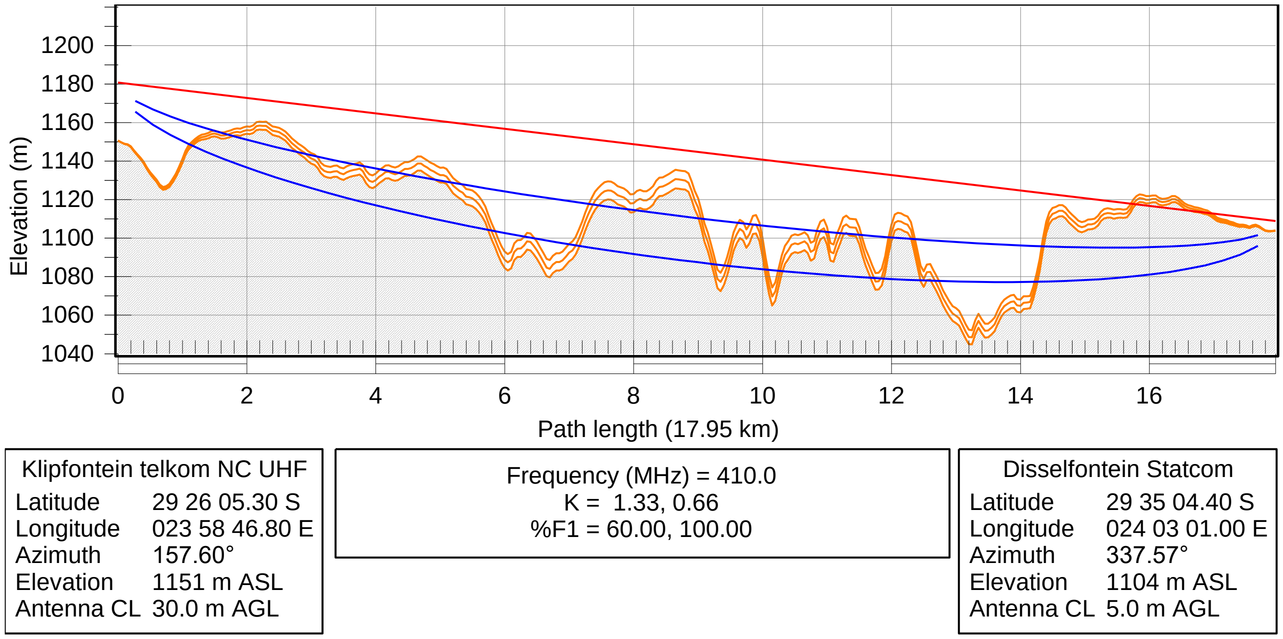

Figure 5: Path Loss Profile for Klipfontein UHF Eskom RS and DSTATCOM

The MTN Tower T1245 is 6.29km away, it has line of sight and passes at -80.24dBm. The Eskom Radio site (Klipfontein Telkom) is 17.96 km away and has an obstruction in the Fresnel Zone. Raising the antenna height to 5 m passes it at -83.68 dBm. It is recommended to ensure that steelwork at the DSTATCOM location does not obstruct the link. More details on the path profiles and results of the communication study are in Annex C.

4.6 DSTATCOM Cooling system and air-conditioning

The cooling system used in a DSTATCOM is an essential component for maintaining the performance of the power electronics. The main function is to remove the heat generated by the power electronics during operation, and dissipate it away from the system. There are several types of cooling systems that can be used in a DSTATCOM and air-conditioning in a built room or enclosure system. The three main types of cooling systems and air-conditioners used in a DSTATCOM are:

4.6.1 Forced-air cooling system

The cooling systems use forced air to cool the power electronics. Air-cooled systems are simple, cost-effective, and easy to maintain. However, they have lower cooling efficiency compared to other cooling systems, and may not be suitable for high-power applications.

4.6.2 Liquid-cooled system

They use a liquid coolant (such as demineralized water or oil) to remove heat from the power electronics. Liquid-cooled systems have higher cooling efficiency compared to air-cooled systems, and can be used in high-power applications. However, they are more complex and require maintenance and additional components such as pumps, heat exchangers, and filters to circulate coolant.

4.6.3 Hybrid Cooling system (Air- and liquid-cooled systems combined)

The Hybrid cooling systems use a combination of air and liquid cooling to achieve high cooling efficiency and reliability. They are more complex and expensive compared to air-cooled or liquid-cooled systems, but they can provide better cooling and reduce the risk of system failure.

4.6.4 Air-conditioners for the Valve buildings and Control room

a) Another critical temperature control for the DSTATCOM with equipment installed inside the buildings, control room, valve rooms, containers and other buildings is the use of air-conditioners.

b) These help to keep the protection, control systems, and power electronic systems in a controlled and regulated temperature that is safe for the operation of these equipment.

c) The supplier is required to provide and install adequate temperature air-conditioning systems for the building(s) or container that may be part of their design with adequate BTU ratings for the building and temperature to be maintained to protect the equipment.

d) The air temperature in an air-conditioned building or enclosure should be controlled between 21°C and 23°C continuously.

The choice of cooling system depends on several factors, including the power rating of the DSTATCOM, the ambient temperature, the availability of cooling resources, and the reliability and maintenance requirements. Generally, air-cooled systems are suitable for low-power applications or applications with low ambient temperatures, while liquid-cooled or hybrid cooling systems are more suitable for high-power applications or applications with high ambient temperatures. The user requirement preference is Forced-air cooling system.

The bidder is required to provide details of how their specific DSTACTOM design will be adequately cooled and to show how they calculate the BTU ratings of the air-conditioners if required. Adequate air-conditioning within the buildings is essential for this project and bidders should design, supply, and install this as per their design requirements when supplying a DSTATCOM enclosed in a containerised or housing that need cooling of the circulating air. There should be no PCB containing material or insulation and cooling fluid.

4.7 Protection, Cooling system and Control indications

Analogue and digital indications recommended to monitor and report on a hybrid DSTATCOM for monitoring and reporting the performance, status, and faults are:

a) Active and reactive power control signals, Reactive power supplied or absorbed

b) Alarm status and indications: The alarm indicators show the status of the DSTATCOM in case of any faults or malfunctions. These indicators can be analogue or digital for diagnosing any issues on the device.

c) Auxiliary power supply status.

d) Breaker and all auxiliary systems (CT, VT, isolators, Disconnector, earthing, etc) status to indicate (failure, open, closed, On, Off, etc).

e) Communication Indications: These indicators show the status of the communication links between the DSTATCOM, the SCADA system, and the overall performance of the DSTATCOM.

f) Cooling system status and health.

g) DC link voltage and current

h) Energy consumption and savings

i) Faults, Errors, and Flags

j) Harmonic Distortion Indicators, and unbalance on Voltage and current: Harmonic distortion levels in the voltage and current waveforms and the unbalance in real time.

k) Operating mode (Grid-Following or Grid-Forming, etc when applicable)

l) Power Factor Indications: This pf indications shows the real-time power factor of the system.

m) Real-time voltage and current values (RMS values), Frequency, active power, reactive power.

n) Supervisory indications: To indicate when the supervisory selected is On or Off

o) System Status Indications: The status indicators show the status of the DSTATCOM, indicating whether it is operating, how it is operation, and its effect on the system.

p) Temperature and thermal overload status

q) Voltage and Current Indicators: These indicators show the real-time voltage and current values at the point of installation of the DSTATCOM. They can be analogue or digital, and the readings can be used to monitor the performance of the device. Positive, negative and zero sequence voltages and currents.

The bidder is required to submit with this bid documents, the list of indications applicable on their specific DSTATCOM design with preliminary list of DSTATCOM indications, alarms, and controls on offer. This will be discussed, reviewed, and agreed to between the supplier and Eskom during the design review stage.

Table 7: DSTATCOM status, Control Indications, Protection alarms

Indications, status, flags, and/or alarms	Available	Comments
Real-time voltage and current values		
Power factor		
Harmonic distortion levels in voltage and current waveforms		
Communication status		
Alarm status		
Operating mode (Grid-Following/Forming)		
Reactive power supplied or absorbed		
Temperature and thermal overload status		
DC link voltage and current		
Active and reactive power control signals		
Faults and error codes		
Energy consumption and savings		
Voltage and current unbalance		
Frequency deviation		
Status of the cooling system		
Supervisory indications		

Overall, a combination of analogue and digital communication indications and alarms can provide a comprehensive view of the status and performance of the DSTATCOM and help in identifying any issues or malfunctions that need to be addressed. A list of applicable indications (both Local and Remote), alarms, and controls to be included in the bid documents to avoid late claims for additional funds after contract award.

4.8 Installation and equipment considerations for Full Turnkey EPC scope on this project

Due to the nature of this project scope as a full turnkey project, the winning or successful bidder will be required to engineer, manufacture, procure, supply, build, and commission a full DSTATCOM solution to be connected on an existing 22 kV distribution feeder. All equipment, components and systems required will be the responsibility of the supplier as part of the Engineer, Procure and Construct (EPC) contract for this project. This will include, but not limited to;

a) Power electronics converter

b) DC Link capacitor

c) Protection and Control systems

d) Communication and Tele-control interface

e) Cooling system and air-conditioning

f) Harmonic filter(s)

g) Auxiliary AC and DC power supply

h) Energy Storage System

i) DSTATCOM Transformer

j) Instrument Transformers (IT), CT and VT equipment

k) MV Breakers/switchgears, Earthing, Disconnector, Isolators, Cables, Insulators, and Surge Arrestors

l) GPS time clocks with antenna

m) Termination cables and glands, or jumper conductors and equipment bushings

All equipment and components should be as per IEC, IEEE, SANS, and to meet ISO standards. The bidder is required to indicate all equipment and components that will be supplied as part of their design and to ensure that all tests and minimum requirements for those systems are as per relevant and appliable standards. Equipment or systems not applicable should be indicated.

The successful bidder to supply a spares strategy, and calculate and supply enough holding spares for RAM & operational maintenance and/or replacement components to Eskom.

4.8.1 Installation considerations

a) The full system installation should be Vermin proof, sealed tank enclosures to be corrosion resistant as per ANSI C57.12.28, seals should prevent foreign object and dust, steel and metal structures to be corrosion resistant.

b) Base must have anti-vibration and suitably rated for vibrations and seismic requirement for the installation point, seismic rating should be 0.3g minimum

c) There should be no routine maintenance to minimal or an easy/simple long term maintenance to minimise outages on the DSTATCOM.

d) High availability with redundancy in control and protection, delta configured 3 phase (or 3 single phase systems)

e) The containerised solution must be for rugged environments, modular construction must allow mobile and quick deployment and future flexibility (replacement, extension, upgrades, and retrofits), the plant must have low noise, and must have IP rating of IP54 or higher.

f) The applicable components are to be stated and the bidder is required to provide a statement on how such will be tested with reference to applicable standards to ensure compliance and for Eskom's review and acceptance.

g) Backup Generators, Capacitor Banks, Energy Storage System (ESS), Harmonic Filter, and Transformer step-up or step-down are not required on this solution. The exception is if the specific OEM's design requires such equipment for its operation and to meet the performance expectations.

5. Network and System parameters

5.1 Network and Feeder data

Table 8: Distribution System information

Specifications	**Eskom/User requirements and comments**	**Bidder read & acknowledged data (Yes/No)**
BIL	The BIL is 50/150 kV for the 22 kV system for the Rated short-duration power-frequency withstand voltage and Rated lightning Impulse withstand voltage respectively	
Connection method on MV line	Preferred direct connection with no transformer. Bidder to indicate if termination to the DSTATCOM will be jumper conductors or by means of a suitably rated Cable.	
Connection Point	Along the feeder, at pole DZO-172, at the GPS co-ordinates 29°35'04.4"S, 24°03'01.0"E	
Frequency	50Hz	
Environmental and Mechanical Parameters	Base Mounting, Building, containerized, Cabinet, Enclosure, Pole mounted, protection IP54 or higher, Open rack, or walk-in container, Floor mounted, Paint RAL 7035. Pole mounted recommended, and for the control unit to be easily accessible.	
Voltage Rating	22 kV (Phase to phase or L-L) The existing voltages on the network currently are; V < 0.95 pu during peak load (no SSEG), and V > 1.48 pu when lightly loaded (at full SSEG generation). The voltage rise exceeds 1.03 pu Grid compliance limit.	

The 22 kV Zoetgat feeder is supplied from Disselfontein Rural substation, the substation has two 132/22 kV Transformers. The focus on this project is on the 22 kV feeder, the busbar (BB) has the following fault levels and X/R parameters that may be useful for the design of the DSTATCOM, associated equipment ratings, and the Harmonic mitigation.

Table 9: 22 kV Busbar fault levels

Single Phase (1 Ph) Fault, 22 kV Busbar	Min Value	Max Value	Value (Normal Operation)
Fault Current (kA)	0.237	0.484	0.477
Fault level (MVA)	3	6.2	6.1
X/R of the network	13.01	13.01	13.01
3 Phase (3 Ph) Fault, Balanced, 22 kV Busbar	Min Value	Max Value	Value (Normal Operation)
Fault Current (kA)	2.564	4.564	4.564
MVA Fault level (MVA)	97.7	173.9	173.9
X/R of the network	23.15	13.01	13.01
Note: The Min and Max Values shows the minimum and maximum fault levels and X/R values of the 22 kV network under different operational contingencies. The fault levels and X/R values are on the 22 kV (L-L) busbar (BB) at Disselfontein Rural Substation supplying the Zoetgat 22 kV feeder. The Zoetgat 22 kV feeder is 22km long from the substation to the installation site selected for the DSTATCOM, and it is made up of HARE and MINK conductors. For more fault level details on the 132 kV Busbar, and the feeder conductor line data, refer to Annex B of this standard.			

5.2 Existing PTM&C equipment at Disselfontein Rural substation for Zoetgat Fdr

a) Zoetgat 22 kV Feeder (Fdr) is currently protected by a standard Eskom 4RF1101 MV feeder protection scheme with directional overcurrent and earth fault Schneider protection relay (MiCom P145).

b) Substation RTU is a Powertech System Integrators Wesdac D20ME II, with a TM8x Radio & modem.

c) Metering on the 22 kV Zoetgat feeder is via Elster A1700 meters with modem for remote access.

d) The substation DC is 110 V and is used for Protection, Telecontrol & Telecommunication, SCADA, Metering, and DC (PTM&C) supply.

Figure 6: Disselfontein Rural substation's existing Protection, Telecontrol, and Metering equipment

Should more information be required on the existing equipment at Disselfontein Rural substation for design and interface with the DSTATCOM, bidders will be provided with this before tendering close date and during design review.

5.3 Background Harmonics

a) Preliminary background harmonic measurements (Harmonic, Unbalance, Voltage regulation, and Flicker data) shall be provided by The Employer at a bid stage to enable the bidder to guarantee compliance with harmonic performance as stated in this specification and to determine harmonic mitigation during design.

b) The Contractor shall conduct background power quality, including harmonic measurements at the DSTATCOM site as soon as possible after the award of contract prior to the detailed design for a minimum period of two (2) weeks.

c) Any variations between measurements provided by The Employer and measurements conducted by The Contractor shall be taken into consideration at the design review stage.

d) The measurements will be repeated as part of the DSTATCOM harmonic performance verification tests and to be done in accordance with IEC 61000-4-7, as well as NRS and IEC standards for power quality, inclusive of all possible parameters on completion of the project.

e) The Contractor shall demonstrate that the DSTATCOM does not cause any magnification of existing background harmonics.

f) The maximum voltage distortion generated by the DSTATCOM shall not exceed the maximum voltage harmonic limits as specified in this specification and other applicable standards at the 22 kV Point of Common Coupling (PCC).

g) The maximum voltage distortion generated by the DSTATCOM shall not exceed limits as per IEEE 519 and NRS 048.

5.4 Operational limits : Voltage ride-through capability at rated current

a) The DSTATCOM must be able to operate as per the limits in the figure below for the overvoltage ride through and low-voltage ride through. The per unit (pu) voltages are on the 22 kV rating as a base.

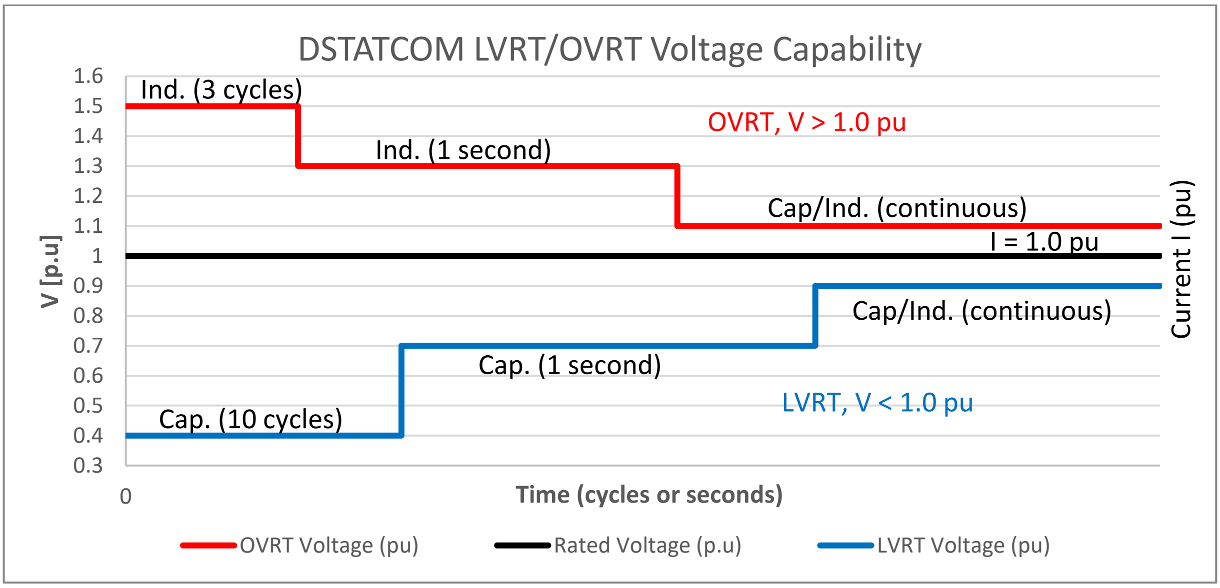

Figure 7: DSTATCOM's Voltage Ride Through Capability curves at rated current output

6. Site and environmental parameters

Table 10: Installation site and environmental parameters

Specifications	Parameters description and comments	Eskom/User requirements and comments
Connection	Connected to the feeder with a transformer or without a transformer.	Preferred direct connection with no transformer
Altitude above sea level (m)	Altitude	1000 – 1800 m
Humidity	Relative humidity	< 95%
Installation location	Along the feeder, at pole DZO-172	Along the feeder, GPS location 29°35'04.4"S, 24°03'01.0"E
Operating Temperature Range	Lowest/minimum to highest/maximum temperature.	-10°C to +50°C

Specifications	**Parameters description and comments**	**Eskom/User requirements and comments**
Pollution level	The selected location of the DSTATCOM is in an agricultural farm and the dust level is high.	High to very high pollution.
Quality	The contractor's products, construction and installation shall not compromise quality at all levels.	ISO 9000 / ISO 9001
Size of the DSTATCOM (all dimensions in metres or cm)	Size H x W x B (cm or meters)	As per OEM's design
Solar radiation in the area	kW/m^2	1.2 ($1200 W/m^2$)
Transformer insulating fluid	Should be as per NRS 079, SANS 780, and SANS 60076*	No PCB and no mineral oil used. Ester Oils accepted.
Weight of DSTATCOM (kg)	Dependent on design	As per OEM's design.
Wind velocity	Wind velocity of 40 m/s (N)	40 m/s (N)

7. General information for noting by bidders and suppliers

Table 11: General information for noting

Specifications	**Parameters description and comments**	**Eskom requirements and comments**
Backup Generators	Backup generators can be used to provide power to the DSTATCOM in the event of a prolonged power outage or other emergency.	Not required
Capacitor Banks	In addition to the ESS, additional capacitor banks may be used to provide reactive power compensation in the distribution system.	Additional Capacitor Banks not required
Energy Storage System (ESS)	An ESS, typically a battery or a capacitor bank, is used to provide a stable DC voltage to the converter and ensure a continuous supply of power when the grid supply fails. The ESS may also help to regulate the voltage and frequency of the distribution system.	Not required, unless if this is a requirement as per the OEM's design.
Harmonic Filter	To eliminate high-frequency harmonics generated by the converter and filter out unwanted signals from the power system. The filter is designed to attenuate these harmonics and improve the overall power quality. The fault levels on the 22 kV and 132 kV busbars at Disselfontein substation are as stated in this standard.	Not required
Transformer step-up or step-down	The transformer, 22 kV to the voltage rating of the DSTATCOM , required to connect the DSTATCOM to the feeder.	Not required

The above are not requirements on this project, but if the specific design requires this, then the OEM or supplier will provide this as part of the tender returnable to ensure that the solution offered meets our performance and functional requirements. Where applicable and required, OEM's shall indicate what is included as part of the design and state accordingly on the bid submission to avoid future claims for additional funds. This must be included in the deviation schedule.

8. RAM & Guarantees, Spares, and Special Tools

8.1 Spares and Tools for DSTATCOM Installation

8.1.1 DSTATCOM Spares

a) The scope of spare parts and special tools must be coordinated with the requirements/guarantees for reliability and availability.

b) An inventory of the spare parts should be prepared at the time when the DSTATCOM is handed over to The Employer and again at the end of the RAM guarantee period. Any shortages should be replenished by The Contractor to 100% spares holding level at the end of the RAM guarantee period.

c) The Contractor shall not use the contractually delivered spares during the start-up phase (i.e. during the installation and commissioning). Start-up spares to be used by The Contractor during the installation and commissioning period shall be separated from the main spares.

d) Each item of the spares in a case shall be suitably identified by means of a label and a list complete with diagrams showing the application of all parts supplied, which shall be provided to Eskom.

e) All spares shall be delivered to the site, correctly calibrated, tested, and configured at the site before the start of the trial operation.

f) All spare parts offered must be of the same specification as, and completely interchangeable with, the original parts.

g) The spares shall be stored in a climate controlled, dust and vermin-proof to the satisfaction of The Employer.

h) The Contractor shall, where practical, optimize the DSTATCOM design to allow the number of spares to be reduced.

i) All spare electronic modules and transducers are to be tested and calibrated before completion of commissioning. The functionality of all electronic modules, transducers, and relays is to be demonstrated by inserting these spares into the control and protection systems to prove and accept.

j) Spare of items not covered above but which will be required during the RAM guarantee period shall be supplied in sufficient quantities to cover the full guarantee period. The minimum number of these spares shall be as calculated and demonstrated by the Contractor to ensure full asset life.

k) Spares holdings for the DSTATCOM shall be available for a period of at least ten (10) years after delivery within a turn-around time of 48 hours.

8.1.2 RAM Spares and spares inventory list

a) The number of spare parts required to satisfy the availability shall be determined by failure rate data used in the RAM calculations, the number of similar parts installed, and the meantime to repair or replace. These calculations should be part of the bid submission reports.

b) The number of spares supplied by the Contractor shall be sufficient for five (5) years of operation taking into consideration the replacement lead time.

c) The Contractor has an obligation to include all required spares in the scope of supply in order to fulfil the RAM guarantees.

d) It is the responsibility of The Contractor to track the spares and supplement them, at own cost, at the end of the RAM period.

e) The RAM spares shall be handed over to The Employer not later than twenty-eight (28) days prior to the start of the tests on Completion.

f) All spare parts, consumables, and special tools shall be labelled, and a consumables inventory list must be created for all these.

g) The inventory list shall include the following:

1) The Employer order/contract number
2) Installed quantity
3) RAM stocking level
4) Type/Description/Value
5) Supplier/Manufacturer
6) Catalogue number
7) Part number
8) Serial number (if applicable)
9) Reference drawing number
10) Storage location
11) Inventory date

8.1.3 Special Tools and equipment

a) One (1) recommended set of special tools, including HMI, software and test equipment, complete with documentation and manuals shall be supplied by the Contractor.

b) Special tools and test equipment are defined as tools, software, and equipment that are not normally available in South Africa from a commercial hardware store or not commonly used by The Employer and are required for testing, re-commissioning, maintenance, diagnostics and/or repairs.

c) If during the installation, testing, and commissioning of the DSTATCOM, The Contractor uses any special tools or test equipment, not listed, The Employer may elect that these items be supplied as part of the Scope of Work with no increase in the contract price.

d) The Contractor shall supply tools and instrumentation suitable for dismantling, re-assembling, and checking the VSC valves, as well as the cooling system.

e) A complete set of finished hardened spanners to fit every nut and bolt head on the equipment supplied and other hand operable devices required for the adjustment and maintenance of the equipment such as VSC shall be supplied as part of this contract.

f) Special tools are inclusive of any special software programs used by The Contractor in the diagnostics or analysis of the DSTATCOM system and control, protection, and monitoring. These must be supplied to Eskom with the software licences applicable.

g) The Contractor shall supply one (1) branded laptop computer and peripherals from a reputable manufacturer as a special tool for control system testing, maintenance, and diagnosis purposes. This shall include all the necessary software licenses, for the operating systems and general software such as the Microsoft software, as used by the Employer.

h) A hand-held infrared camera will also be supplied to the Employer as part of the special tools.

i) A list of special tools and test instruments which The Contractor considers The Employer will need to test, re-commission, and service the plant and material and fault diagnostics, shall be supplied.

j) Software and hardware system required for Augmented Reality (AR), Artificial Intelligence (AI) used for optimised diagnostics and Cyber security solution, to allow technical support of the plant from remote, shall be provided to The Employer.

k) Configuration software for the communication interface, RTU, IRTU, control system, protection systems, cooling system, and diagnostics will be documented comprehensively, and functions explained to ensure ease of use by the Employer. The software and documentation shall be supplied to Eskom.

8.2 Reliability, Availability and Maintainability (RAM)

8.2.1 Required DSTATCOM Availability and Reliability

a) Refer to IEEE 1052 for the definitions of Reliability, Availability and Maintainability.

b) The annual equivalent availability for forced outages for a DSTATCOM shall be at least 99.7%. This is exclusive of scheduled outages. The annual RAM availability is given by the formula:

$$A = \left(1 - \frac{\sum \text{Duration Unavailability}}{8760}\right) * 100\%$$

c) Duration unavailable is in hours, and 8760 is the total hours in a year.

d) The RAM guarantee period is two (2) years.

e) The maximum number of forced outages shall not exceed 2 outages per year. This is exclusive of scheduled outages. But inclusive of any false alarms, sporadic alarms, trips, and occasions that require the device to be taken out of service to reset alarms amongst other potential causes.

f) The Bidders shall state the expected / guaranteed average number and duration of scheduled outages per year and must guarantee the availability performance for 2 years from the commissioning date.

g) The Contractor shall be notified of major outages. During the guarantee period, The Employer shall maintain records of the number and duration of forced and scheduled outages, hours of operation, and any other relevant data, and will make those records available to The Contractor upon request.

h) If the actual performance is below the values stated above, The Contractor shall provide corrections and modifications to meet the availability guarantees at no extra cost to The Employer.

i) The availability guarantee shall then continue until 2 consecutive years of successful operation.

8.2.2 Instruction Manuals and Documentation

a) OEM's instruction manuals and documentation shall be provided and accepted prior to the acceptance of the DSTATCOM, it's protection & control, communication, and cooling systems.

b) Manuals and instructions must be supplied with bid documents, they must be in English.

c) Preliminary operating, installation, and user manuals must be supplied during bid stage with tender documents.

d) The final documentation and manuals are to be supplied to the Employer before commissioning.

8.2.3 HMI Off-Site Access

a) A facility shall be provided whereby the HMI features and functions shall be accessible from an off-site location. This facility shall conform to the Eskom Remote Access Standard.

b) The Contractor shall provide and install and Human-Machine Interface (HMI), with the following information related to the remote access requirements of the HMI:

   1) A description of the mechanism to meet this requirement,

   2) The communication requirements (medium, data speed, transport)

   3) The functionality provided by the remote software application.

c) Access security shall be provided by password and roles for interlocking and to prevent unauthorized access and operations.

d) A remote user shall be able to view screens and change the DSTATCOM parameter settings. The contractor must demonstrate this requirement to the Employer before handover.

9. Testing and acceptance

9.1 Testing Procedure

a) The scope and details of the following items shall be submitted to The Employer eight (8) weeks after the Contract award, whereafter the final scope and details of all testing shall be agreed upon with Eskom within sixteen (16) weeks after the Contract Award. In addition to the tests called for by the respective and applicable equipment standards, the Contractor shall submit proposals for tests to demonstrate the capability of the complete DSTATCOM device to meet the required performance.

1) A Master Test Plan (MTP)
2) Manufacturing Specific Test Plans (FAT, type, special, routine, etc.)
3) Inspection Test Plan (ITP)
4) Transport Test Plan (ship, road, rail, air)
5) Site Acceptance Test Plan
6) Installation, construction, and Commissioning Test Plans
7) Performance Verification and Acceptance Test Plan,
8) Extended Verification and Acceptance Test Plan.

b) The Contractor shall furnish all necessary labour and test equipment to perform all tests and inspections that are The Contractor's responsibility.

c) The cost of all type tests, special tests, routine tests, site, and commissioning tests shall be included in the price for the plant and material as part of the tender/bid documents.

d) Type and Special tests establishing the performance detailed in the Schedules and elsewhere in this specification shall be carried out in accordance with the requirements of the relevant standards.

e) Type and Special tests shall demonstrate the adequacy of a particular type, style, or model of plant and material to meet assigned ratings and to operate satisfactorily under specified operating conditions.

f) If Type and Special tests have been carried out previously on identical plant and material, valid copies of test certificates may be accepted.

g) Routine tests shall demonstrate the integrity of the plant and material and its ability to operate satisfactorily under specified conditions.

9.2 Factory Testing

a) The Employer may witness any or all factory tests performed.

b) A minimum of three (3) months' notice shall be given by the Contractor of the readiness to start factory tests.

c) The Contractor shall include, as a minimum, all the tests as specified by The Employer, in addition to the manufacturer's factory tests.

d) The factory test shall confirm that:

1) All materials satisfy the requirements of this specification and all further requirements to guarantee a complete working system.
2) All materials meet the performance requirements.

e) All test results shall be recorded and signed by the Contractor's Test and Quality Assurance personnel. Any deficiency shall be corrected by the Contractor, and all tests shall be repeated.

f) Copies of the complete test report with all the test data sheets shall be submitted to The Employer. All test data shall be retained by the Contractor throughout the warranty period.

g) Upon The Employer's review and approval of all test results.

9.3 Site Acceptance Tests and Factory accreditation

a) During the design review stage, the Employer may choose to visit and assess the OEM's test facilities and to do a site inspection and acceptance tests.

b) Once potential suppliers have been identified, it is important that the factory capability be assessed in line with relevant quality requirements. It is required that all power electronics related equipment be sourced from the factories that have been at least technically and quality evaluated and were found to be acceptable.

c) A factory with poor or no quality controls cannot provide quality a DSTATCOM. This stage is incorporated into the design review process and will be conducted after contract award. The accreditation of a factory is based on the following parameters:-

1) Work Systems,
2) Operation – manufacturing,
3) Design Practices and Application,
4) Testing Facility and Practices and
5) Research and Development Capabilities
6) Field and Factory failure rates

As part of the design review process, Eskom SME knowledgeable with the relevant technology and quality management systems may conduct a factory assessment to confirm capability and quality controls.

9.4 In-production inspection

The supplier shall, in line with quality systems and procedures, make available to Eskom the inspection and test plans (ITP) or production quality plans. Eskom will then indicate the intervention points that are necessary for the realization of the product. These intervention points must be agreed and documented at the design review stage and should cover at least inspections of:

a) Incoming material

b) Manufacturing of major components and/or material

c) Assembling of critical material used

d) Drying inspections

e) Bushing installations where applicable.

f) Insulation fluid and material

g) Sealing and packaging.

The ITP will be reviewed and signed off by Eskom once accepted.

9.5 Testing (Including type tests, routine tests, and special tests)

a) Type test assessment and previously performed type tests shall be attached to the bid.

b) The Contractor shall carry out tests on a VSC valve section and valves in accordance with the requirements and with applicable portions of IEC 62927 and other standards.

c) The Employer reserves the right to require any additional tests it deems necessary after the Commencement Date.

d) The VSC valve or VSC phase unit used for type tests shall first pass all production tests, and the same VSC valve section or VSC valve shall be used for all type tests.

e) Material for the type tests shall be selected at random.

f) Not more than one valve failure shall be permitted during any one type test item, and no more than two cumulative valve failures shall be permitted during and after complete type test program.

g) Operation Type Tests shall be performed to verify the valve design for combined voltage and current stresses under normal and abnormal repetitive conditions as well as under transient fault conditions. They shall demonstrate that under specified conditions:

   1) The valve functions properly

   2) The turn-on and turn-off voltage and current stresses are within capability limits.

   3) The cooling provided is adequate and no component is overheated

   4) The overcurrent withstand capability of the valve is adequate.

h) All operational tests shall be carried out under conditions that would result in the highest component temperature and the highest semiconductor junction temperature that may occur in real operation.

i) A list of all tests to be performed on all auxiliary plant and material associated with the valve shall be submitted to The Employer for review and acceptance.

j) The Contractor shall provide certified test reports of all type tests on the valves.

k) The Contractor shall submit a detailed test program for the VSC valve section and valve which shall include type and production (routine and sample) tests to be carried out in the factory.

l) The test program shall include details such as test levels (and their derivation) test duration, test circuits, test procedures and the pass/fail criteria to be used.

m) The system used by the Contractor to protect the valve against the effect of overvoltages shall be demonstrated to Eskom.

n) The valve failure location indicator and failure alarm, where applicable, shall be tested to the satisfaction of The Employer.

The Contractor shall propose a test for verifying the operational losses of the valve. Such a test may include measurements on individual components, measurements during type tests and calculations.

9.6 Test Certificates

a) The Contractor shall provide copies of test certificates (certified by the manufacturer) summarising all tests conducted on the plant and material.

b) Where appropriate, copies of the latest logs and graphs for all tests of all such certificates shall be supplied for acceptance as specified.

c) The number of the copies of test certificates will be as proposed and agreed on MTP and ITP’s.

d) Information shall be given on each test certificate, sufficient to identify the material or plant, to which the certificate, test log, and graph refer.

e) Inspection reports submitted to The Employer, notwithstanding that these may contain full details of all readings taken, shall not be accepted in lieu of test certificates or type test results.

f) A copy of all instrument readings recorded, all graphs drawn, and all calculations made during any tests conducted to prove compliance with this specification shall be supplied to Eskom on completion.

g) The Test certificates and reports will be written in English.

10. Trial operation and verifications

a) After completion of all tests, the DSTATCOM shall be placed in trial operation for a duration of two (2) weeks without any failures.

b) The DSTATCOM must operate at 100% availability for fourteen (14) days.

c) If problems occur which reduce the availability of the maximum MVAr output of the DSTATCOM (either capacitive or inductive) within this trial period, the problem shall be corrected, and the test period shall be restarted.

d) This shall be repeated until the DRPC operates at 100% availability, fault-free, for the full test duration

11. Training documentation and training execution

11.1 Training Requirements for the DSTATCOM Equipment / Systems

a) The Contractor shall design and implement a theoretical and practical training course to enable The Employer personnel to engineer, operate, undertake intrusive maintenance, troubleshoot, and maintain all supplied plant equipment/system used in this project.

b) Training content must be done on four (4) different level to target different areas of the DSTATCOM technology, with basic introductory level for all users, second level for controllers and dispatch operators, level three for field maintenance and operational staff doing maintenance, fault finding, and diagnostics, and the last level for planners, commissioning technicians, and engineers in design and planning responsible for modelling, simulations, testing and commissioning.

c) The Contractor shall ensure the implementation of the training course to be at a balance for theory and the practical aspect of the training. Contractor shall tailor the curriculum for the theoretical and practical training courses to meet The Employer's requirements and specifications which shall be sent to the Employer for review and approval.

d) There shall be training developed for Dispatch/Control centre operators/controllers, Substation operating staff, and Technicians and Engineers from Protection, Telecontrol, Telecommunication, Measurements and Control, Maintenance, Operations, and Design. Training shall be designed and executed so that all trainees can accomplish all diagnosing, isolating, and repairing of failed components and all routine or special maintenance required on the DSTATCOM to perform.

e) Course Materials: Manuals, Documentation, Recorded videos, Lecture notes, and other special tools such as computerized tests and other hand-held test sets and training material including handouts that are necessary for demonstration and use during all course presentations in paper and electronic format such as PowerPoint slides and pdf must be provided to trainees and the Employer as part of the contract documentation.

f) The Contractor shall use the English language in making all presentations and the Contractor shall ensure that its oral presentations and instructions are easy to comprehend by the participants.

g) All training sessions to cater for a minimum of 8 participants and a maximum of 12 participants for local training at Employer's venue, and a maximum of 4 participants for in-factory training. At most, the length of each course shall be two (2) days for the Dispatch control centre operators/controllers, five (5) days for Substation operations staff, and two (2) weeks for advanced operations.

h) The Contractor's training shall be completed prior to the final commissioning activities and there shall be an agreement timely, on the date of training between the Employer the Contractor.

i) Contractor shall ensure that all approved course manuals must be at the designated training site at least three (3) working days prior to the start of each training course.

j) Contractor shall issue individual completion certificates to all participants completing the training courses. The Contractor shall provide a full, complete, and detailed summary of all of the required tasks and duties covered under the certification-training course for each participant.

k) The Contractor shall submit to The Employer the résumés or CV's of the proposed instructor(s) for each training course for The Employer's approval as part of the Contractor's detailed training plan.

l) The Employer shall be free to use the training material provided by The Contractor for subsequent in-house training of Eskom employees.

m) The Contractor shall conduct the theoretical, practical, and certification training courses respectively at factory training facilities by the OEM of each equipment/system for in-factory training.

n) Local / Onsite / In-country training will be provided at the Employer's venue.

o) The practical part of the courses for maintenance and operational staff where possible, shall be at the DSTATCOM installation site for local / in-country training.

12. Diagnostics, online condition monitoring, and artificial intelligence

The bidder must provide a report or statement confirming the diagnostics method and equipment used to do online condition monitoring and diagnostics on the DSTACOM for status, operational efficiency, and diagnostics via local wired and wireless, as well as online/remote access. This shall include, but not limited to;

a) Remote continuous online condition monitoring, voltage, temperature, and current measurements

b) Remote trouble shooting, HMI with audible notifications & alerts, and allow virtual support

c) Automatic notifications, alerts, alarms, and early warning signals & detection system, predictive maintenance, trending analysis.

d) Event logging and visualization, system performance reports, digital recording of system action, and with multiple inputs.

e) Augmented reality, artificial intelligence and cyber security shall be central to online monitoring and diagnostics. All measures shall be made to ensure a safe and secure connectivity to the DSTATCOM in line with 240-55410927 standard for operational technology (OT).

13. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Lehlohonolo Mashego	Snr Engineer – Grid Planning
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Neels Van Staden	Senior Consultant – TX Power Electronics (HVDC & FACTS) devices
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Masekoala Marake	Project Co-ordinator

14. Revisions

Date	Rev.	Compiler	Remarks
March 2023	1	Selby Mudau	This is a new document

15. Development team

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

- Selby Mudau

16. Acknowledgements

- Tjaart Van Der Walt
- Marilize Kramer

Annex A – Schedule A & B for the DSTATCOM system

Notes:

1) Schedule A is Eskom's requirements (User, Employer, Client)

2) Schedule B is the guaranteed OEM/Bidder/Supplier's offered data (Contractor)

XXXXXXXX – Bidder to complete the required information as per their offer or design in English.

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
1	**Basic Insulation Level (BIL):** The BIL is 50/150 kV for the 22 kV system for the Rated short-duration power-frequency withstand voltage and Rated lightning Impulse withstand voltage respectively	kV	50/150 kV	
2	**Capacity of the DSTATCOM** The capacity of a DSTATCOM depends on the load requirements and reactive power demand of the distribution network. The capacity is typically expressed in terms of MVA (Mega Volt-Ampere) or MVAr (Mega Volt-Ampere Reactive).	MVAr	±1 MVAr	
3	**Communication Interface and medium** The communication interface of a DSTATCOM allows for remote access, online monitoring & diagnostics, indications & alarms, and control. The common communication interfaces include SCADA RTU/IRTU with communication protocols such as Modbus, DNP3, IEC 61850, Profibus, IEC 60870-5-101, DMS, RS232, MDLC, RS485, X21, X.25, and Ethernet. Trio UHF Radio for the Eskom Radio sites, an Engineering Port to MTN T1245 with a 3 m high Candlestick (OMNI A0121) antenna and LMR 195 cable, a SCADA Port to Klipfontein Eskom/Telkom RS with a 5 m height Corner Reflector antenna and LMR 400 cable.		XXXXXXXX RTU/IRTU with DNP V3.0, MDLC, RS232, RS485, Serial Ports, IEC 61850, USB 3.0, and RJ45 Ethernet. The preferred communication for DSTATCOM's Control system as per Communication interface scope in this standard.	
4	**Connection method** Connected to the feeder with a transformer or without a transformer.		Preferred direct connection with no transformer	
5	**Control Algorithm** The control algorithm of a DSTATCOM should be designed to provide fast and accurate voltage regulation and reactive power compensation.		XXXXXXXX	
6	**Control Strategy** The control strategy of a DSTATCOM should provide optimal voltage regulation and reactive power compensation based on either voltage source or current source control, and may include various control modes such as voltage control, reactive power control, power factor control, and harmonic control.		XXXXXXXX	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
7	**Control System** The control system of a DSTATCOM should be designed to provide precise voltage regulation and reactive power compensation. It must be able to communicate with the distribution network's control system.		XXXXXXXX	
8	**Cooling System** The cooling system determines the temperature control and thermal stability of the DSTATCOM during operation. The cooling medium can be air or water, or hybrid. There should be air-conditioners to control air temperature and to cool equipment housed in a building of container systems.		Forced Air cooling XXXXXXXX	
9	**Current rating** Dependent on application	A	The current rating for the Reactive power capacity and voltage rating stated.	
10	**DC Link Capacitor** Stores DC voltage or Energy in the form of an electric field and supplies the energy to the power electronics converter / inverter. The capacitor also acts as a low impedance path for high-frequency components of the load current.		Capacitance and ratings of the DC link shall be as per OEM's design.	
11	**Energy Storage System (ESS)** An ESS, typically a battery or a capacitor bank, is used to provide a stable DC voltage to the converter and ensure a continuous supply of power when the grid supply fails. The ESS may also help to regulate the voltage and frequency of the distribution system.		ESS not required on the Grid-following DSTATCOM.	
12	**Efficiency** The efficiency of a DSTATCOM is an important parameter as it determines the amount of losses during operation. The efficiency required is 99% at all operating points.	%	99%	
13	**Event recorders and performance trending** There should be QoS instrument, fault recorder, and system event recorder installed as part of the system for trending and analysis of performance and failures. Eskom to be provided all software tools for access and diagnostics.		XXXXXXXX	
14	**Extended overload rating** Overload current for 1 minute.	A (kA)	1.3x nominal rating load current of the DSTATCOM	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
15	**FAT Testing and acceptance** Remote testing and witnessing for FAT tests, remote witnessing via online tools can be utilised. The witnessing will be discussed and agreed to with Eskom.		XXXXXXXX	
16	**Fault Ride-through Capability** The fault ride-through capability determines the ability to withstand and recover from faults in the distribution network. The DSTATCOM should be able to maintain its operation during faults and recover to its normal operation once the fault is cleared. It is typically in the range of a few milliseconds to a few seconds.	%	300% rated power output in 1 minute.	
17	**Frequency** The frequency of the DSTATCOM should match the frequency of the distribution network to ensure proper operation, which is 50Hz in South Africa.	Hz	50 Hz	
18	**Full current output at reduced voltages** The STATCOM must be able to provide full rated current for all sequence components down to 0.3pu of the primary voltage rating (low operating point), this includes during all unbalance faults.		XXXXXXXX DSTADCOM must operate with full current and MVAr output at 0.3 pu voltage	
19	**Grid-Forming or Grid-Following** The DSTATCOM can operate in either Grid-Forming or Grid-Following mode. In Grid-Forming mode, the DSTATCOM generates the voltage and frequency of the distribution network, while in Grid-Following mode, it adjusts its voltage and reactive power output to match the voltage and frequency of the distribution network. Grid-Forming DSTATCOM technology can provide short circuit current during faults. The supplier must provide a Grid forming technology, not a Grid-following DSTATCOM. Bidders are free to propose and offer a Hybrid technology (with both Grid forming and grid following).		XXXXXXXX Depending on application	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
20	**Harmonic Distortion** The harmonic distortion of a DSTATCOM determines the amount of distortion introduced to the distribution network. The total harmonic distortion must be less than 3% at the rated capacity or the limits set by the relevant standards. The DSTATCOM should be designed to minimize the harmonic distortion introduced into the network or the background harmonics from the system. This can be achieved through the use of filters or by selecting appropriate switching schemes. Eskom to provide 2 weeks QOS data (Harmonic, Unbalance, Voltage regulation, and Flicker data) for background harmonics.	%	< 0.3% as per IEEE519 and NRS048-2	
21	**Harmonic Filter** To eliminate high-frequency harmonics generated by the converter and filter out unwanted signals from the power system. The filter is designed to attenuate these harmonics and improve the overall power quality.		If the specific design requires, the OEM will provide this as part of the system on frequency rating of 50 Hz. The attenuation and Power rating will be as per OEM.	
22	**HMI, interlocking, software, cyber security and data protection** HMI and software, with interlocking on different access levels. The anti-virus software should allow regular updating and the HMI, and all other systems should have a firewall or other cyber security measures.		XXXXXXXX	
23	**Humidity** The relative humidity of the surrounding air, between 10 and 95 %.	%	< 95%	
24	**Installation Requirements** The installation requirements of a DSTATCOM depend on the application and installation site. They may include equipment grounding, insulation coordination, and electromagnetic compatibility (EMC) compliance.		XXXXXXXX	
25	**Losses** The losses of a DSTATCOM include both the active power losses and reactive power losses. The active power losses are due to the resistance of the components, while the reactive power losses are due to the reactive power consumption by the capacitors and inductors. The losses are expressed as a percentage of the rated power which must < 1% for the total losses.	%	< 0.5% for the DSTATCOM, and < 1% for the total system losses including auxiliary system and transformer.	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
26	**Measurements sensors and transducers** All sensors for the measurement of currents, voltages, airflow, cooling water or oil flow and temperature sensors, humidity, etc. will be as per OEM's design and shall be for the contractor's account.		As per OEM's design	
27	**Minimal maintenance** Critical high-risk equipment/components should have redundancy, allow for maintenance and repairs while the system is running to minimise unavailability. Eskom requires a maintenance free DSTATCOM, no routine maintenance and no moving parts.		XXXXXXXX	
28	**Mean Time Between Failures (MTBF), and Service life** The MTBF of a DSTATCOM determines the lifespan, reliability, and maintenance requirements of the system. Life time of the DSTATCOM > 30 years, and for the Protection & Control (P&C) systems > 15 years.	Years	> 30 yrs (DSTATCOM) > 15 years (P&C)	
29	**Noise limits and measurements** The Noise limit levels, and measurement location must be as per IEE/IEC standards and the measurements should be within the limits at the boundary of the system (i.e. on the enclosure or at 2m from the equipment). The system shall be designed to run free of excessive vibration and noise under all conditions of load.	dBm	80	
30	**Online Diagnostics and condition monitoring** Diagnostic Equipment and Online condition monitoring should be possible for local and remote access for fault diagnostics, and equipment self-diagnosis (checking) for the DSTATCOM and the network. Online condition monitoring and remote access are needed to safeguard RAM performance and guarantees.		XXXXXXXX	
31	**Operating Temperature Range** The operating temperature range of a DSTATCOM should be specified to ensure proper operation, reliability, and maximised performance. The temperature range can vary depending on the design of the cooling system and design requirements.	°C	-10°C to +50°C.	
32	**Output Control** As per OEM's but should meet performance levels.		Independent phase control recommended.	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
33	**Portable, pole mounted System** The required DSTATCOM is a portable, pole mounted distribution STATCOM rated 22 kV. Pole mounted solution recommended.		XXXXXXXX The site is 1100 m above sea level, it is in a very area, and at time with high humidity.	
34	**Power Electronics Converter / Inverter** The AC/DC (AC-DC) Converter, and/or AC/AC Converter. Responsible for converting the AC voltage from the distribution system to DC voltage, and then back to AC voltage with the desired magnitude and phase angle. It also provides reactive power compensation, which is necessary for improving the power factor. The DC/AC or inverter converts DC voltage to AC. Voltage Source Converter / inverter (VSC/VSI) required. Efficiency >99%; Power factor >0.99 for the VSC; Power rating ±1 MVAr.		As per OEM's design. We noted that some DSTATCOM designs use AC/AC converters while it is typical to use AC/DC converters on Transmission STATCOM to interface network.	
35	**Power Factor (Pf) Correction** The power factor correction capability of a DSTATCOM determines the ability to correct the power factor of the distribution network. The required power factor correction capability of the VSC is 0.99 with no external load, and Pf > 0.95 during peak load.		Pf > 0.99 for the VSC converters, Pf > 0.97 for the lightly loaded DX network, and Pf > 0.95 for during peak load condition.	
36	**Protection System** The protection system of a DSTATCOM is important in that it protects the system components and prevent damage from faults and abnormal operating conditions. The protection system can include overcurrent protection, overvoltage protection, undervoltage protection, and temperature protection.		XXXXXXXX Dual redundancy required on protection.	
37	**RAM, Spares and Guarantees** Spares for the guarantee period to be supplied to meet the RAM guarantees, supplier to include guarantee for RAM performance and to provide support to Eskom within 24 hours during the RAM period of two (2) years after commissioning date.	%	RAM > 99.7%	
38	**Regulating mode** As per OEM's but to meet performance levels.		Single phase and 3 phase control	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
39	**<u>Response Time</u>** The response time of a DSTATCOM defines the speed at which the DSTATCOM responds to changes in the system voltage. The duration (Sub-cycle) from a step change in control signal input until the voltage changes by 90% of its final change, before any overshoot. The maximum overshoot allowed is 10 % of the ordered change on the control input.	ms	< 5 ms (0.005 s) or < ¼ cycle on 50 Hz for the DSTATCOM and its control system, and < 10 % overshoot	
40	**<u>Settling Time</u>** The duration from a step change in control signal input until the STATCOM output settles to within ±5% of the required control output.	ms	As per OEM's design. Settling time < 100 ms	
41	**<u>Short term overload capability</u>** The MVAr fault level rated for (2s)	MVAr	3 x (or 300%) Continuous Reactive power output rating	
42	**<u>Size of the DSTATCOM</u>** The size and weight of a DSTATCOM define the installation space and transportation requirements. The dimensions for sizes should be in m or cm.	H x W x B	XXXXXXXX	
43	**<u>Software Tools, digital models, and licences</u>** All software tools should have licenses to allow engineering simulations, testing, and studies. The software and network must have comprehensive cyber security solutions, full antivirus licenses for virus protection, and white-listing when applicable. Software models to be provided, actual control and protection functions should be included, bidders should also do the EMT studies justifying compliance of the DSTATCOM to the specification for control and protection functions, engineering training, and with testing licences for all tools if required.		XXXXXXXX	
44	**<u>Special tools, Test and Commissioning equipment</u>** All special tools, testing and commissioning equipment used during the project must be supplied to Eskom, including one (1) Laptop, one (1) Infra-red camera, and one (1) Off-site HMI system.		XXXXXXXX	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
45	**<u>Star or Delta configuration VSC's</u>** Some DSTATCOM are designed for Single Star configured VSCs while others are in Delta configured VSC. The Single Star VSCs are good for balanced network conditions, and the Delta configured VSCs have a better performance for unbalanced network conditions. We require a Delta configured VSC technology on this DSTATCOM.		Delta Configured VSC's	
46	**<u>Type testing</u>** Type tests to be done/validated for the VSC on IEEE / IEC 62927 standards. The bidder to provide test results for all other equipment and materials must be within ten (10) years of the tender enquiry date.		XXXXXXXX For supplier's account	
47	**<u>Voltage and Current THD Limits</u>** The voltage and current total harmonic distortion (THD) limits of a DSTATCOM should be specified to ensure the power quality of the distribution network.		THD < 3% as per IEEE 519	
48	**<u>Voltage Control Range.</u>** The Voltage limits on the network are; V < 0.95 pu during peak load (no SSEG), V > 1.48 pu when lightly loaded (at full SSEG generation). The voltage rise exceeds 1.03 pu Grid code compliance limit. The voltage control range requirements are from 0.3pu to 1.5pu continuous operation of the DSTATCOM.	%	± 30% XXXXXXXX	
49	**<u>Voltage Rating</u>** The voltage rating of a DSTATCOM should match the voltage level of the distribution network to ensure operation at 22 kV (L-L) on the Disselfontein Zoetgat feeder. The voltage rating range of this DSTATCOM should be wide enough to accommodate the voltage variations of the distribution network.	kV	22 kV (Phase-to-phase).	
50	**<u>Voltage Step Size</u>** The voltage step size of a DSTATCOM determines the precision of the voltage regulation. It is typically in the range of a few volts to a few tens of volts.		XXXXXXXX < 0.1 % (22 V on the AC)	
51	**<u>Unbalance</u>** Negative and Positive phase sequence voltage and current unbalance < 2%	%	< 2%	

Item	Description	Unit	Schedule A Client's Requirement	Schedule B Guaranteed Data
52	**Weight of the DSTATCOM** The size and weight of a DSTATCOM define the installation space and transportation requirements. The weight shall be in kg or tons.	kg	XXXXXXXX	
53	**Current Transformers (CT)** For the measurement of current in the distribution system and provide feedback to the control system. CT's are used to scale down the current do a measurable current for protection and control. Bidder to ensure a 1A secondary CT ratio.		As per OEM's design, specify CT Ratio if applicable.	
54	**Surge Arresters and MOV** Surge arresters are used to protect the DSTATCOM from voltage surges and transients in the distribution system. The MOV is for overvoltage protection.		As per OEM's design, where applicable.	
55	**Switchgears, Disconnector** MV disconnectors, Breakers, Isolators, and earth/grounding switches where applicable are used to isolate the DSTATCOM from the distribution system when necessary, such as during faults and maintenance outages and for repairs.		As per OEM's design, where applicable.	
56	**Transformer** A transformer is used to couple the DSTATCOM to the distribution system at the point of common coupling (PCC). It provides voltage matching and isolation between the DSTATCOM and the distribution system, which is important for ensuring the safety and reliability of the installation. A transformer is used to step-up or step-down the voltage level as per the requirement of the system.		Power rating 1 MVA with; Efficiency > 98% Note: Requirement of the transformer will be as per OEM's design. The contractor shall calculate the rating and include details with the bid documents if required.	
57	**Voltage transformer (VT)** These are used to measure the voltage at various points in the distribution system and provide feedback to the control system. Voltage on the secondary side to be 110 V AC phase to phase or 63.51 V phase to ground for this DSTATCOM.		As per OEM's design. Secondary Voltage 110 V AC (phase to phase) or 63.51 V AC Phase to Neutral	

Annex B – Fault levels Disselfontein 132 kV BB and conductor data

132 kV Busbar Fault Types/levels	Single Phase (1 Ph) Fault, 132 kV	Balanced Three Phase (3 Ph)
Fault Current (kA)	3.529	3.477
MVA Fault level	269	794.8
X/R of the network	2.87	2.87

Substation: Disselfontein Rural

Busbar: busbar_name

Fault Level Report [Min/Max under contingency, Normal Operation]

Fault Type	1Ph									3Ph								
Value Type	max			min			normal			max			min			normal		
busbar_name	Ikss (kA)	Skss (MVA)	X_R	Ikss (kA)	Skss (MVA)	X_R	Ikss (kA)	Skss (MVA)	X_R	Ikss (kA)	Skss (MVA)	X_R	Ikss (kA)	Skss (MVA)	X_R	Ikss (kA)	Skss (MVA)	X_R
Disselfontein 132 BB	3.368	256.700	2.87	1.721	131.100	2.53	3.529	269.000	2.87	3.477	794.800	2.87	1.583	361.900	2.53	3.477	794.800	2.87
Disselfontein 22 BB 1	0.484	6.200	13.01	0.237	3.000	13.01	0.477	6.100	13.01	4.564	173.900	13.01	2.564	97.700	23.15	4.564	173.900	13.01

Size code		SQUIRREL	FOX	MINK	HARE	CHICADEE	WOLF
No. of Wires (Aluminium/Steel)	mm	6 / 1	6 / 1	6 / 1	6 / 1	18 / 1	30 / 7
Wire Diameter (Aluminium)	mm	2.11	2.79	3.66	4.72	3.77	2.59
Wire Diameter (Steel)	mm	2.11	2.79	3.66	4.72	3.77	2.59
Conductor Diameter	mm	6.33	8.37	11.0	14.16	18.87	18.13
Total Area (Aluminium)	mm²	21.0	36.7	63.1	105.0	200.9	158.1
Total Area (Steel)	mm²	3.5	6.1	10.5	17.5	11.2	36.9
Total Conductor Area	mm²	24.5	42.8	73.6	122.5	212.1	195.0
Linear Mass (Aluminium)	kg/km	57.6	100.7	173.2	288.1	553.4	437.5
Linear Mass (Steel)	kg/km	27.3	47.7	82.1	136.5	87.1	289.9
Conductor Linear Mass	kg/km	84.8	148.3	255.3	424.6	640.5	727.4
Conductor Linear Mass (Greased)	kg/km	86.9	151.9	261.4	434.8	667.1	755.6
Resistance dc @ 20°C	Ω/km	1.3677	0.7822	0.4555	0.2733	0.1427	0.1828
Resistance dc @ 50°C	Ω/km	1.5330	0.8768	0.5106	0.3063	0.1600	0.2409
Ultimate tensile strength	kN	8.0	13.1	21.6	36.0	44.9	69.2
Modulus of Elasticity	MPa	86121	86121	86121	86121	75787	83400
Coefficient of Linear Expansion	/ °C $x10^{-6}$	19.3	19.3	19.3	19.3	21.6	18.4
Creep constant *	mm/m	0.360	0.360	0.360	0.360	0.425	0.335
Current rating under Normal Conditions							
AT 50°C	Amps	106	148	209	292	433	378
AT 60°C	Amps	130	184	258	357	541	473
AT 70°C	Amps	149	210	297	408	625	548
AT 80°C	Amps	165	233	330	455	698	610
AT 90°C	Amps	178	253	357	496	758	663

The conductor data for Disselfontein Zoetgat 22 kV feeder backbone from the substation to the selected pilot site where the DSTATCOM will be installed: MINK (Code Number 63) and HARE (Code Number 100) – IEC / SANS 61089

Annex C – Communication path loss profile report

Detail report – MTN Tower T1245 to Disselfontein DSTATCOM

	MTN T 1245	Disselfontein Statcom
Latitude	29 37 56.20 S	29 35 04.40 S
Longitude	024 05 07.40 E	024 03 01.00 E
Easting (m)	88575.6	92019.5
Northing (m)	3279444.1	3274181.5
Standard meridian	25° E	25° E
True azimuth (°)	327.25	147.27
Vertical angle (°)	-0.51	0.47
Elevation (m)	1112.07	1103.80
Tower height (m)	50.00	
Antenna model	Base (TR)	Candle stick Poyntin (TR)
Antenna gain (dBd)	5.85	0.85
Antenna height (m)	48.50	3.00
TX line model	3/8" LDF	LMR 195
TX line unit loss (dB/100 m)	7.55	23.00
TX line length (m)	50.00	4.00
TX line loss (dB)	3.77	0.92
Connector loss (dB)	2.50	1.00
Miscellaneous loss (dB)	3.00	2.00
Duplexer loss (dB)	3.50	
Frequency (MHz)	900.00	
Polarization	Vertical	
Path length (km)	6.29	
Free space loss (dB)	107.52	
Atmospheric absorption loss (dB)	0.03	
Diffraction loss	0.00	
Net path loss (dB)	113.25	113.25
Radio model	GPRS	TruTeq GPRS
TX power (dBm)	46.53	33.01
EIRP (dBm)	41.76	32.09
RX threshold criteria	-110	-102
RX threshold level (dBm)	-110.00	-104.00
RX threshold level (µv)	0.71	1.41
Receive signal (dBm)	-80.24	-66.72

	MTN T 1245	Disselfontein Statcom
Receive signal (µv)	21.75	103.18
Receive field strength (µv/m)	3359.58	708.26
Thermal fade margin (dB)	29.76	37.28
Climatic factor	1.00	
Average annual temperature (°C)	10.00	
Fade occurrence factor (Po)		

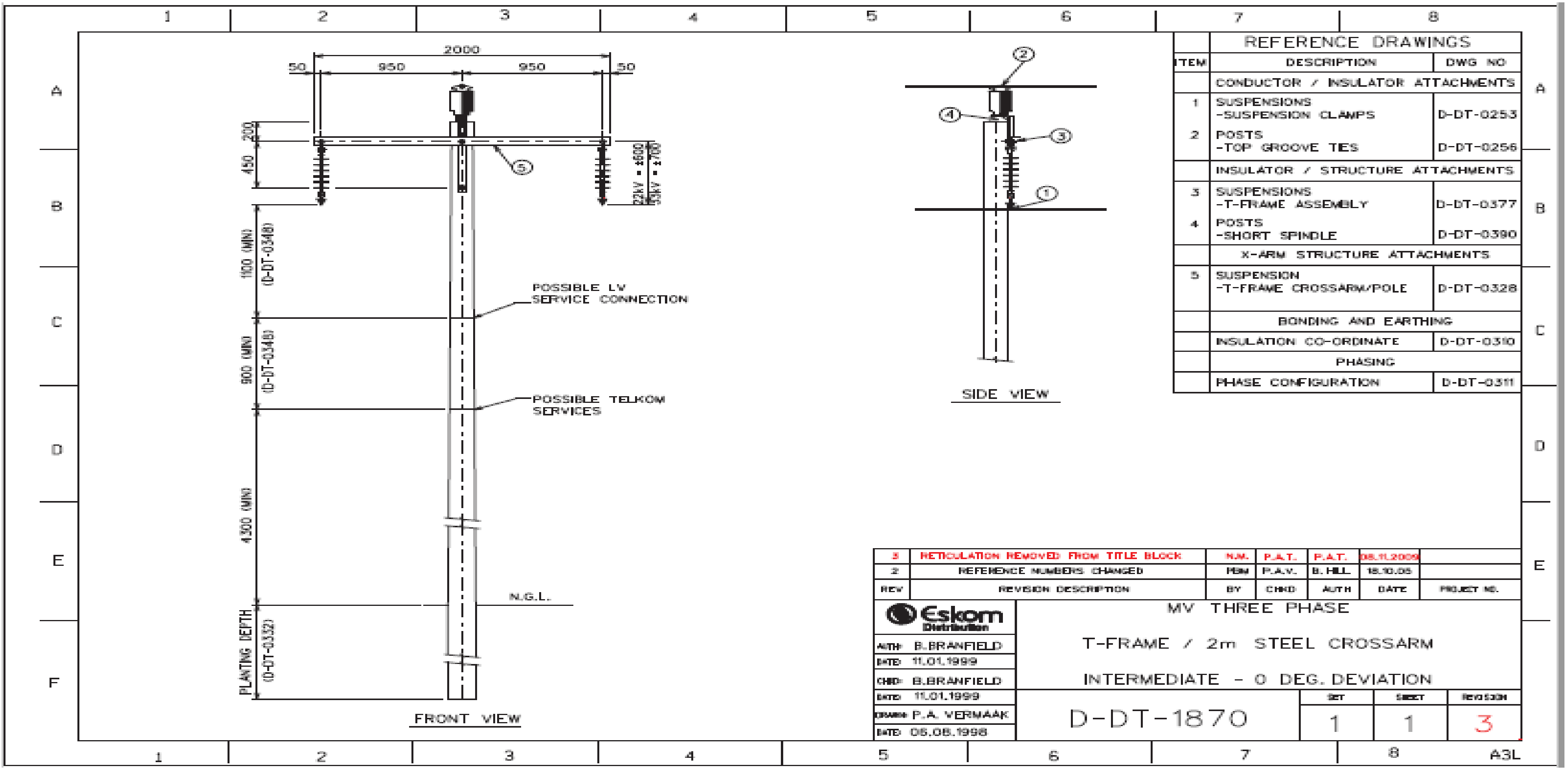
Detail report Eskom RS to Disselfontein DSTATCOM

	Klipfontein telkom NC UHF	Disselfontein Statcom
Latitude	29 26 05.30 S	29 35 04.40 S
Longitude	023 58 46.80 E	024 03 01.00 E
Easting (m)	-95060.8	92019.5
Northing (m)	3257606.3	3274181.5
Standard meridian	23° E	25° E
True azimuth (°)	157.60	337.57
Vertical angle (°)	-0.27	0.36
Elevation (m)	1150.62	1103.80
Tower height (m)	30.00	5.00
Antenna model	Co-linear (TR)	Corner Reflect G400 (TR)
Antenna gain (dBd)	5.85	9.00
Antenna height (m)	30.00	5.00
TX line model	1/2" Heliax	LMR 400
TX line unit loss (dB/100 m)	4.50	8.86
TX line length (m)	36.00	4.00
TX line loss (dB)	1.62	0.35
Connector loss (dB)	2.00	1.00
Duplexer loss (dB)	2.00	
Frequency (MHz)	410.00	
Polarization	Vertical	
Path length (km)	17.96	
Free space loss (dB)	109.81	
Atmospheric absorption loss (dB)	0.05	
Diffraction loss	23.00	
Net path loss (dB)	120.67	120.67
Radio model	Exicom	Tait 8000
TX power (dBm)	36.99	36.99
ERP (dbm)	37.22	44.64

	Klipfontein telkom NC UHF	Disselfontein Statcom
ERP (watts)	5.27	29.08
RX threshold criteria	110dB Squelch	-90dBm
RX threshold level (dBm)	-110.00	-110.00
RX threshold level (µv)	0.71	0.71
Receive signal (dBm)	-83.68	-83.68
Receive signal (µv)	14.63	14.63
Receive field strength (µv/m)	63.20	63.20
Thermal fade margin (dB)	26.32	26.32
Climatic factor	1.00	
Average annual temperature (°C)	10.00	
Fade occurrence factor (Po)		

Multipath fading method - Vigants – Barnett

Annex D – Existing Zoetgat 22 kV feeder Pole DZO172 (Drawing D-DT1870)



Annex E – Deviations Schedule list

All deviations on the specification in this standard must be declared and listed in this table format. Copies of this template may be used if more deviations are to be recorded. Ensure all pages are signed, dated, and stamped.

Item# Section	Deviation, reasons for deviation, including or excluding this specific item from bid and design	Risk and alternative offered, or risk mitigation for the deviation

NAME OF AUTHORIZED REPRESENTATIVE	SIGNATURE	COMPANY STAMP AND DATE