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CONTENTS

	Page
FOREWORD	1
1.SCOPE	2
2.NORMATIVE REFERENCES	3
2.1 NORMATIVE	3
2.2 INFORMATIVE	9
3.DEFINITIONS AND ABBREVIATIONS	9
3.1 DEFINITIONS	9
3.2 ABBREVIATIONS	10

4.GENERAL REQUIREMENTS	10
4.1 BASIC REQUIREMENTS	10
4.2 STANDARDS.....	11
4.3 NOMENCLATURE STANDARDISATION.....	11
4.4 CONTRACTOR SCOPE OF WORK.....	12
4.5 ESKOM SCOPE OF WORK.....	15
4.6 ESKOM / CONTRACTOR INTERFACE POINTS	16
4.7 GENERAL INFORMATION AND CONTRACT CONDITIONS	18
4.7.1 A/B Schedules	18
4.7.2 Deviations from any part of this specification or A/B Schedules	18
4.7.3 Design Review Process	19
4.7.4 Independent assessment of Design	20
4.7.5 Access to site and Outage arrangements.....	21
4.7.6 Acceptance Tests, Trial Operation and Take-Over.....	21
5.AC SYSTEM AND STATCOM CHARACTERISTICS	22
5.1 STATCOM OUTPUT AT NOMINAL VOLTAGE.....	23
5.1.1 Voltages.....	23
5.1.2 Short-Circuit Characteristics – at present and in future	24
5.1.3 Frequency.....	24
5.2 AUXILIARY SUPPLIES	25
5.3 ENVIRONMENTAL CONDITIONS.....	25
5.4 AC SYSTEM HARMONIC IMPEDANCE CHARACTERISTIC	26
5.4.1 AC System Harmonic Impedance Characteristic	26
5.5 FILTERS AND HARMONICS	26
5.5.1 Definition of filtering performance	28
5.5.2 Definition of Filter Ratings.....	29
5.5.3 Telephone Interference.....	30

5.6	NETWORK CONFIGURATION.....	30
5.6.1	Network Configuration	30
5.7	FUNCTIONAL CHARACTERISTICS.....	31
5.7.1	General Concept	31
5.7.2	Definition of Terms	32
5.7.3	STATCOM Rating.....	32
6.	CONTROL AND MONITORING.....	36
6.1	OVERALL CONTROL CONCEPT (CONTROL OBJECTIVES).....	36
6.1.1	Voltage Control Mode (Rapid Voltage Regulator)	36
6.1.2	Fixed Susceptance Mode - Manual Control	37
6.1.3	Negative Phase Sequence Voltage Control.....	37
6.1.4	Supplementary Control Functions.....	38
6.1.5	Undervoltage Strategies	39
6.1.6	Overvoltage Strategies for load rejection	39
6.1.7	Automatic energising – Sequence control.....	40
6.2	SUBSTATION CONTROL AND MONITORING REQUIREMENTS	42
6.2.1	Information reporting.....	42
6.2.2	Time Synchronisation	43
6.2.3	Interfacing with Eskom Substation Gateway	43
6.2.4	Signal Requirements	45
6.2.5	Local reporting.....	46
6.2.6	HMI Control Requirements	46
6.3	STATCOM OPEN AND CLOSED LOOP CONTROL INTERLOCKING AND STATUS CONTROL	49
6.3.1	Interlocking System	49
6.4	CONTROL SYSTEM TESTS.....	50
6.4.1	Standards.....	50
6.4.2	Tests at site	50

7.PROTECTION PHILOSOPHY	51
7.1 GENERAL REQUIREMENTS	51
7.2 MINIMUM REQUIRED DEVICE PROTECTION	52
7.2.1 STATCOM Transformer and 275kV Bus.....	52
7.2.2 STATCOM HV Circuit Breaker and other breakers or switches	53
7.2.3 STATCOM Low Voltage Bus Circuit	53
7.2.4 TCR Air Core Reactor.....	53
7.2.5 Thyristor Controlled Reactor branch	53
7.2.6 Harmonic Filters	54
7.3 OPERATION INDICATORS.....	54
7.4 STANDARDS AND TESTS.....	54
8. INSULATION COORDINATION	54
8.1 SURGE ARRESTERS.....	55
8.2 PRECAUTIONARY INSULATION OF LIVE PLANT AND MATERIAL.....	56
9. MAIN COMPONENTS – REQUIRED FUNCTION AND FEATURES.....	56
9.1 IEGT / THYRISTOR VALVES.....	56
9.2 ADDITIONAL REQUIREMENTS FOR THE VALVES	58
9.3 THYRISTOR CONTROLLED REACTOR.....	59
9.4 COOLING SYSTEM	60
9.5 REACTORS.....	63
9.5.1 Type Tests and Routine Tests	64
9.6 ISOLATORS, EARTHING SWITCHES AND INTERLOCKS.....	64
9.6.1 General Requirements.....	65
9.7 POST INSULATORS, BUSBAR AND BUSBAR ACCESSORIES	66
9.7.1. Post Insulators.....	66
9.7.2. Busbar and accessories	66
9.7.3. LV side earth fault current limitation.....	67

9.8	AUXILIARY POWER SUPPLIES	67
9.8.1	Testing	68
9.9	POWER TRANSFORMER	68
9.10	CIRCUIT BREAKERS	69
9.11	INSTRUMENT TRANSFORMERS.....	69
10.	CIVIL ENGINEERING AND CONTAINER REQUIREMENTS.....	69
10.1	DESIGN CRITERIA	70
10.1.1	General Requirements.....	70
10.1.2	Scope	70
10.2	GENERAL DESCRIPTION OF WORK.....	72
10.2.1	Terrace drainage	72
10.2.2	Cable Trench (yard).....	72
10.2.3	Support structures for the LV equipment.....	72
10.2.4	Fencing	72
10.2.5	STATCOM Container.....	72
10.2.6	Standards.....	73
11.	ENGINEERING STUDIES.....	74
11.1	SIMULATOR STUDIES.....	75
11.1.1	EMTDC Model	75
11.1.2	Power Factory (DigSilent) Model	75
12.	RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM).....	76
12.1	DEFINITIONS	76
12.2	REQUIRED AVAILABILITY AND RELIABILITY.....	76
13	SPARES.....	77
13.1	SPARES STRATEGY	77
13.2	SPARE PARTS STORAGE	77
13.3	SPARE PARTS ACCOUNTING.....	78

13.4 AVAILABILITY OF SPARES	78
14TEST AND COMMISSIONING REQUIREMENTS	78
14.1 GENERAL REQUIREMENTS	78
14.2 NOTIFICATION OF TESTS	80
14.3 FACTORY ACCEPTANCE TESTS.....	80
14.4 RTDS TESTS	80
14.5 SITE ACCEPTANCE TESTS.....	81
14.6 COMMISSIONING TESTS	81
15TRAINING REQUIREMENT	83
15.1 TRAINING SCHEDULE	84
15.2 COURSE OBJECTIVES	84
15.3 TRAINING CONTENT	85
15.3.1 Course Content for Level 1 (National Controllers).....	86
15.3.2 Course Content for Level 2 (Substation Personnel)	87
15.3.3 Course Content for Level 3.....	87
16DOCUMENTATION	90
16.1 DESIGN DOCUMENTATION	90
16.2 OTHER DOCUMENTS AND ACTIVITIES	91
16.3 PRE COMMISSIONING DOCUMENTATION.....	91
16.4 POST COMMISSIONING DOCUMENTATION.....	92
17.DESIGN AND CONSTRUCTION REQUIREMENTS.....	92
17.1 PLANT AND MATERIAL CHARACTERISTICS	92
17.2 LAYOUT AND DESIGN	93
17.3 MAINTAINABILITY	93
17.4 POLYCHLORINATED BIPHENYLS (PCB).....	93
17.5 VERMIN PROOFING	93
18.SAFETY REQUIREMENTS AND ENVIRONMENTAL IMPACT	94

18.1 SAFETY REQUIREMENTS	94
18.2 ENVIRONMENTAL IMPACT	95
19.GENERAL PLANT REQUIREMENTS	95
19.1 SECONDARY EQUIPMENT DESIGN AND CONSTRUCTION STANDARDS	95
19.2 SPECIAL TOOLS.....	96
19.3 MECHANISM, JUNCTION BOXES AND TERMINALS.....	97
19.4 STATUTORY, LABELING AND LABELING OF PRIMARY PLANT	97
19.5 SPECIAL DESIGN REQUIREMENTS FOR FIBRE OPTIC CABLES.....	97
19.6 PAINTING SPECIFICATION.....	97
20.ELECTROMAGNETIC INTERFERENCE	98
20.1 RADIO INTERFERENCE	98
20.1.1 Conducted Noise	98
20.1.2 Radiated Noise	98
20.1.3 Radio / Television Interference	98
20.1.4 Magnetic and Electric field strengths	98
21.AUDIBLE SOUND LEVEL.....	99
22.STATCOM LOSS EVALUATION.....	99
ANNEXURE A: SYSTEM CONTINGENCIES	100
ANNEXURE B: TSC REQUIREMENTS	101
ANNEXURE C: EQUIPMENT INSULATION LEVELS.....	104
ANNEXURE D: STANDARD ELECTRICAL AND WORKING CLEARANCES	105
ANNEXURE E	106
SCHEDULE A: ESKOM'S PARTICULAR REQUIREMENTS.....	106
A.1: General Requirements.....	106
ESKOM'S SCOPE OF SUPPLY HV & EQUIPMENT INFORMATION.....	107
A.2 STATCOM HV Circuit Breaker.....	107
A. 3 STATCOM HV Isolators.....	108

A.4 275kV Surge Arresters Isolators	108
ANNEXURE F	109
SCHEDULE B: GUARANTEES AND TECHNICAL DETAILS OF EQUIPMENT OFFERED	109
B.1 STATCOM Performance.....	109
B.2 STATCOM Performance: Losses.....	111
B.3 STATCOM Performance: Rated Values.....	112
B.4 STATCOM Voltage Control.....	113
B.5 Audible Noise Levels	114
B.6: Air-Core Reactors	115
B.7: Air-cooled Resistors.....	117
B.8: IEGT Valves for each phase	118
B.9: Valve Cooling System.....	120
B.10: Control and Monitoring	122
B.11: Protection	123
B.12: Measuring Current Transformer.....	123
B.13: Measuring Voltage Transformer.....	124
B.14: Isolators.....	125
B.15: Power Transformer	127
Eskom Transmission Design Information: Annexure to A&B Schedules.....	143
ANNEXURE G: SCHEDULE A/B2 ADDITIONAL ITEMS.....	149
ANNEXURE I: SCHEDULE B3 STATEMENT OF COMPLIANCE	150

FOREWORD

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Applicability

This specification shall apply to the Garona 275kV STATCOM project.

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Overview

This specification document describes minimum requirements for the design, installation and commissioning of (+)45 MVar (inductive) to (-)45 MVar (capacitive) Eskom Static Compensator (STATCOM) at Garona substation. The STATCOM at Garona shall be connected to the 275kV bus. The STATCOM shall form part of the transmission system and shall operate as a self-contained system. The rated capacity of the STATCOM shall be obtained using the most suitable technology for the application.

The main purpose of this STATCOM is to control voltage unbalance due to phase-to-phase connected single phase traction load. Any reserved capacity should be utilized to control symmetrical voltages. Although the specification generally refers to TCR and filter modules technology, Eskom is open to optimized solutions that will satisfy the conditions and requirements of the intent specified herein. The solution shall meet the requirements in terms of Reliability, Availability, and Maintainability at optimal cost also taking capitalized losses into consideration. Eskom reserves the right to select the best solution based on its overall assessment.

1. SCOPE

This document sets out Eskom's basic requirements for a STATCOM required at Garona 275kV substation.

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2. NORMATIVE REFERENCES

Parties using this document shall use the most recent edition(s) of the document(s) listed in this section.

The following standards are referenced in this specification; all works related to the supply of the STATCOM system shall be in accordance with the requirements of these standards. All Standards are subject to revision, and parties shall apply the most recent editions of the Standards listed below.

If the requirements of this specification conflict with any of the below standards, discrepancies shall be notified to Eskom, who shall then instruct the Contractor thereon.

In all matters on which this specification is silent, a ruling shall be sought from Eskom and such ruling shall then form part of this specification. Eskom has a preference for IEC standards and CIGRE guidelines. If other international standards are used, their differences to IEC standard shall be indicated.

All documents, drawings, instruction manuals and test certificates shall use metric units and shall be consistent throughout and shall be in English.

2.1 Normative

ISO Standards

ISO9001:2000 Quality systems standard

Reference Number	Title
	IEC Specifications
IEC 60146	Semiconductor converters
IEC / TR 62543-1	Voltage Source Converters
IEC 61954	Power electronics for electrical transmission and distribution systems - Testing of thyristor valves for static var compensators
IEC 60160	Standard atmospheric conditions for test purposes
IEC 61869-1	General Requirements for Instrument Transformers
IEC 60044-2, 5 &6	Instrument transformers –Inductive voltage transformers (EMVT's),

	CVT's and Transient response for CT's.
IEC 60273	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V
IEC/TR 60815	Guide to the selection of insulators in respect of polluted conditions
IEC 60289	Reactors
IEC 60383-1&2	Tests on insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1000 V
IEC 60437	Radio interference test on high voltage insulators
IEC 62271	High Voltage Switchgear and Control gear
IEC 60518	Dimensional standardisation of terminals for high voltage switchgear and control gear.
IEC 60549	HV Fuses for the protection of shunt power capacitors
IEC 60282 (Parts 1,2,3)	High voltage fuses
IEC 60269 (Parts 1-4)	Low voltage fuses
IEC 60551	Audible sound
IEC 60076-10	Power Transformers – Determination of transformer and reactor sound levels – User guide
IEC 60654	Operating conditions for industrial – process measurement and control equipment
IEC 60694:1980	Common specification for high voltage switchgear and control gear standards
IEC 60146	Semiconductor devices, discrete devices and integrated circuits; thyristors
IEC 60794-1,2	Optical Fibre cables
IEC 61000	Electromagnetic compatibility

IEC 60870-5-101	Tele-control equipment and systems – Transmission Protocols
IEC 61071-1	Power electronic capacitors: General
IEC 61071-2	Power electronic capacitors: Requirements for disconnecting tests on fuses, destruction test, self-healing test and endurance test.
IEC 60871 (Part I and II)	Shunt capacitors for AC power systems having a rated voltage above 1000 V
IEC 60721	Classification of environmental conditions
IEC 60721-1 (1990)	Environmental parameters and their severities
IEC 60529	Degrees of protection provided by enclosures
IEC 60068-2-33	Guidance on change of temperature tests
IEC 61850	Design of electrical substation automation
ISO 3746	Acoustics. Determination of sound power levels of noise sources using sound pressure
	IEEE Standards
IEEE 1031	Guide for the Functional Specification of Transmission Static VAr Compensators
IEEE 1303	Guide for Static VAr Compensator Field Tests
IEEE 80	Guide for safety in AC Substation Grounding
	CIGRE
CIGRE	Guidelines for testing of Thyristor Valves for Static VAr Compensators prepared by CIGRE WG14-01, TF02.
	South African Standards
SANS 2001 – BE1	Construction works Part BE1: Earthworks (general)

SANS 2001 – CS1	Construction works Part CS1: Structural steelwork
SANS 2001 – CT2	Construction works Part CT2: Structural timberwork (roofing)
SANS 2001 – CM1	Construction works Part CM1: Masonry walling
SANS 1090	For sand
SANS 1083	For coarse aggregates
SANS 920/1024	Steel reinforcement for reinforced concrete works
SANS 044	Welding
SANS 1200	Standardized Specification for civil engineering construction
SANS 878	Ready mixed concrete
SABS 156	Moulded case circuit breakers. 10 kA rupturing capacity
SANS 1507	Polyvinyl chloride (PVC) - insulated electric cables and flexible cords
SANS 1339	Electric cables - Cross-linked polyethylene (XLPE) insulated cables for rated voltages 3,8/6,6 kV to 19/33 kV
SANS 1431	Weldable structural Steel
SANS 1433	Electrical terminals and connectors
SANS 10142	The wiring of premises
SANS ISO 121	Hot dip galvanised coatings on fabricated iron & steel articles
SANS 1816	Electricity supply - Quality of supply: Power quality instruments
NRS048-2	Voltage Characteristics, Compatibility Levels, Limits and Assessment Methods
	American Standards

NEMA CP-1: 1988	Shunt Capacitors
	Eskom Standards
TSP41-1009	Labels for Eskom Transmission Substations
TST41-1062	Standard for Electronic Protection and Fault Monitoring Equipment for Power Systems
ESKPVAEY6	ESKOM Operating Regulations for High Voltage Systems
DSP34-1974	Distribution Spec Part 7 Substation Connectors
TST41-168	Quality assurance requirements for the procurement of assets, goods and services
	Transmission Specifications, Reports and Standards
TST41-634	Drawing Office Standard
TPC41-246	Management of equipment manufacturers/suppliers drawings
TSP41-363	Standard specification for outdoor metal oxide surge arresters without spark gaps for system voltages of 220kV and above
TST41-134	Statutory safety signs in Transmission substations and buildings
TST41-655	Specification for the design, manufacture and installation of outdoor high voltage equipment labels for transmission substations
TSP41-592	Specification for outdoor circuit breakers for voltages above 1kV
TSP41-606	Specification for HV outdoor isolators and earth switches
TSP41-121	Auxiliary Transformers
TRMSCAAB1	Specification for power line carrier coupling capacitors and capacitor voltage transformers
TPL41-142	Safety Earthing of Capacitor Banks

TST41-644	Standard for Battery rooms
TSP41-601	Specification for Switch Mode Battery Chargers
TSP41-599	Outdoor Junction boxes for substations
TSP41-665	Multimode Fibre Optic Duct Cable
TST41-627	Specification for secondary equipment labelling
TRMCABS9	Specification For Polymeric Longrod Insulators For Voltages of 220kV and Above
TSP41-452	Glass Cap and Pin Insulators for Eskom Transmission HVAC
TSP41-1004	Specification For Substation Tubular Conductors
TSP41-727	Stringing, Cabling, Earthing and Erection Specification for Substation
TST41-877	Transmission Substation Earthing Standards
TSP41-87	Specification For Large Power Transformers
Drawing 0.54/390	Sheets 0 –78 Civil work standard details
Drawing 0.54/412	Sheets 0 – 54 HV Yard current carrying clamps, hardware and accessories
Drawing 0.54/4963	1,8m high HV Yard Safety fence
Drawing 0.54/5633	2,4m high Security fence with over-hang
TPC41-141	Check sheets for HV substation work to be taken over by the asset owner
TST41-139	Commissioning of Current transformers
TPC41-547	Commissioning of Isolators

Other Reference Documents / Acknowledgements

In addition to the IEEE 1031, the following documents have been used as guidelines for the compilation of this specification.

1. Guidelines for the Preparation of a Static Var Compensator (SVC) Specification - NR 500-021 E
2. Technical Specification for the Grassridge and Dedisa Static Var Compensators prepared by Power System Dynamics.

Legislation

Occupational Health and Safety Act, Act no. 85 of 1993 of the Republic of South Africa, and amendments

Regulations under the Environmental Conservation Act, 1989 (Act no. 73 of 1989) (No. R 638 28 March 1991 of the Republic of South Africa (page 86) and amendments.

Relevant Environmental legislation, i.e. legislation on water matters, waste and amendments will be specified in the Environmental Management Plan.

2.2 Informative

Not applicable

3. DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Unless otherwise stated, the definitions used in IEEE 1031, IEC 60050 and IEEE Std 100-1977 are applicable to this document.

The word SVC designates the complete functional system including components supplied by Eskom outside this Contract. The integration of all the components supplied by Eskom is an integral part of this contract at no extra cost.

Hereafter the term SVC refers to both SVC and STATCOM where applicable and can be used interchangeably.

Note that in the case of a STATCOM rating shall be \pm the highest MVAR of the specified range. The rating shall thus have a symmetrical capacitive / inductive range.

Transmission: A division of Eskom Holdings Limited (Reg. No. 2002/015527/06) a juristic person incorporated in terms of the company laws of the Republic of South Africa, with its registered office at Megawatt Park, Maxwell Drive, Sandton, herein referred to as Eskom.

3.2 Abbreviations

Abbreviation	Description
RTU	Remote Terminal Unit
ERTU	Enhanced Remote Terminal Unit
IED	Intelligent Electronic Device
RAM	Reliability Availability and Maintainability
VQR	Voltage Quality Recorder

4. GENERAL REQUIREMENTS

4.1 Basic Requirements

The works information and specification described in this document are for a turn-key project for the contractor to design, supply, deliver, offload, install and commission a complete STATCOM that will be connected to the 275kV bus at Garona substation.

The STATCOM is required to control the negative and positive phase sequence components on the 275kV network, with priority on the negative phase sequence.

The Eskom client (Spoornet) intends to increase the single phase load and the frequency of train operations on this traction supply network. The studies conducted showed that with the upgrades on the traction network, load increase and frequency of operating trains; the voltage unbalance will be unacceptably high at Garona on the 275kV network. Hence a (+45MVar) inductive to (-45MVar) capacitive STATCOM is required at the Garona 275kV bus.

The engineering, design and quality etc. shall reflect a design life of at least 30 years, with high reliability, availability and maintainability (RAM).

Although a TCR/filter arrangement is assumed in this specification, the Contractor must propose the most suitable SVC layout based on RAM, losses and the intended application.

All plant and material used in the STATCOM system shall have a proven record of good performance; products in development or without any service history shall not be used.

A fail safe design shall be applied throughout.

After the failure of one control / protection system, the other shall continue to operate and to keep the STATCOM in normal operation.

With the dual redundant control / protection system specified there shall be no consequential damage when one or both systems fail.

The protection system shall be IEC61850 protocol.

Original documentation or data sheets shall be supplied for all equipment and components.

4.2 Standards

The references given in Section 2 “Normative References” indicate where a Transmission standard or guideline exists for certain equipment or methods.

The Contractor shall comply with Transmission specifications and standards.

In the event of conflict between standards, the Eskom requirements, shall take preference. In case of doubt, the Contractor shall seek clarification from Eskom’s Project Manager.

If the Contractor wishes to rather use any other IEC or equivalent acceptable international specification not listed in Section 2, then the Contractor shall indicate this fact specifically in the Tender documentation and must obtain written permission from Eskom’s Project Manager.

Eskom requires compliance with the ISO9001:2000 quality standard.

Drawings supplied with the STATCOM shall comply with the requirements of Eskom specifications TST41-634 and TPC41-246. The drawings shall be clear and of appropriate size.

4.3 Nomenclature Standardisation

The following nomenclature shall be used.

- For the dual redundant Protection Systems Main 1 and Main 2 shall be used
- For phase designation R,W and B – Red, White and Blue shall be used

Naming and labelling shall be to Eskom’s approval. Naming and labelling for the STATCOM yard shall be submitted to Eskom for acceptance in good time before designs are finalised.

The quality of the labels shall be suitable for the 30 year expected life under environment conditions specified.

4.4 Contractor Scope of Work

The work and services to be supplied by the Contractor for the complete STATCOM installations shall include (but not be limited to) the following:

1. The complete engineering design, manufacture, testing of all STATCOM components and systems, transport; delivery to site, off load, install, commission, performance verification and field acceptance testing of the complete STATCOM system.
2. All studies required to verify SVC performance shall be an integral part of the contract e.g. SVC system design, harmonic studies, insulation co-ordination etc. including RTDS simulator studies to verify SVC performance.
3. All site tests to confirm radio interference, acoustic noise and harmonic performance.
4. RAM studies and guarantees.
5. The thyristor valves, including their protection, control, monitoring and cooling system.
6. All reactors and capacitor banks as required by the design.
7. All filters required for stability and harmonic performance.
8. Dual redundant systems for Control and Protection as well as measurement, monitoring and interlocking systems.
9. Integrated Transient Fault Recorder (TFR), Sequential Event Recorder (SER) and Voltage Quality Recorder (VQR).
10. Develop; implement and commission a complete external device control program for eight external devices, which includes presently installed and future devices.
11. Provide and install all hardware and software needed for the control of eight (8) external devices including interfacing with the existing equipment in Eskom's control room and display on the HMI.
12. Develop, implement, provide and install software, all required I/O's and other hardware for the intelligent control of traction breakers or load-break switches of four traction feeders (two Garona & two Lewensaar) as well as the traction busbars at the two substations. The intension of this is to control the situation arising from losing the 275kV connection to one or both of the substations and to protect the 132kV load (Upington town). That is managing potential undervoltage, overload of coupling transformer, excessive harmonics, and excessive negative

phase sequence by controlling the traction loads. The control system shall optimise the re-connection of the traction loads after the 275kV system has recovered. When the STATCOM is off this function shall still be available if selected to be so. The Garona and Lewensaar signals related to the traction must be collected / delivered at terminals in the existing Garona control room.

13. Provide optimised logic for the above to anticipate the future 400/275kV in-feed at Garona.
14. Provide strategies for protecting the STATCOM and Eskom network in case all or part of the above (12) is not implemented or not functional.
15. Provide STATCOM operation and harmonic trending in relation to the traction loads at Garona and Lewensaar
16. GPS clock for time stamping events and fault recordings.
17. All cables and cabling for equipment in the STATCOM.
18. Two three-phase AC and DC auxiliary power cables to feed the STATCOM system from the designated Eskom's supply points.
19. The necessary cabling from Eskom's 275 kV HV yard junction boxes for CT, Breaker, Earth Switches and Isolator control and monitoring signals for incorporation into the overall STATCOM control, monitoring and supervision systems.
20. STATCOM Control HMI (human-machine interface) with system and control variables shown on the mimic.
21. STATCOM dual 400V AC auxiliary supply distribution, complete with automatic chop-over system, protection and necessary inverters, derived from the single Eskom three-phase supply and the internal STATCOM auxiliary transformer. The STATCOM aux supply is derived from the STATCOM LV busbar.
22. STATCOM dual 110V DC auxiliary supply distribution, complete with load transfer system and protection, derived from Eskom's DC supply or other reliable source.
23. All fully (SVC housing) equipped containers related to a containerized solution.
24. The container positioning shall be designed to take into account Eskom's passive fire fighting requirements associated with the transformers.
25. All dual redundant air-conditioning for the said containers.
26. Design of all civil works i.e. foundations, plinths, cable trenches, fencing etc.
27. Design and specification of the LV yard earthmat including the required earth tails.

28. Supply and installation of all components in the LV yard on top of Eskom provided foundations and trenches.
29. Earthing of all STATCOM equipment in the LV yard, utilizing the earth tails provided by Eskom.
30. Design, supply and install all the LV bus work within the STATCOM yard, including steel structures, insulators, isolators, breakers, joints, fittings etc.
31. Specify requirements for HV VT foundations.
32. Supply; install 275kV HV Voltage Transformers and all associated cabling. The VT's must be terminated to a lockable junction box to avoid unauthorized connections.
33. Specify any special requirements for High-voltage (275kV) AC equipment which Eskom will provide e.g. circuit breaker, disconnects, current transformers (CTs), surge arresters.
34. Specify, design, test, supply, deliver, off-load, install and integrate a three-phase STATCOM Step-down transformer, control, protection, dual redundant sensors and interlocking. A list of Eskom approved transformer suppliers is attached; any other supplier must be approved by Eskom for this turn-key project.
35. Price option to deliver, off-load and erect spare three-phase transformer on specified foundations at Garona.
36. Integration of STATCOM HV Yard plant and material (isolators, earthing switches and breakers) control, protection and interlocking
37. Provide install, interface and test the systems and protocols to communicate with the Eskom SCADA for the remote interrogation and control status information i.e. trends, alarms and TFR.
38. Labelling of the primary and secondary equipment including safety warning labels.
39. Organize and conduct training for Eskom's engineers, operators and maintenance personnel before commissioning.
40. Three days of repeat training every second year on site for engineers and technicians for the first five (5) years. The timing of the training will be determined by Eskom and may coincide with annual maintenance of the STATCOM and traction system. This option shall be priced separately.
41. Response time of 12 hour during the guarantee period or first 12 months.
42. Provide price option for maintenance and repair service for additional five years after guarantee period.
43. These optional prices (point 39 &41) will be evaluated as part of the total project cost.

44. Provide with the tender, a priced list of all spares that will be supplied as part of the contract. The price of supplied spares will be evaluated as part of the overall project cost.
45. Delivery of Spare parts as well as all special tools needed for maintenance of the STATCOM, to Eskom's designated location. The spare parts to meet the guaranteed availability and reliability shall be included in the scope of work. All spares shall be interchangeable with the equipment furnished.
46. STATCOM container must have a work station desk and facility for the Eskom telephone system.
47. Provide required documentation in five hard and soft copies.
48. Although all plant and materials, studies, design and installations shall meet Eskom's requirements, it remains the Contractor's responsibility to provide fully functional and reliable Static VAr Compensator.
49. All deviations from Eskom's specification shall be clearly stated by the Contractor at the bidding stage and approved in writing by Eskom
50. Deliver, off-load, erect, install, commission the spare transformer ready for service.

4.5 Eskom Scope of Work

Eskom shall furnish the following equipment, materials, and services:

1. Site for the STATCOM
2. Source of water for construction.
3. Source of temporary auxiliary power for construction.
4. Supply and install HV Support Structures for equipment supplied by Eskom.
5. STATCOM 275kV Bay Plant and material – supply and install standard current transformers, surge arresters, two sets of busbar isolators, earthing, single pole circuit breaker, two sets of earth switches,
6. The 275kV stringing between the busbar and transformer bushings to complete the HV circuit.
7. STATCOM yard stoning, gates and floodlighting.
8. All Civil works for STATCOM including terracing, fencing, cable trenches and drainage, foundations and plinths according to Contractors requirements.

9. Terrace earth works. The work shall include excavation, importing of material (if required), hauling, dumping and spreading of topsoil, compacting excavated material, fill areas and disposing of unsuitable or excess materials.
10. All the foundations and plinths for HV and LV according to Contractors design and requirements.
11. Eskom will provide the foundations and plinths for a spare transformer to be stored on site.
12. Eskom will design & install the earthmat for HV yard including the connections to the fencing and to the existing substation earthmat.
13. Eskom will install the earthmat for LV yard including the connections to the fencing according to the Contractor's design and requirements.
14. Supply and install safety fences and live chamber outdoor fencing and gates.
15. Lightning screen wires for the HV and LV side based on Contractors requirements
16. Updating/ commissioning of Substation ERTU database.
17. Supply access to three-phase 400V AC auxiliary supply for Contractors to terminate his cables
18. Supply access to the two x 110V DC station supplies for the Contractor to terminate his cables.
19. Eskom will design and install the oil spillage containment associated with passive fire fighting features around the transformer.
20. Eskom will provide an appropriate store room at site, with cupboards for storage of electronic spares.

4.6 Eskom / Contractor Interface Points

- HV bay interface.

The transformer shall be provided and installed by the contractor on the foundations supplied by Eskom according to Contractors requirements. Eskom will provide and install all the HV bay equipment except for the VTs. Eskom will provide all the HV stringing from the two HV busbars to the transformer HV terminals. Eskom will also provide the oil drainage and passive fire protection around the transformer. The positioning of the transformer will be influenced by the transformer protection requirements and access. The access road for the transformer installation must be clarified with Eskom.

The contractor will be responsible for the cabling and control from the Eskom junction boxes to the STATCOM. The contractor must provide his own junction boxes for the HV VT's. The type of signal cable terminals and the interface boxes, plugs etc. shall be subject to Eskom's approval.

- Civil works interface.

Eskom will provide all the civil works for HV and LV bays, the Contractor shall supply complete design requirements for civil works. This shall include the total layout, sections, design loads (plant and material), drawings, etc. The boundary of the works shall be:

- The foundations and plinths for power plant and material supplied by the Contractor,
- Drainage and cable trenches on the HV and LV bays.

- STATCOM External Control, Monitoring and communications.

The Contractor shall supply, install and commission all communication plant and material, cables, communication interfaces and their associated terminations to the Bay Level Switch (STATCOM RTU).

Eskom will be responsible for all Telecontrol related interfaces from the Bay Level Switch and the Substation Gateway.

The supplier shall provide the necessary interfaces to connect the Eskom-provided communications interface (fibre optic) cable into the protection scheme (Bay Level IED) to facilitate communications between the Bay Level IED and Substation Gateway.

Any fibre optic cabling between supplier's equipment and Eskom must be coordinated to suit Eskom standards.

- STATCOM Auxiliary Supplies.

Three-phase AC - The contractor shall cable and connect the auxiliary power from the STATCOM's internal auxiliary transformer supplied by the Contractor and the auxiliary power from the existing AC 400V distribution boards, to the STATCOM room distribution board. Eskom will provide the termination details for the distribution board.

Note: The AC supply from Eskom is a single supply at the moment but in future it maybe derived via a chop-over system from two separate supplies.

110V DC - The contractor shall also cable and connect the dual DC auxiliary supply from Eskom's DC room to the STATCOM distribution board.

The contractor shall provide and install all switching, protection and monitoring means associated with the use of these supplies within the STATCOM.

- STATCOM Cabling to STATCOM HV Bay Equipment.

The termination points for the control, protection, measurement and indication cabling of the STATCOM HV circuit breaker, current transformers, isolators and earth switches shall be the junction boxes, marshalling kiosks at the equipment in the HV yard. The Contractor shall supply all termination material.

- Earthing

The Contractor shall be responsible for the design of LV yard earthmat which Eskom will install. The Contractor shall terminate the earth tails from this earthmat to his equipment and structures above ground. The transformer neutral shall be connected to the HV earthmat.

- HV Buszone Protection

The termination points for the HV buszone protection shall be the terminal strip inside the HV junction box in the HV yard, the STATCOM protection equipment panel inside the STATCOM Controls and the terminal strip inside the Main Substation Buszone protection panel.

The Contractor shall ensure that the STATCOM HV protection scheme is interfaced with Eskom's existing HV Buszone protection.

4.7 General Information and Contract Conditions

4.7.1 A/B Schedules

The A Schedules defining Eskom's requirements are attached to this specification. The B schedules are to be completed by the tenderer. Failure to do so will result in the disqualification of the tender.

4.7.2 Deviations from any part of this specification or A/B Schedules

The Contractor will confirm compliance with the specification in Schedules A/B and shall list deviations per section and sub-section of this document, including the listed normative references, in Schedule B3. Make a copy of Schedule B3 form and change to applicable numbering.

4.7.3 Design Review Process

The first Design Review process will be held no more than 12 weeks after contract award. The successful tenderer will be required to participate with Eskom in a series of design review meetings where the details of the design will be agreed upon.

All Contractors' relevant information shall be available at these meetings. The final design reports shall be submitted to Eskom for review and comments. These reports shall be detailed, where applicable calculated parameters shall be included and methodology followed.

Amongst the issues that will be discussed at the Design Review meetings, are the following:

1. All the interfaces
2. STATCOM design principles and layout
3. Control concept
4. Protection functions and coordination
5. Control functions
6. Valve design
7. Cooling system design
8. Acoustic and radio noise
9. STATCOM loss evaluation
10. Insulation co-ordination
11. Circuit breaker, Isolators and Earth Switches
12. Substation Control and communication Interfaces
13. STATCOM External Devices Control Design
14. Filter / Capacitor bank design
 - Capacitor unit Fusing technology (if applicable)
 - Harmonic performance and rating
 - Safety earthing and discharging of units
 - Capacitor unit sizing
15. AC & DC Auxiliary power system design
16. STATCOM normal and "*black*" start (without AC Aux.).
17. SVC normal and protection stop
18. Primary voltage measuring circuit
19. HMI design.
20. Disturbance recording, trending and sequence of events recording
21. Civil engineering and structural designs

22. Earthmat design
23. Busbar layout design
24. Main and Auxiliary transformer designs
25. Container Designs
26. Drawing format, numbering and details
27. Logic and flow diagrams
28. RAM Studies
29. Spares number justifications / transformers, capacitors, electronics, reactors etc.
30. Sub-suppliers
31. Factory Testing / Type, Routine Program
32. System factory testing (RTDS tests) Program
33. Installation, testing and commissioning and acceptance test programs.
34. Project Program
35. Documentation
36. Training

Note that Eskom requires a commissioning program that specifies all testing, one month before the STATCOM is contractually energized for commercial operation.

The final week prior to commercial operation is to allow hands-on training for Eskom staff and to familiarise themselves with the equipment.

During this period the Contractor shall provide a supervising engineer to instruct and assist the Eskom's operators and engineers in operating and testing the plant and also to carry out any demonstration tests that may be deemed necessary by Eskom.

4.7.3.1 Changes to Design

Eskom reserves the right to require changes to the design at the Design Review meeting.

The design review process shall not absolve the Contractor from his responsibility to finally deliver the fully functional and well integrated operational system meeting overall requirements of Eskom.

4.7.4 Independent assessment of Design

Eskom reserves the right to subject any or all features of the design to an independent assessment.

Eskom gives the assurance that any proprietary information that it provides to non-Eskom people or organizations for review will be supplied under rules of strict confidentiality and non-disclosure.

4.7.5 Access to site and Outage arrangements

Arrangements for access to site at any time shall be made only with Eskom's Project Manager or with his Site Representative.

All outage arrangements shall be made through the Project Manager who will then arrange with the Outage Scheduler of the Grid.

Please note that outages may, under certain conditions in the power system, **not** be freely given, except at night or over weekends. In addition to Eskom's outage constraints that might exist, the client Spoornet must be notified 3 months prior to the planned outage. Tenderers are strongly advised to confirm the outage before planning or preparations are done and they must inspect the route to site for delivery of equipment. The section of the road from the main road to Garona substation belongs to Spoornet thus the Contractor must get a permit to use the road.

4.7.6 Acceptance Tests, Trial Operation and Take-Over

As soon as commissioning and Eskom's acceptance tests are completed, the Contractor shall advise the Employer in writing that the equipment is ready for service. From the time the Employer has accepted in writing that the equipment is ready for service, Trial Operation shall start and last for 90 days, to confirm to the Employer that the system is working flawlessly.

Trial Operation shall consist of a continuous 90 day period with no interruption caused by the STATCOM and no human intervention.

Trial Operation shall continue until finally an interruption-free period has been attained.

During Trial Operation Period the STATCOM shall at all times be fully functional for any required duty.

The Guarantee Period shall only start at the end of a successful Trial Operation Period.

The Contractor shall continuously provide support for the operation of the plant for the duration of the Trial Operation Period. This applies even if failures occur outside normal working hours.

Final Contractual Take-Over for the release of the retention money will not occur until the following deliverables have been achieved:

- The STATCOM is fully operational and meets the Eskom's performance requirements; Acceptance tests and Trial Operation have been completed.
- All spares have been tested, calibrated and delivered to site, test equipment calibrated and special tools have been delivered to site.
- All defects have been fixed and any other necessary project clean-up i.e. software upgrades has been done.
- Complete documentation including drawings has been delivered to site and soft copies handed to the Project Manager.
- Eskom engineers, technicians and operators have been trained.
- Successful conclusion of the guarantee period.

5. AC SYSTEM AND STATCOM CHARACTERISTICS

The following ac power system characteristics apply at the point of connection prior to STATCOM installation.

Normal STATCOM operation is required within the parameter values and durations given. Eskom will provide relevant, network data files. These files will depict normal and credible operating contingency conditions and will also reflect future planning of the networks surrounding Garona at the time of the implementation project as well as beyond.

NOTE: All references to per unit (pu) are on 100 MVA, 275 kV, 50 Hz base, unless otherwise stated.

5.1 STATCOM Output at Nominal Voltage

5.1.1 Voltages

(i)	Nominal system voltage U_N (line –to line)	kV	275
(ii)	Normal operating voltage	kV	290
(iii)	STATCOM operational voltage		
	<ul style="list-style-type: none"> Maximum continuous system voltage Minimum continuous system voltage 	kV kV	303 (1.1 p.u) 192.5 (0.7 p.u)
(iv)	Over voltages		
	<ul style="list-style-type: none"> continuous 	p.u	1.1
	<ul style="list-style-type: none"> 3 s 	p.u	1.2
	<ul style="list-style-type: none"> 1 s 	p.u	1.3
(v)	Voltage unbalance at 50 Hz (NPS)		
	<ul style="list-style-type: none"> steady state, see definitions of NRS048/2. 	%	2
(vi)	Insulation Co-ordination STATCOM HV		
	<ul style="list-style-type: none"> BIL (Basic Lightning Impulse withstand level) 	kV peak	1050
	<ul style="list-style-type: none"> Switching impulse withstand level 	kV peak	850
	<ul style="list-style-type: none"> 60s power frequency withstand voltage at sea level 	kVrms	460

5.1.2 Short-Circuit Characteristics – at present and in future

(i)	Symmetrical 3-phase short circuit current		
	Future:		
	• maximum	kA	2.9
	• minimum	kA	2.3
	Present (2012):		
	• maximum	kA	1.8
	• minimum	kA	0.18
(ii)	Single phase short circuit current		
	Future:		
	• maximum	kA	4.5
	• minimum	kA	3.4
	Present (2012):		
	• maximum	kA	1.95
	• minimum	kA	0.25
(iii)	Abnormal short circuit level at STATCOM HV Busbar minimum duration 100ms (Black start or system restoration)	kA	0.18
(iv)	Design maximum fault clearance time	ms	250

5.1.3 Frequency

(i)	Nominal frequency	Hz	50
(ii)	Maximum steady state variation	Hz	0.15
(iii)	Minimum steady state variation	Hz	0.15
(iv)	Minimum system frequency	Hz	47.5
(v)	Duration for minimum system frequency	s	60
(vi)	Maximum system frequency	Hz	51
(vii)	Duration for maximum system frequency	s	15
(viii)	Maximum guaranteed performance	Hz	50.5
(ix)	Minimum guaranteed performance	Hz	49.5

5.2 Auxiliary Supplies

Single 3-phase 4-wire AC 50Hz	V	400/231
Dual DC	V	110 at 275kV Yard
DC, unearthed	V	±110

5.3 Environmental Conditions

(i)	Ambient temperature • Maximum temperature • Minimum temperature	°C °C	50 -10
(ii)	Icing conditions		yes
(iii)	Maximum relative humidity	%	95
(iv)	Maximum solar radiation	kW/m ²	1.2
(v)	Altitude above sea level	m	501 - 1000
(vi)	Pollution level and creepage distance • Pollution level according to IEC 60815 • Specific creepage distance according to IEC 60815	mm/kV _{ph-ph}	Heavy 25
(vii)	Dry Corrosivity		Moderate
(viii)	• Isokeraunic Level – Flashes per km ² /year	days/yr	less than 10
(ix)	Maximum steady wind velocity	m/s	40

5.4 AC System Harmonic Impedance Characteristic

5.4.1 AC System Harmonic Impedance Characteristic

The AC system harmonic impedances to be used for the design of the AC filters are to be derived from the transmission system data for the Eskom grid around Garona, supplied with this specification. System contingencies listed in Annexure A shall be considered.

The contractor shall derive the impedance sectors, from the data supplied by Eskom, for the line impedance seen from the SVC HV bus for all possible system configurations and shunt device states. Both present and predicted future system conditions shall be considered. The sectors shall be specified from the fundamental to the 25th harmonic. The Contractor must also study the network for 2nd harmonic instability for normal and contingency operations; protect and mitigate in his design against it.

5.5 Filters and Harmonics

The filter branches are utilized in the SVC to provide capacitive MVA output and filtering harmonics generated by the SVC and other customer devices in the network. The harmonic filter branches shall specially consider all the risks of unsafe resonances created by the new SVC installation.

Possible resonance phenomena shall be accounted and mitigated for in the design. Frequency scan simulations shall be included in the bid.

The SVC system shall be designed to avoid resonance between its filter branches, and the ac system, and to limit the harmonic distortion imposed on the connected transmission system.

1. An important part of designing the filters will be the design and optimization studies (to be undertaken by the Contractor) based on the present and future network parameters.
2. The filter reactors and resistors shall be air core, air cooled type.
3. The reactors, resistors and capacitors shall be designed for maximum SVC supply system voltage, and such that the total harmonic currents from the power system and the SVC do not overload the filter reactors or capacitors.
4. The capacitor voltage rating shall be chosen with consideration of maximum system voltages, harmonic currents and voltage increase due to filter inductance and tolerances.
5. The capacitors shall be of non-PCB types.

6. The Contractor shall provide an optimized capacitor unit design that meets the employer's requirements. He must justify the design chosen over other technologies for this specific application.
7. Reactor, capacitor and resistor tolerances (i.e. detuning, frequency deviations, temperature etc.) shall be considered in the design.
8. Unless there is a strong motivation to the contrary only one interchangeable capacitor unit shall be used throughout the SVC.
9. The insulation requirements shall be determined by the Contractor as required by the SVC design.
10. Each filter bank shall be protected against short- and long-term overvoltage and overcurrent, under-frequency or over-frequency.
11. Each capacitor units shall have a discharge device according to the IEC60143.
12. The need for, and purpose of any damping resistor shall be fully explained and justified.
13. Any damping resistor shall be air-cooled.
14. All the filters shall be fixed to the LV busbar.
15. The design of filter banks shall be such that there is not more than one forced outage every two years.
16. The Contractor shall determine and specify the conditions of harmonic resonance between the AC network and the SVC and shall supply means to withstand possible resonances.
17. All risks of resonance between the various filters or between the filters and the network must be avoided.
18. The components of characteristic and non-characteristic harmonic filters shall be sized upon the following factors:
 - Absorption of characteristic and non-characteristic harmonic currents generated by the proposed SVC, background harmonics as described in clause 5.5.2, requirements and contingencies described herein.
 - The filtering must be adequate to maintain the harmonic distortions within the specified limits while the network is being operated within contingencies described herein.

The filters shall be supplied with complete control, protection and monitoring systems that are well integrated into the new SVC HMI (both local and remote) that is to be provided by the Contractor.

5.5.1 Definition of filtering performance

The following filtering requirements must be satisfied for all possible SVC configurations and under the indicated contingencies and network states see Annexure A The maximum voltage distortion generated by the SVC under steady state conditions, capacitor states (on the surrounding) and (N-1) line and transformer contingencies on the AC network shall not cause the values shown in Table1 of IEEE Std 519-1992 to be exceeded.

These requirements shall, as a minimum be met for the following:

- The continuous range of system and environmental conditions stated in clause 5.3
- Variation in tolerance of total filter capacitance, including permissible fuse failures (if used)
- Variation in tolerance for SVC parameters, such as transformer winding unbalances, valve firing.
- Variations, and unequal reactor and capacitor reactance between phases

These performance requirements may be exceeded for system conditions outside the continuous normal (steady state) envelope specified in clause 5.1.

IEEE STD 519-1981

Table 1 Planning levels for harmonic voltages as a percentage of the measured fundamental AC voltage.

Odd harmonics (non-multiples of 3)		Odd harmonics (multiples of 3)		Even harmonics	
Order	Harmonic voltage %	Order	Harmonic voltage %	Order	Harmonic voltage %
<i>H</i>	275kV	<i>H</i>	275kV	<i>H</i>	275kV
5	2,0	3	2,0	2	1,5
7	2,0	9	2,0	4	1,0
11	1,5	15	0,3	6	0,5
13	1,5	21	0,2	8	0,4
17	1,0	> 21	0,2	10	0,4
19	1,0			12	0,2
23	0,7			> 12	0,2
25	0,7				
> 25	0,2+				
	$0,5 \frac{25}{h}$				
Total harmonic distortion (THD): ≤ 3 % in HV networks.					

The total harmonic (voltage) distortion (THD) is defined as:

$$THD = D_{eff} = \frac{I}{U_1} * \sqrt{\sum_{n=2}^m U_n^2}$$

The individual harmonic voltage distortion is defined as:

$$D_{ind} = \frac{U_n}{U_1}$$

where: U_n = voltage at harmonic n

U_1 = fundamental voltage

- The contribution to the voltage distortion shall be measured according to NRS 048-2 (10 minute RMS values). The voltage measurements shall be the phase-to-ground 275kV busbar voltages.
- Data on harmonic performance levels D_n , THD and in all possible AC system contingency conditions shall be calculated by the Contractor and verified by Eskom.
- The Contractor shall submit all calculated filter parameters and demonstrate that the filters perform adequately for the entire SVC control range and under system contingencies.

5.5.2 Definition of Filter Ratings

The harmonic filter components (and other SVC components) shall be rated to also carry the harmonic currents caused by the background harmonic distortion of the system together with the harmonic currents produced by the SVC itself.

It must be considered that overvoltage and over frequency may occur simultaneously during load rejections in the network and the filter(s) must not cause the SVC to trip during these transients.

The following rating requirements shall be satisfied for the full ranges in operating conditions as defined in Section 5.1 (AC system characteristics).

- The steady state thermal and voltage ratings of all components shall be designed for continuous operation at maximum AC system voltage, maximum daytime ambient temperature.

- In addition the harmonic thermal rating must take into consideration background harmonic levels, resulting from 80% of the Eskom harmonic voltage “planning levels” being permitted concurrently on (See Table1 above) all nearby 132kV and 88kV step-down AC stations from 275kV (i.e. Ferrum, MTSE, Garona, Upington etc).

5.5.3 Telephone Interference

The potential for higher frequency emissions should be limited to avoid interference with any properly licensed or authorized radio, television, microwave, or other equipment in service. The measurements should be made in accordance with IEEE Std 139-1988, based on quasi-peak detector readings.

Refer to section 6.9 of IEEE 519 - 1992: Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, for the TIF weighting factor.

5.6 Network Configuration

5.6.1 Network Configuration

A single line diagram of Garona Substation, as well as the location of the required STATCOM is given in the Station Electric and Key Plan diagrams attached to this specification. The Station Electric diagram shows the planned network configuration for year 2012. Planned development of the transmission network can also be viewed on DigSilent file. The network data is given in the form of DigSilent and PSS/E case files.

5.6.1.1 Substation

The substation layout is shown in the substation Key Plans, attached to this specification

5.6.1.2 Geographical Location

A diagram showing the geographical location of the Substation, the major transmission lines and substations are indicated on the Figure1 below - refer to the GPS coordinates on Annexure E, Schedule A.

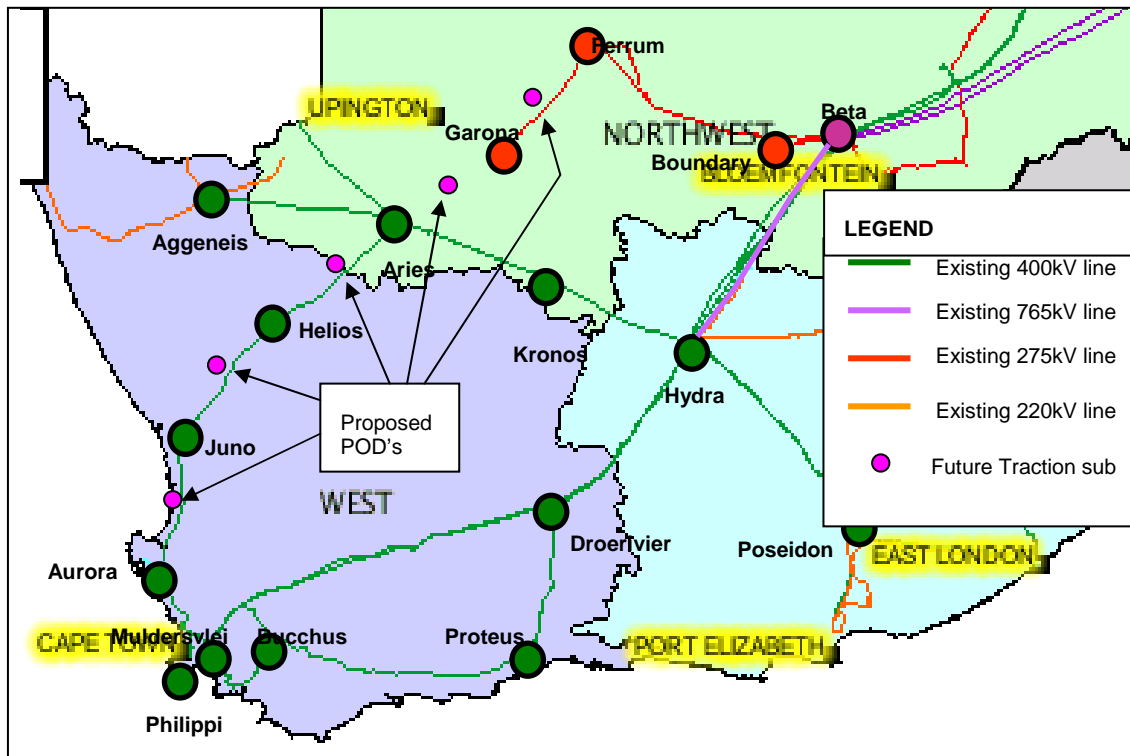


Figure 1: Geographical location of Garona Substation on transmission network

5.7 Functional Characteristics

5.7.1 General Concept

The principal function of this STATCOM is to control single phase voltage unbalance caused by traction loads. It shall also help combating transients in the Transmission system by provision of a rapid voltage control function.

The STATCOM shall be capable of achieving its output continuously and dynamically over its full operating range. The STATCOM shall fulfil the following functions, which shall be selectable:

- Control NPS voltage level without modifying PPS level
- Control NPS voltage level together with an adjustable PPS level
- Control PPS voltage level while ignoring NPS level

2. Continuously adjustable between	p.u.	0.95 to 1.1
3. Accuracy of control system	p.u.	0.005
4. Accuracy for NPS control	%	5 (of 2%NPS target)
5. The nominal slope step size	%.	0.5
6. Slope range for PPS	%	0 to 10
7. Slope SVC Base	MVA	100

Where applicable reference shall be made to IEEE Std 1031-200, clause for definition of the following:

- a) The SVC shall be capable of continuous operation from 0.95 p.u. to 1.1 p.u. primary voltage.
- b) The Contractor shall select the nominal operating voltage for the low voltage side of the step-down transformer, in order to optimize the design of the SVC.
- c) The nominal capacitive reactive power output of the SVC at point A shall be 0.45 p.u. on 100MVA base at 1.0 p.u. AC bus voltage and nominal system frequency. Refer to Figure 2 below.
- d) The nominal inductive reactive power output of the SVC at point B shall be 0.45 p.u. on 100MVA base at 1.0 p.u. AC bus voltage. Refer to figure 2 below.
- e) The SVC shall be capable of continuous operation over the voltage range from 0.95 p.u. to 1.1 p.u., over the full range including the maximum slope. All equipment shall be capable of operation within this system voltage range.
- f) The SVC shall be operable during a temporary undervoltage down to the value of 0.3 p.u. for the duration of 10s (point C on Figure 2 below); the SVC shall be blocked if the undervoltage persists for more than 10s. The SVC shall be ready for immediate voltage control as soon as the HV voltage is above 0.3 p.u.
- g) The SVC shall continue to absorb reactive power during a temporary overvoltage up to the value of 1.3 p.u. for the duration of 1s, or 1.2 p.u for 3 seconds (point D on Figure 2 below). The Contractor shall determine the maximum overload and overvoltage requirement based on the network data provided in the specification.
- h) The SVC shall be capable of repeating short-term operations as defined in any one of f) or g) above, every one (1) hour.
- i) The nominal slope of the characteristic shall be adjustable in steps of not greater than 0.5% between 0% and 10%, on a basis of 65 MVA. (Refer to Figure 2 below).

Where the slope, SL, is defined by:

$$SL = [U_{primary} (I_{ind-rated}) - U_{primary} (I_{cap-rated})] / U_{primary-rated}$$

where:

$$Q_{\text{ind-rated}} = \sqrt{3} \times U_{\text{primary-rated}} \times I_{\text{ind-rated}}$$

$$Q_{\text{cap-rated}} = \sqrt{3} \times U_{\text{primary-rated}} \times I_{\text{cap-rated}}$$

and the nominal current is given at 1.0 pu primary voltage and 100 MVA reactive output.

- j) The STATCOM transformer and all bus equipment such as filter branches, thyristor valve branches shall be rated to withstand the specified continuous and short-term operation, and to withstand or be protected against voltage and current stresses that exceed these conditions.
- k) The LV system must be designed to withstand the fault currents (phase to ground, phase to phase and three phase faults) when the HV source impedance of the network is neglected and the system is operating at maximum HV voltage – that is when the LV fault currents are only constrained by the impedance of the STATCOM transformer.
- l) A secondary voltage limiting function in the control equipment, shall limit the capacitive output on the secondary side for SVC voltage references above 1.1 pu if the system voltage is also above 1.1 pu.
- m) To control the load of the TCR branch, an overcurrent limitation function shall be included in the control system. The overcurrent limitation may be required when a low SVC voltage setting coincides with a high system voltage which can result in currents higher than 1.3 pu through the reactor. With the overcurrent limitation in operation the SVC shall be designed to continuously withstand the voltage and current stresses up to 1.1 p.u primary voltage. The current limit shall be set to allow unaffected operation at 1.1 p.u voltage reference, maximum slope and fully conducting TCR valves.
- n) In the event of minor and major network disturbances, the STATCOM shall remain stable and in service. The major network disturbances consist of multiple flash-overs on the HV and LV systems with delayed voltage recovery and auto re-closure cycles lasting up to 4 seconds.
- o) Overload cycles: The components of the STATCOM shall be designed for operation consistent with the V-I characteristic defined in (a) above, in the presence of power frequency surges at the STATCOM HV bus corresponding to the overvoltages specified in 5.1.1 (v). The SVC is not required to sustain the cycles consecutively however; it shall not be tripped or prevented from operation during these network conditions.

When the overload cycles are lower than those defined, permissible overload times shall be longer to allow full use of the overload capability of the STATCOM.

A three-phase or single phase fault on the 275kV bus usually last for 4 seconds, the SVC must be able to sustain the specified overload cycles following a fault on the HV bus and the voltage must recover to 1.1 p.u.

- p) Under-frequency: In the event that the network frequency drops below the minimum value stated in 5.1.3 (iv), the SVC shall be blocked and remain on standby until the frequency recovers, the SVC shall then continue with its normal operation.
- q) The Contractor shall describe the overload capabilities of all the equipment. The Contractor shall supply Eskom, after factory testing, with details on the overload capabilities of the STATCOM and all the components.

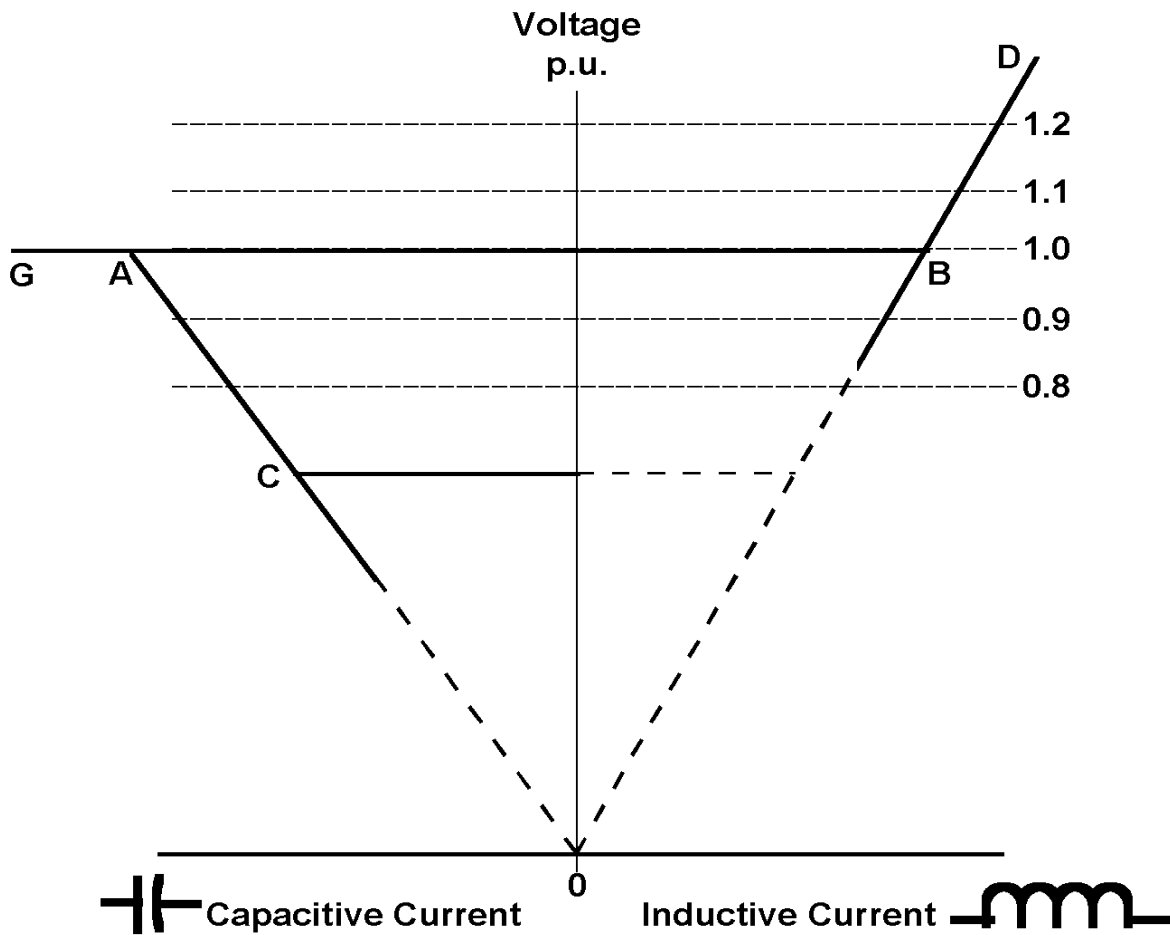


Figure: 2 - V/I characteristics of the SVC to define ratings at nominal voltage

5.7.3.1 Response

When in operation, the SVC shall meet the following requirements on speed of response time to a Step Change:

The change of measured system voltage should reach 90% of the desired total change within 30 ms of the initiating control signal of voltage reference. The maximum overshoot should not exceed 10 % of the ordered change and the settling time should not exceed 100 ms, after which the voltage should be within 5 % of the ordered value. This response is required when the system three-phase fault MVA is at the minimum value defined in Clause 5.1.2 (refer to IEEE Std 1031-2000, clause 8.2.2, Figure 3).

6. CONTROL AND MONITORING

6.1 Overall Control Concept (Control Objectives)

The control shall be dual redundant, fully computerized and digital programmable and have sufficient margins and flexibility to permit re-programming according to future changes in the power system. The control shall be designed such that a continuous control of STATCOM is achieved. The controller shall have diagnostics and self-checking features for both itself and interface circuits. The control and monitoring equipment shall be used to implement the functional requirements in this specification.

The control system must function such that under normal steady state operation the STATCOM shall remain stable for all network contingencies and during transients.

6.1.1 Voltage Control Mode (Rapid Voltage Regulator)

In this control mode the control system shall perform a three phase voltage regulation based on a voltage error and using a slope correction for stationary output control. The error shall be determined by the difference between a set voltage reference and the positive sequence voltage response from the primary side of the step-down transformer. The slope shall be controllable in the interval specified in clause 5.6.3.

The secondary voltage limiter and the current limiter shall override the output from the voltage regulator.

The STATCOM is required to provide fast reactive power compensation for:

1. control of voltage during:
 - 1.1 system and transmission line energisation or de-energisation
 - 1.2 system fault including single pole auto-reclosure
 - 1.3 post fault

1.4 load rejection

1.6 system restoration or black start

1.7 frequency excursions above or below nominal frequency

1.8 overvoltages, voltage collapse or voltage instability

2. control of voltage under normal conditions (positive phase sequence control)

The control system shall be designed to achieve stable dynamic operation of the STATCOM

6.1.2 Fixed Susceptance Mode - Manual Control

In this mode the susceptance of the SVC should be manually controlled, by direct operator action. The operator should set the susceptance reference and the MVAR output is then given by the product of the value of this reference and the square of the primary voltage. The susceptance reference should be continuously variable within an interval that corresponds to the output specified in clause 5.7.3 item c) & d).

The secondary voltage limiter and the current limiter shall override the fixed susceptance setting.

The manual control operation shall only be allowed within the limits of the SVC rating of the main components and shall not cause automatic under- or overvoltage conditions on the network.

There shall be no transient or disturbance during the transition from one control mode to another i.e. automatic control to manual control at any operating point within the SVC range.

The rate of adjustment during transfer from manual to automatic control mode shall be approximately 5 MVAR per second.

This mode of control shall be available for commissioning, testing and maintenance / fault finding purposes.

6.1.3 Negative Phase Sequence Voltage Control

The STATCOM is required to reduce the negative sequence component of the 275 kV AC bus voltage, to the extent possible within the capability of the equipment. The full dynamic range of the TCR shall be used for NPS control and NPS control shall not be limited by filter design.

For normal steady state network conditions the NPS control shall reduce the voltage unbalance better than 2% any remaining capability must be applied for controlling PPS. For network contingencies requiring positive phase control while there is NPS, the NPS control can be relaxed to maintain a maximum value less than 2% NPS.

During dynamic conditions up to 4 seconds domain the SVC shall concentrate on controlling PPS

When all the available range to NPS is not consumed for the above control and the remaining capacity shall be optimally applied to bring the positive phase sequence (PPS) voltage towards the set value for PPS.

The harmonic performance of the SVC shall include the fact that positive and negative phase sequence 3rd harmonics, etc. will be generated during unbalance control.

6.1.4 Supplementary Control Functions

6.1.4.1 Slow Susceptance Regulator Function

When the STATCOM is in voltage control mode it shall be possible to activate a slow susceptance regulator. When this regulator is activated the stationary output from the STATCOM is controlled to a specific susceptance as long as the difference between the line voltage and the voltage reference stays within a certain deadband. If the difference is larger than the deadband the stationary output from the STATCOM will follow the slope.

The transient response from the SVC will still follow the slope, even when the susceptance regulator is activated.

The susceptance reference shall be continuously variable from 1 to 60 seconds within an interval of 1 second. The output shall be within the deadband of 0 to 0.5 p.u. of the reference voltage defined by the capacitive and inductive limits at an interval of 5 MVAr.

The activation and deactivation of the slow susceptance regulator shall be possible without transients in the reactive output from the SVC.

6.1.4.2 Gain Supervision

A gain supervisor, which shall be a function for supervision of the stability of the closed loop voltage control, shall be included.

The function of the supervisor is that when the supervision of the gain in the voltage regulator detects oscillations, the gain shall gradually be reduced until stability is reached.

The reduction of the gain shall only be in the open loop gain of the voltage regulator; the closed loop gain shall remain in the same or increase. Normally it is an increase in the transmission system contribution to the closed loop gain that results in the instability. The reduction in the voltage regulator gain shall only balance the external increase.

It shall be possible to reset the gain to nominal value by means of commands from the operator interface. A relative gain factor shall also be able to be changed from a gain optimizer.

6.1.4.3 Gain Optimization

The action of the Gain Optimizer must not produce large changes in the STATCOM output; the output changes must be limited to 10% of the total range. By adjusting the gain, fast voltage response shall be obtained with stable SVC output at the short circuit power levels specified in clause 5.1.2

6.1.4.4 Control of TCR Direct Current

Second harmonic interaction, e.g. between the TCR and the step-down transformer, could drive the transformer into saturation. The phenomena shall be prevented by a control function which eliminates DC currents in the TCR.

6.1.5 Undervoltage Strategies

At under-voltage conditions for the primary voltage, special control strategies are activated which override the normal control modes presented above. It shall be possible to enable and disable this function from local control.

If the voltage in all three phases goes below the adjustable threshold of 0.3 p.u to 0.7 p.u a special undervoltage strategy should be activated with an adjustable delay of 0 to 400ms. One of the following strategies should be selectable:

- The SVC reacts to the output of the rapid voltage SVC controller.
- The firing pulses to the TCR-valves are blocked and control the SVC to full capacitive output. This is when the voltage is above 0.7 p.u
- The TCR branches should receive continuous firing of pulses whilst all filter branches are connected - zero MVar output or
- The SVC output is controlled to zero MVar by allowing the TCR to compensate for the reactive power output of the filters.

As soon as the voltage in all three phases goes higher than 0.7 p.u the undervoltage strategy shall be deactivated with an adjustable delay of 0 to 400ms and the normal control will be in operation.

6.1.6 Overvoltage Strategies for load rejection

The TCR valves shall be controllable up to 1.3 pu primary voltage.

If the voltage in all three phases goes above the adjustable threshold of 1.1 p.u to 1.3 p.u a special overvoltage strategy shall be activated after an adjustable **delay** of 0 to 200ms.

One of the following overvoltage control strategies shall be selectable:

- a) Force the TCR firing for maximum possible inductive power.
- b) Allow the voltage controller to respond to the overvoltage.
- c) Force the TCR output for zero SVC output
- d) Using the voltage controller force the SVC to zero output.

The overvoltage strategy shall be deactivated when the voltage is or below 1.1 p.u with an adjustable delay of 0 to 400ms and the normal control shall be in operation.

The control strategy should be optimised considering the following factors but not excluding:

- Ferrum – Lewensaar switching
- Back feed from 132kV lines
- The coupling transformer in and out
- Traction loads starting and stopping, together or
- Taking into account the switching of the 275kV lines, single and three-phase switching

6.1.7 Automatic energising – Sequence control

1. All energising or re-energising of the SVC shall be designed to cause minimum disturbance on the network and no risk to other equipment.
2. In the case of the only 275kV feeder from Ferrum being tripped in a 3-phase mode, two contingencies can arise:
 - a. Back feed through the 132kV line via 132/275kV 120MVA coupling transformer
 - b. The 275kV busbar is switched off with the 275kV feeder and re-energised when the local 275kV feeder breaker re-closes after 4 seconds.
3. In the 1st case when there is back-feed from 132kV side via the coupling transformer, with significantly increased source impedance, the SVC shall continue in operation and stabilise the 275kV bus voltage without becoming unstable. It shall also optimally control the shunt devices on the Garona 275kV and 132kV busbars to maintain voltages. Under this condition it is assumed that it will be necessary to disconnect / interrupt the traction feeds because they maybe overloading the weak supply and cause excessive harmonic distortion. The present strategy of tripping the 275kV breaker of the 132/275kV coupling transformer to reject the traction load must be revised. It is assumed that the 275kV line to Lewensaar is already open. The control strategy and I/O's must also provide for future presence of a 400kV in-feed into Garona.

4. The 2nd case when the 275kV line from Garona to Lewensaar is being switched without back-feed from Uppington, the SVC 275kV busbar will go dead for 4s. Three seconds for the remote Ferrum/ Lewensaar breaker to re-close, followed by an additional delay of 1 second for the local Garona breaker to re-close and to re-energise the Gerona 275kV busbar. In this case there maybe no AC auxiliary supply at all until the STATCOM internal AC auxiliary supply is re-established. The station AC auxiliary supply is coupled to the tertiary of the 132/275kV coupling transformer. Under this condition the STATCOM shall remain connected and re-start automatically as soon as the 275kV bus voltage returns.
5. The behaviour of the traction loads and the imposed harmonics during these events must be clarified. Questions being: do they trip, do they tend to continue, or do they regenerate. From experience significant harmonics up to 5% for the 3rd, 5th and 7th must be expected.
6. The ARC event of the 275kV line may or not be successful to re-establish normal 275kV busbar voltage. If a line fault persists the 275kV line will be locked out awaiting further actions from the remote operator. For the normal ARC event the STATCOM is expected to remain in operation either to control the voltage on the busbar or to resume control as soon as the voltage is re-established.
7. When a line lockout occurs the STATCOM shall remain connected for a further 5 to 15 minutes while awaiting operator re-closure of the line. After this delay the STATCOM shall open its breaker and await a restart instruction from the remote operator.
8. With the breaker open, but on receipt of instruction from the remote operator to be on standby for automatic re-start. The STATCOM shall again remain in this status for another 5 to 15 minutes. This re-start must be immediately after the busbar voltage has been re-established.
9. The STATCOM must remain in-service for single-phase ARC events in the 275 kV feeder as well as future 400kV feeder.
10. STATCOM trip and Lock-out (equal to remote restart block combined with automatic 275kV breaker and busbar isolator openings) shall only occur for faults that could result in STATCOM damage or jeopardize safety of personnel if restart would be allowed.
11. No alarms shall prevent restart after a normal shutdown: Integration of the control interlocking system and the protection functionality is required.

12. During normal shutdown condition, the capacitors shall not be discharged through the transformer but the thyristors shall continue to be fired in order to discharge the capacitors to the lowest possible voltage level.
13. During energising of the STATCOM (ON), the SVC shall not cause a transient change in the voltage. The Contractor shall specify the guaranteed transient voltage variation and duration as well as the energisation time, including transformer inrush, etc.
14. When the SVC is switched ON or OFF the ramping rate shall not exceed 5MVAR per second. The trip signal shall always override the ON and OFF controls.
15. Whenever the SVC has been shut down due to abnormal conditions outside the SVC, the SVC must remain available and ready without local intervention for remote start up after the external conditions have been brought back to the range where the SVC has been specified to be operable.

6.2 Substation Control and Monitoring Requirements

6.2.1 Information reporting.

This section describes Eskom's requirements for protocol between the STATCOM and Eskom's Substation Control System (SCS).

The Contractor shall provide a Communication Interface (CI) in the STATCOM controller that will facilitate the exchange of data between the STATCOM and the Substation Gateway. The control scheme shall provide enough information for 3 different groups of users or contexts about the STATCOM status, its switchgear and about failure conditions:

- The first context will be real time data for National and regional Control centres. Adequate information is required from the protection and control system within 10 seconds about the performance and status of the STATCOM that will enable the Control centre operator or the local operator to assess the condition of the STATCOM. Details of information required by the Control Centre will be provided at the first design review meeting.

- The second context will be non-real time data for the station operator and field technician. The station operator needs to make an assessment of the state of the primary plant within a short period of time. Sufficient information shall be provided in order that a trained technician will be able to find the fault within one hour.
- The third context is non-real time data for performance analysis office at a remote location. This office produces reports, trend analysis and similar outputs from all power system performance data. The data used in this context will be the same data used in the second context above

In addition information about the substation (not directly measured by the STATCOM controller) shall be communicated to the STATCOM controller.

The control scheme shall provide a station master clock GPS unit, (NTP, IRIG B and 1PPM are acceptable).

Captured data shall be time stamped with a resolution of at least 1ms.

6.2.2 Time Synchronisation

The STATCOM Control System must include an interface to allow all components of the STATCOM Control System to be time synchronised to an external precise time source. This includes the complete STATCOM Control and monitoring system as well as the SCS (Bay Processor), DFR, SER, DSM and VQR.

6.2.3 Interfacing with Eskom Substation Gateway

Eskom require that the STATCOM (IED) interface with the Substation Gateway using **IEC61850**.

The STATCOM protection scheme IEC 61850 **IED** (Bay Level IED) will communicate to the Substation Gateway via a Bay Level Switch using a fibre optic cable. Communications between the Bay Level IED and Bay Level Switch will also utilize fibre optic cable.

This Bay Level Switch shall be housed in the STATCOM Interface panel.

Eskom will be responsible for all Telecontrol related interfaces from the Bay Level Switch (STATCOM) and the Substation Gateway.

The supplier shall provide the connection interface for the Eskom provided communications interface cable into the protection scheme (Bay Level IED) to facilitate communications between the Bay Level IED and Substation Gateway.

Commissioning of these systems through to the end user will be an integral part of the contract at no extra cost to the Employer.

The Bay Level IED must support the following ESKOM standard protocol for facilitating communications;

- **IEC 61850**

The supplier is required to provide ESKOM with their proposed Protocol Implementation Documentation (PID) for IEC61850 implementation on STATCOM Bay Level IED.

Eskom's requirement for the IEC 61850 implementation is that no Generic Process I/O's (GGIO) Logical Nodes be used for the protocol implementation.

6.2.3.1 Input/Output Type (General Requirements)

The Substation Gateway must have at its disposal a database sourced from the IED's containing, but not limited to, the following information for Telecontrol purposes:

- Plant statuses (indications and alarms). All one line diagram indications must be double bit points. For the purposes of data consistency at the National Control Centre.
- Plant measured values (analogue measured values). This will typically be values such as reactive power and 3 phase currents.
- Commands for remote switching (command outputs). All commands for switching primary plant or mode selections for secondary plant must each have a double bit feedback indication to the Substation Gateway of either digital or analogue nature to indicate a successful operation.

The supplier must make available to the Substation Gateway all I/O deemed necessary to safely and efficiently monitor and control the primary plant for local and remote purposes.

6.2.3.2 Isolation of Remote Control Functionality (General Requirements)

Control isolation on the IEC 61850(STATCOM IED) device facilitating supervisory control shall be affected via a **Local/Remote Switch** and shall provide the capability to isolate all controls from station level and bay level.

The Local/Remote switch shall be annunciated locally and remotely. This Local/Remote Switch is required to ensure that these outputs can be isolated from the supervisory relays in the protection panel during commissioning, fault finding and maintenance

Controls shall be capable on the STATCOM IED from the following sources:

- From **remote control centres**. Controls shall be possible, provided the IED is in **Remote Mode** and there is no blocking function and interlocks.
- From Station HMI. Controls shall be possible, provided the IED is in **Remote Mode** and there is no blocking function and interlocks.
- From Bay HMI (Incorporated in IED). Controls shall be possible, provided the IED is in **Local Mode** and there is no blocking function and interlocks.
- From STATCOM Panel. Controls from this source will always be active. Controls will always function provided there is no blocking function active.

The **Local/Remote Switch** must be located on the panel containing the Bay Level IED with the appropriate indication to the Bay Level IED.

This **Local/Remote Switch** is required to ensure that these Digital Control outputs can be isolated from the supervisory relays in the protection panel during commissioning, fault finding and maintenance.

The contractor must indicate to Eskom in detail the operation of circuitry involved in the issuing of controls output signals. Eskom will reserve the right to alter the circuitry to ensure that the security of control output signals is not compromised.

Each control output signal must contain a feedback indication of either digital or analogue nature to indicate a successful operation.

All control signals available for remote control must also be available locally to ensure that a local operator can operate the STATCOM if the communications link to the remote control centres is lost.

The data exchange between the Substation Gateway and IED's must be tested as part of an Eskom approved Factory Acceptance Test (FAT) procedure and approved by Eskom to ensure data integrity.

The Contractor must allow for full Site Acceptance testing of the Protocol.

6.2.4 Signal Requirements

A spare capacity of at least 20% of each type of signal complete with necessary I/O devices and or terminals shall be provided for in the STATCOM control system communication interface database. In all cases the wetting voltage will be provided by the Eskom Substation control side.

6.2.5 Local reporting

Information is required in the form of flags (a small number of bits of information in non-volatile form) and also in electronic format. The electronic data storage shall also be non-volatile. The electronic information can have an access time of the order of minutes. The storage of the data may be in the manufacturer's own protocol, provided that the data can be downloaded with a standard Personal Computer. The manufacturer shall provide the necessary down loading software and connections and cables. Such software shall be "free ware" and shall be compatible with present and future releases of standard Windows operating systems.

The contractor shall submit a local digital Station Control and Monitoring system with, at a minimum, the following capabilities and features:

1. Indication (local and remote) of equipment status.
2. Alarms (local and remote)
3. Setting/adjustment (local and remote) of certain control parameters/protection settings
4. Command of operating equipment (breakers, disconnectors etc.).

All features of the local Station Control and Monitoring system shall be precisely identified to enable proper use by the system operators. The operator interface shall be realized using the Windows NT environment. Different levels (at least three) of access shall be distinguished, using passwords.

The communication between the local Station Control and Monitoring system and an existing remote Control and Supervision system (SCADA) shall be established by means of a serial interface. The communication protocol must be completely open and implemented according to conformity, interoperative and withstand patterns, established by ISO (International Standardization Organization). The protocol shall comply with OSI (Open System Interconnection) Reference Model of OSI/EPA protocol.

6.2.6 HMI Control Requirements

All features of the HMI shall be precisely identified to enable proper use by the system operators. The Contractor shall provide a local PC based HMI with the minimum of the following capabilities and features:

- The time resolution for alarms and events shall be 1ms or better.

- Supervision and recording of events (i.e. SER functionality), internal and external.
The event information shall be stored on a recoverable data media, for later access and must be time stamped with GPS clock.
- All data (SER, TFR, Trending etc.) must be stored for at least one year and be readily recoverable for analysis within the HMI system. The data must not be automatically erased. This data must be secured with redundant storage against accidental loss due to component failures using at least RAID1 disk system.
- Disturbance recording (i.e. TFR functionality): GPS time-stamped simultaneous recording of at least 12 analogue and 12 binary variables (e.g. Primary voltages and currents, secondary voltages, TCR currents, control and event and alarm parameters) shall be possible. Beyond its capacity of 12 of each type of variables the TFR recorder must be able to acquire and record other selectable internal STATCOM measurants, control and event variables for fault and performance investigations.
- The resolution of the TFR for event inputs shall be at least 1ms. The triggering of the TFR recordings shall be adjustable by the user and the duration of recordings shall be long enough to ensure that the required initiating events are captured in the sequence.
All start/stop, breaker operation and system dynamic events as well as STATCOM equipment failures shall be recorded in order to facilitate performance monitoring, ongoing optimisation and failure analysis.
If a separate (non integrated TFR system) is supplied it shall have redundant storage capacity to avoid any inadvertent loss of fault recording information and data.
- An integrated or stand-alone Voltage Quality Recorder (VQR) shall monitor the three HV voltages and currents. The VQR shall be set up to measure power quality parameters in accordance with NRS 048 standard from the Republic of South Africa.
- The Local HMI (PC screen based) shall be provided for the normal operating and observation (as approved by Eskom) of the status of all the STATCOM components. The screen format must be 1600 x 1200 (16:9 ratio)
The remote HMI shall provide exactly the same facilities
- All HMI PC's must be full tower case units.
- In the event of the local HMI being out of service, emergency switching of the breaker and the isolators shall be possible from a local mimic on the control panel. These emergency control switches shall either be hard wired from the control panel to the equipment in the yard, or shall be implemented by providing dual redundant HMIs.

- Remote Access Service (RAS) function. The RAS shall enable access to the local PC LAN for remote retrieval of data over modems operating over ordinary telephone and/or cellphone connections or preferable a secure VPN network. The necessary I/O's and access systems/software for both local and remote retrieval of (VQR, Sequence of events, Transient fault recorder, STATCOM trend data etc.) shall be provided.
- Protection system shall be an integrated part of the system.
All STATCOM control, cooling system and protection settings shall be available on the HMI.
- An overall description of the structure of the control and monitoring system shall be supplied in the bid.
- All computer-based circuit boards shall be self-supervised.
- The contractor shall provide a local remote (in the control room of the substation) HMI (OWS) graphic display. The screen shall be a high quality active LCD display of at least 22 inch, and (16:9 aspect ratio).
- All dual redundant control and protection systems of the complete STATCOM shall be monitored to alarm any loss of redundancy. The design shall be fail safe such that the STATCOM is switched off and no equipment is damaged if the last remaining control/protection system fails.

6.2.6.1 Remote control

The "remote" HMI within the substation as well as that with the remote Grid operator shall have the same control monitoring and alarm facilities as that in the STATCOM room.

A changeover switch in the STATCOM room shall control the selection of local or remote control.

The remote users shall only be able to change or adjust the main control/operation parameters.

6.2.6.2 HMI display requirements

As a minimum the following equipment status or indications shall be displayed:

- All indications shall be double bit secured.
- All alarms shall be flagged and displayed in order of occurrence. The name of the affected component shall be displayed on the alarm list.
- All the events shall be displayed on the event list.
- Flag protection operations
- All three phase line currents, phase voltages, MVARs and harmonic voltage distortion at HV bus.
- Percentage Negative Phase Sequence voltage

- Ambient temperature
- Position of the Local-Off-Remote switches of the breaker and the isolators. This may be a common indication.
- Complete STATCOM single line diagram including HV and LV busses and plants
- External Device(s) control status and control mode
- AC Auxiliary supply and distribution
- DC Auxiliary supply and distribution
- Thyristor cooling system
- Open and Closed Loop control systems
- Interlocking system - the general design of interlocks in the scheme of control will be resolved at the Design Review.
- The Open/close pushbuttons of the Isolators must be labelled as Open and Close only. No colour coding is needed.

6.2.6.3 HMI security

The HMI software shall make provision for a number of access levels (at least three). Each level shall have a unique password. Different levels of access shall be distinguished, using passwords.

The first level is for viewing only.

The second level, "Operating Level", is for the operator only. In this level only, switching may be done.

In the third level, "Engineering Level", changes may be made to the settings and to the programmes etc. No switching is allowed in this level.

6.3 STATCOM Open and Closed Loop Control Interlocking and Status Control

6.3.1 Interlocking System

The Contractor shall provide an interlocking scheme. An interlocking scheme shall monitor, supervise and prevent prohibited operation in the STATCOM system. The interlocking system shall include:

- The AC isolators and earthing switches for all the STATCOM HV equipment.
- The STATCOM transformer
- All isolators, earthing switches in the STATCOM LV yard.

- The control, monitoring, protection and auxiliary systems.
- Entrance into the valve room area

The system shall indicate when the plant or equipment is ready or when maintenance is required.

The earth switches shall be interlocked with the disconnectors in such a way that a disconnector cannot be operated if its earth switch is not in the fully Open position. The earth switch shall not be operable unless the disconnector is fully Open. Mechanical and electrical interlocking is required.

6.4 Control System Tests

6.4.1 Standards

All control and protection plant and material shall be tested according to *Eskom* TST41-1062 and for Surge Withstand Capability (SWC) according to IEC 1000-4-5, Electrostatic Discharge according to IEC 1000-4-2, Electrical Fast Transient Burst according to IEC 1000-4-4 and Radio Frequency Interference according to IEC 1000-4-3. Control plant and material shall be tested for static discharge according to IEC 60801-2. The design of the relays shall comply with the relevant clauses of IEC Publication 60255.

6.4.2 Tests at site

6.4.2.1 General

The tests shall include interlocking, sequence control, manual and automatic control changeover, trip checks, alarm annunciation, fail-over and recovery of redundant systems, demonstration of all SCADA control and alarm points, sequence of events logging and time tagging, relay setting in accordance with protection co-ordination settings, Substation Control System Interface, Transient Fault Recorder, etc.

All control and protective functions including redundancy and interlocking systems as specified in this document shall be tested.

6.4.2.2 Cables and cabling

The insulation resistance of each cable shall be measured and recorded by the Contractor see *Eskom* TST41-1062, clause 3.6.5.6 and IEC 60255-5.

7. PROTECTION PHILOSOPHY

The Contractor shall be responsible for the integration of all protection schemes for all the equipment interfacing with the STATCOM, into the STATCOM protection system, with the exception of bus zone protection. The protection system shall be built on the principle of a Main 1 and Main 2 protection, for each protected zone/equipment. All protection equipment and systems shall be properly co-ordinated to provide reliable and safe protection and to prevent incorrect operations during steady state STATCOM operation or transient conditions as specified. The STATCOM equipment shall withstand maximum fault current and clearing time specified in clause 5.1.2 & 5.1.1 respectively, whilst being protected against all damaging conditions. All protective functions shall satisfy a high degree of speed, reliability, selectivity, sensitivity and stability requirements.

7.1 General Requirements

- a) A complete protection system to protect the STATCOM shall be provided, in addition to the protective features which are part of the control system. The STATCOM plant and material shall be protected against all abnormal / damaging operating conditions which may occur, such as:
 1. Excessive overcurrent and overvoltage,
 2. Excessive reactive power loading,
 3. Unbalance due to loss of capacitor elements,
 4. Phase-to-phase and phase-to-ground faults, three phase faults,
 5. Loss of cooling, thyristor valve or control malfunction,
 6. Faults on individual primary connected components of the STATCOM, HV and LV system faults, etc.
- b) The protection relays and equipment shall receive their primary input from current transformers, voltage transformers, etc., that are supplied as part of the STATCOM equipment or, where indicated, provided by Eskom. Redundant protective functions shall be included and demonstrated.
- c) In addition to the protective features provided as part of the dual redundant control system, a dual redundant conventional protection system shall also be provided, to protect the compensator equipment against abnormal operating conditions which may occur. This system shall be fail-safe.

- d) The protection system shall be based on the principle of a main and a back-up protection, for each protected zone and equipment.
- e) Each of the dual-redundant protection systems, Main1 and Main2, must be connected to separate DC auxiliary supplies, and to separate sensors / instrument transformer cores and shall differ in protection principles where possible.
- f) The installation shall have a protection scheme that will ensure that the STATCOM will not suffer consequential damage in the event of either a fault on the installation, or a potentially damaging condition within the installation or on the power system. The latter state could be due to the once off or repeated passage of fault current.
- g) The scheme shall have a dual-redundant, control and protection system for maximum RAM. No failure of any component or interface within any one of the two control/protection systems shall influence the availability of the other.
- h) The control/protection to be designed, equipment supplied and installed by the contractor includes all the necessary elements for the effective operation of the systems.
- i) Failure of any SCADA systems shall not result in a protection trip of the STATCOM.
- j) The protection system shall be designed to allow full use of overload capability of equipment. The contractor shall describe all overload capabilities of all equipment.
- k) The capacitor/filter bank(s) shall be protected to detect any failure of capacitors. The first failure shall only produce an alarm while the secondary failures causing more than 2pu of the alarm level may cause the SVC or the associated bank to trip. However, the filters/capacitor banks shall be designed for maximum RAM of the overall SVC. No capacitors shall be operated with more than 110% voltage during alarm conditions

7.2 Minimum Required Device Protection

As a minimum the following protection shall be provided for equipment listed below: The contractor shall provide additional protection as considered to be necessary. All the protection must be designed such that full use of the overload capability for all equipment is achieved and shall consider presence of DC components where applicable.

7.2.1 STATCOM Transformer and 275kV Bus

1. Transformer and STATCOM bus differential protection

2. Overcurrent protection
3. Restricted earth fault protection
4. High and low voltage winding temperature protection
5. Low oil level protection
6. Pressure relief valve.(Qualitrol)
7. Gas accumulation (Buchholz)
8. Oil temperature

See also Eskom Standard Specification TSP41-87, for large power transformers

7.2.2 STATCOM HV Circuit Breaker and other breakers or switches

1. Breaker failure function
2. Pole discrepancy
4. SF6 gas monitoring

7.2.3 STATCOM Low Voltage Bus Circuit

1. Overvoltage protection.
2. Differential protection
3. Ground fault protection

7.2.4 TCR Air Core Reactor

1. Differential protection
2. Reactor thermal protection

7.2.5 Thyristor Controlled Reactor branch

Each TCR branch must have its own protection.

1. Three, single-phase differential protections for the TCR delta. The differential protection shall detect all phase and earth faults within the reactor zone including thyristor valves.
2. Three phase overcurrent protection for the TCR branch.
3. Overvoltage protection. The valves of the TCR branches shall be protected against overvoltages that cause excessive conduction. This must not prevent phase control of the TCR branches up to the specified level.

4. Thyristor fault protection for thyristor monitoring. Failed thyristors must be identified and located.

7.2.6 Harmonic Filters

The filter banks must be protected to withstand harmonic voltages and overvoltages under all possible operating conditions. Protection of filter banks shall include but not be limited to the following:

1. Overcurrent protection
2. Capacitor overload protection for the filter branch.
3. Capacitor bank unbalance protection
4. Ground fault protection.

7.3 Operation Indicators

The protection scheme shall have the following local and remote operation indications for all electrical and mechanical protection trip and alarms functions:

1. Indication of phase or phases involved in the faults.
2. Type of fault
3. Fault location
4. Trip/Alarm indication

7.4 Standards and Tests

The design and testing of the relays shall comply with Eskom's specification for Protection and Relays and IEC 60255 standard.

8. INSULATION COORDINATION

The contractor shall be responsible for the insulation coordination of the STATCOM plant and material. The responsibility includes the high voltage equipment installed on the 275 kV side specified in the scope

of supply in clause 4.3. The insulation coordination shall be based on IEC 60071: "Insulation Coordination", also refer to Annexure C and D Tables of this document.

Clearances selected must be in accordance with the insulation levels, taking into account safety and maintenance viewpoints.

The events to be used for insulation coordination of STATCOM plant and material shall include normal to abnormal occurrences not only in the STATCOM itself, but also in the surrounding network including but not limited to:

- All transients and overvoltages on the AC system and those resulting from the operating characteristics of the SVC; switching surges and lightning; both with and without ground faults or phase to phase on HV and LV side.
- Faults on the HV or LV equipment and bus.
- Proper insulation coordination must be considered for thyristor valve blocking and misfiring including protective firing of the valves.

The studies must demonstrate the thermal capability of all the surge arresters assuming maximum rated energy discharge immediately prior to the fault condition.

The *Contractor* must propose appropriate condition and operation monitoring devices.

The protective characteristics of the arresters shall be selected by the *Contractor* to meet the requirements of the overvoltage protection of equipment and all worst case operating conditions, subject to approval by the *Employer*.

The strike/clearance distance between outdoor live conductors and between energized parts and ground shall be selected according to IEC 60071. Care must be taken to ensure all levels are vermin proof.

Creepage distances shall be selected according to IEC/TR 60815

For the insulation requirements of the thyristor valves, IEC 61954 is referred to.

The LV voltage level as specified shall take into consideration the minimum clearances as specified in section 8.3 below and Annexure D

8.1 Surge Arresters

Refer to Eskom Standard for surge arresters TSP41-363.

The surge arresters required for the protection of the STATCOM HV plant and material will be supplied by Eskom. Except for the arresters associated with the LV equipment including STATCOM transformer LV side, these will be supplied by the Contractor. Full descriptions of these arresters shall be supplied to Eskom.

8.2 Precautionary Insulation of live plant and material

Refer to Annexure D for safety and working clearances.

The minimum height above ground level for all live parts of outdoor plant and material; in accessible areas shall be at least 2m, in live chambers it must at least be 1m. Clearances selected must be in accordance with the insulation levels, taking into account safety and maintenance viewpoints.

All live busbars, plant and material inside the control building not mounted in steel cubicles shall be adequately protected and in accordance with Eskom's Operating Regulations for High-Voltage Systems.

9. MAIN COMPONENTS – REQUIRED FUNCTION AND FEATURES

The following equipment shall be designed to ensure operation according to overall performance requirements and guarantees. The equipment shall comply with the requirements of the IEC and IEEE standards.

9.1 IEGT / Thyristor Valves

The valves shall be designed and rated to meet overall performance requirements of the STATCOM with individual thyristors and other components with regard to their basic design parameters, as follows:

1. The IEGT / thyristor valves and all associated equipment shall be designed to withstand the stresses associated with the steady state and transient operation conditions in clause 5.7.3. The basis for calculation of overcurrent stresses shall be the maximum fault level current specified in clause 5.1.1.
2. Transformer saturation shall not be considered in calculating the above stresses, except where it increases these stresses.
3. They shall be of modular or sectional design and have removable components for ease of maintenance.
4. The TCR shall be controllable up to 1.3 p.u. of rated voltage.

5. The design of the thyristor structure shall permit easy access for visual inspection and maintenance.
6. It shall be possible to replace failed thyristors without interruption of the cooling water circuit.
7. Each single phase IEGT / thyristor stack (or equivalent) shall consist of anti-parallel series connected thyristors, including all necessary heat sinks, snubber circuits, voltage grading circuits and firing circuits.
8. In each phase of TCR branch the single phase thyristor valve shall be connected in series between two half reactors.
9. The IEGT / thyristor firing circuits shall not be affected by external influences such as ultra-violet light, corona discharges, humidity or dust. They shall be protected from mechanical damage or abrasion once installed.
10. The IEGT valve shall include not less than two set of redundant anti-parallel IEGT, in each single-phase thyristor valve. All rating, performance and protection requirements shall be met with all redundant IEGT short-circuited.
11. A continuous monitoring system shall be provided to detect failed thyristors and provide indication of each failure and its location in the valve. An alarm signal shall be provided. The TCR branch shall be automatically isolated if the number of failed thyristor positions is more than the number of redundant thyristors.
12. The voltage rating of the IEGT shall be such that no cascading failure shall result in the event of failure of all redundant IEGT. The tenderers shall demonstrate compliance with this redundancy requirement in the tender submission.
13. Each thyristor level in the TCR valve shall be protected by voltage break-over device (overvoltage protection). These devices shall provide emergency firing of thyristors in event of an overvoltage or failure to deliver firing pulses to one or more individual thyristors and the voltage shall be uniformly distributed across each thyristor level.
14. Electrically triggered or self-protecting direct-light-triggered thyristors may be used. In the latter case, the *Contractor* shall prove the successful implementation of direct-light-triggered thyristor with integrated overvoltage protection by stating SVC systems in commercial operation as a reference.
15. Protective firing for overvoltage protection shall be provided. The valves shall be designed to allow continuous operation of protective firing of individual thyristor levels.

16. The valve firing must be robust. Misfiring due to control system maloperation, or AC system disturbances and switching events including maximum voltage unbalances and harmonics in the AC network, shall be prevented. The Contractor shall describe the details of prevention or withstand inherent in its design.
17. The control and valve firing system shall be insensitive to variations in, or complete loss of, the auxiliary AC supply voltage.
18. The thyristor valve shall be supplied complete with cooling plant and material and all auxiliaries for gating, monitoring and grading.
19. The best engineering methods available shall be employed to ensure that no cooling water leakage or blockage can occur in service and that leakage is minimized during maintenance procedures. No cooling connections shall have to be opened to change thyristors. If a minor leak should occur, efficiency of the valve shall not be impaired. Valve components shall be designed to ensure that cooling water spray or minor leakage will not cause damage to any component.
20. The proposed thyristors shall be of a type already in commercial production with fully proven characteristics.
21. Bi-directional thyristors are not acceptable.
22. The thyristor valves shall be capable of withstanding the highest overcurrents expected in service and be capable of blocking corresponding voltages at the highest thyristor junction temperature reached.
23. The valves and valve hall plant shall be designed to minimize the risk of fire, initiated from whatever source, being propagated within the valves. Where the use of non-metallic materials in the valve cannot be avoided, such materials shall have flame-retardant self-extinguishing characteristics with classification equal to UL94 V-0 or for small quantities UL94 HB.
24. The valves shall be tested according to the latest edition of IEC 61954 in effect at the time of placing the contract.

9.2 Additional requirements for the Valves

1. The IEGT over voltage protection shall have turn-off overvoltage protection, transient surge voltage protection and DC voltage protection.
2. The IEGT must be able to work properly without a snubber circuit at turn-off

3. The DC capacitor shall be protected from overvoltages resulting from abnormal system voltage levels or control failure.
4. IEGTs must be protected from overcurrents resulting from overload, system short circuit and bridge phase shoot-through.
5. It shall be possible to turn-off the IEGT in the event where the peak current level caused by overload or system short circuit is smaller than the safe turn-off value. If the peak current level is higher than the safe turn-off value, the IEGT shall not be turned-off. In such an event the IEGT drive circuit may be kept in pulse condition, in order to prevent the IEGT from turning-off, from the start of the short circuit until the current is cut off using the IEGT's short circuit withstand capability. "Parallel to this operation" the main circuit breaker trip protection must be initiated to protect IEGT from any damage resulting from this operation.

9.3 Thyristor Controlled Reactor

The Thyristor Controlled Reactors shall under no load conditions be designed to fully compensate the reactive power generated by the parallel-connected harmonic filter branches at maximum system voltage.

1. The reactors shall be of single phase, air core design, self-cooled and suitable for outdoor installation.
2. The reactors shall be designed for continuous operation at maximum system voltage; they shall be capable of withstanding mechanical and thermal stress that may arise due to abnormal conditions in the system or SVC fault.
3. The reactors shall be capable of handling short circuit forces based on maximum design short circuit level.
4. The reactors shall be designed to fully compensate for tolerances of other components (e.g. harmonic filter branches).
5. The BIL rating shall be determined by the Contractor as required by the STATCOM design and the insulation requirements given in this document.
6. Manufacture of the reactors shall have a record of manufacturing reactors at least for the past two years for the application in arc furnaces, SVC and HVDC installations.
7. Audible noise levels from the reactors shall be coordinated to meet the requirements for the STATCOM installation in section 20 and the applicable IEC standards.

8. All structural and fence metalwork, including foundations, should be designed to avoid, as far as possible, metallic loops and parallel circuits in which induced currents can run.
9. In each phase of TCR branch the single phase thyristor valve shall be connected in series between two reactors.

9.4 Cooling System

The Contractor shall provide a complete cooling system, plant and material; it shall be designed to operate within this specification requirements including the RAM requirements, for a period of at least 25 years.

1. A closed-loop re-circulating system shall provide full heat rejection capacity with redundancy for pumps, heat exchangers, and fans appropriate to the STATCOM availability requirements. The cooling system shall be able to maintain full capacity at maximum ambient temperature and maximum STATCOM reactive power output.
2. The cooling system shall be able to operate at the lowest ambient temperature and zero output specified, and the Contractor shall describe how this operation is done.
3. Each thyristor valve shall have its own cooling system.
4. It shall include but not be limited to the following: interconnecting piping, make-up reservoirs, filters, water treatment circuits, instrumentation, automatic control and internal auxiliary power distribution.
5. The cooling system must be designed to support steady state and transient overload operation at the rated power of the STATCOM in any mode of operation at worst ambient conditions without utilizing the installed redundancies.
6. The cooling systems shall be designed to eliminate the risk of freezing. A water / glycol mixture of not more than 20% can be used to prevent freezing.
7. A closed circuit de-ionized re-circulating cooling medium system shall be used. The piping for each thyristor branch shall have manual valves to isolate it from the rest of the system without disrupting the operating flow.
8. The resistivity shall be controlled to suite the plant design and the expected life. A resistivity transducer located in the outgoing water from the deionizer shall detect the depletion of the material and display an alarm. The second purifying loop will continue to operate in the presence of a primary-loop alarm until its deionizer is depleted.

The contractor shall state the design value of liquid resistivity and describe methods of detecting and responding to abnormal conditions.

9. The heat transfer from the closed cooling medium system to the outside ambient air shall take place in a dry water to air heat exchanger.
10. Deionised water circuit components at ground potential, i.e. piping, valves, heat exchangers, filters etc., shall be made of stainless steel of quality as ANSI 304 L or ANSI 316 L. Except valve interconnecting piping and piping in the thyristor valve stack, which shall be cross-linked polyethylene (PEX), or equal. Corrosive material shall not be used anywhere in the circuit.

The contract price reduction for using aluminium instead of stainless steel shall be stated.

11. A make-up tank for supply of additional cooling medium shall be supplied together with a pump unit.
12. One pump shall normally operate and a redundant pump shall be standing by. If a pump failure occurs, the second pump shall automatically switch in without shutting down the STATCOM. The pump shall change over automatically every month in order to cycle the second pump. A set of alarms shall be displayed at the appropriate local and remote control cabinets to alert the operator that a pump or any other cooling plant and material problem exist.
13. The cooling system shall be constructed to permit work on a defective plant and material without shutting down the STATCOM.
14. It shall be possible to replace or recharge deionizers and filters in a relatively short time without shutting down of the cooling system. Normal replacement must not be required more than once every 12 months.

The Contractor shall describe the necessary maintenance actions and their frequency. The *Contractor* must also indicate the maximum time required to prepare the water circuit after a complete refilling.

15. The design shall allow the cooling system to be completely drained when not in use.
16. For reliability sake, all instruments and transducers shall be DC-powered.
17. The cooling system shall monitor its own operation and the condition of the cooling medium.
- 18.1 The protection system shall include, as a minimum, the following warning alarms:
 - a) Depleted deionizer
 - b) Low water resistivity

- c) High coolant temperature
- d) Low expansion tank level.
- e) Low coolant level
- f) Pump malfunction
- g) Heat exchanger malfunction
- h) High coolant temperature
- i) Low flow rate

18.2 The protection system shall include, as a minimum, the following shutdown alarms, at different measured values than in 18.1:

- a) High temperature
- b) Low coolant level
- c) Both pumps stopped
- d) Abnormal flow rate
- e) Very low expansion tank level

18.3 Gauges and indicators for the following properties shall be included as a minimum:

- a) Thermometers
- b) Water flow meter
- c) Flow and pressure sensing devices
- d) Expansion tank coolant level

19. Audible noise levels from the outdoor heat exchangers shall be coordinated to meet the requirements for the STATCOM installation and the applicable IEC standards.

20. Special attention is needed to detect leaks in the system. The Contractor must explain in detail how water leaks, will be detected and managed. It is necessary to optimise the recovery procedures and to reinstate the cooling water as fast as possible.

21. Monitoring – sufficient gauges and indicators shall indicate the status of any part of the cooling plant for both normal operations and maintenance.

22. Maintenance of closed loop systems and make up for loss of liquid shall not be required more than once a year.

23. The design and testing of the complete cooling system shall comply with IEC standard or other relevant standard i.e. applicable to piping system.

24. To reduce the impact of the hot air arising from the ground surface the minimum height for air inlet of the fans shall be at least 2m.
25. All fans must be fitted with suitable birds and hail stone screens. They must be stainless steel, self-supporting and must be vibration resistant. The design and arrangement shall be such that steam or high pressure cleaning is possible while in service.
26. The fan blades shall be securely fastened to avoid inadvertent loosening resulting in changes of the pitch, vibration and noise.
27. The complete cooling system shall be factory tested, to verify controls, piping integrity, and complete operational capability.

9.5 Reactors

The reactors are utilized in the TCR branches to provide the inductive MVar output and in the filter branches to limit inrush currents.

Design requirements for reactors should include the following:

- The reactors shall be of single phase, air-core design, self-cooled and suitable for outdoor installation, ambient conditions in section 5.3 shall be considered.
- Each phase reactor shall be divided into two reactors, one on each side of the thyristor valve to limit short-circuit currents resulting when one reactor is shorted or a ground fault occurs.
- Supporting structural steel work, including foundations and fences shall be designed to avoid currents induced by the magnetic fields of the reactor.
- All structural and fence metalwork, including foundations, shall be designed to avoid, as far as possible, metallic loops and parallel circuits in which induced currents can run.
- Reactors shall be capable of withstanding short circuit forces based on maximum design fault levels and must be designed to avoid vibrations.
- The TCR reactors shall be designed to allow for the trapped decaying component of current caused by a three phase zero impedance fault on the primary side of the step-down transformer which is cleared in 5 cycles and followed by temporary overvoltage specified in clause 5.1.1.

- The reactor voltage rating shall be as required by the STATCOM design. The BIL rating shall be determined by the contractor as required by the STATCOM design and the insulation requirements in section 8.
- Audible noise levels from the reactors shall be coordinated to meet the requirements for the STATCOM installation and the applicable IEC standards.
- Must be designed and constructed such that maintenance can be carried out safely and conveniently.
- The plant and material shall comply in all respects with this specification and with IEC 60289 (Reactors).

9.5.1 Type Tests and Routine Tests

Each reactor shall be subjected to type and routine tests in accordance with IEC 60289.

The Temperature rise test shall be carried out on each reactor with maximum continuous rating and during this test the following shall be measured;

- a. Total losses
- b. Current and reactance

9.6 Isolators, Earthing Switches and Interlocks

Grounding equipment for maintenance and repair shall be supplied with the complete STATCOM circuit or with each separate circuit (where applicable). Grounding equipment for the STATCOM secondary bus system and for the transformer shall also be supplied.

Where it is required that a STATCOM circuit be isolated, disconnect switches shall be supplied. That is where one side can be alive while work is being performed on the other side. If this is not possible then no isolating switches are required towards the transformer LV side. In case of an auxiliary supply transformer on the LV busbar; it must be possible to operate the supply with the STATCOM transformer alive while at the same work is done on non-operational / isolated STATCOM equipment. Isolation with the LV breaker alone is not considered safe.

Disconnect switches and earth switches shall be adequately sized to carry the maximum steady-state current that can flow in it and the momentary currents due to faults.

All disconnect and earthing switches shall be indicated on the STATCOM Single Line Diagram provided by the Contractor.

The disconnect switches are required to isolate any apparatus for which maintenance is needed. As minimum the following major components shall have disconnect and / or earthing switches:

1. Incoming 275 kV feeder
2. Each thyristor controlled reactor branch.
3. Fixed capacitor bank.
4. Filter branches.

9.6.1 General Requirements

- All disconnectors and earthing switches shall be designed to ensure satisfactory operation and maintenance.
- All disconnectors shall be motor-operated, but with provision for manual operation.
- All disconnectors and earthing switches shall have a clearly visible position-indicating device.
- If the disconnectors and earth switches for the LV equipment (e.g. TCR) are provided they shall be integrated into the control, monitoring and protection system hardware and software
- All operating equipment, including auxiliary switches shall be housed in a weatherproof cabinet.

An interlocking scheme shall prevent any unpermitted operations. The interlocking system shall include:

- The AC disconnectors and earthing switches for the transformers.
- All disconnectors, earthing switches etc., within the Scope of Supply.
- Entrance into the valve enclosure area

The earth switches shall be interlocked with the disconnectors in such a way that disconnector cannot be operated if its earth switch is not in the fully Open position. The earth switch shall not be operable unless the disconnector is fully open. Mechanical and electrical interlocking is required.

The information on the disconnector and earthing switches shall include but not be limited to:

1. Type and rating.
2. Insulation level.
3. Creepage distances.

9.7 Post Insulators, Busbar and busbar accessories

All bus works shall be rated and designed for the STATCOM application.

9.7.1. Post Insulators

The insulation requirements in section 8 shall be met. The insulators shall be of post type, brown / grey colour. The post insulators shall be tested in accordance with IEC 60168.

The information on the bus and insulators shall include but not be limited to:

1. Insulation level.
2. Creepage distances and clearances (ground and phase to phase).

9.7.2. Busbar and accessories

The design of tubular* busbar shall ensure that differential expansion of the tube does not put strain on the support insulators. Due to high currents on the LV busbar, no busbar clamps shall be used on the LV side to connect the transformer terminals or the STATCOM branches.

Reference shall be made to IEC 60518: Dimensional standardisation of terminals for high voltage switchgear and control gear; for busbars, clamps etc.

Eskom standard TSP41-1004 shall apply, for tubular conductors and stranded all aluminium conductors, must be used in conjunction with IEC standard.

Other reference documents for All Aluminium conductors are:

- a) BS 215 Part1: Aluminium Conductors and Aluminium conductors, steel reinforced.
- b) SABS 182 Part2: Conductors for overhead electrical transmission lines

*Other busbar designs are subject to Eskom's approval. If cabling is used care must be taken for the magnetic fields and heating that may result from harmonics and unbalanced phase currents.

9.7.3. LV side earth fault current limitation

The single-phase to ground fault current shall be resistively limited to less than 300A. This current limiting device shall have a minimum time rating of 10 seconds.

For protection purposes the current through this limiting resistor shall be measured by its own CT.

9.8 Auxiliary Power Supplies

The SVC equipment shall include all the power supplies and material necessary for its operation, including step-down transformer, ac distribution boards, etc. The power supplies shall be sufficient to supply all pumps, fans, valves and valve controls, building cooling, lighting etc. It is the responsibility of the contractor to ensure that the auxiliary system is fully functional.

The following principal requirements shall be met for both DC and AC auxiliary supplies:

- b) The AC and DC auxiliary supplies shall each have dual redundant systems installed.
- c) The DC distribution shall be separated into two independent circuits.
- d) An automatic chop-over facility of AC feeder shall be provided by the Contractor. Switching must not cause significant disturbances in the MVAR output of the STATCOM. The chop-over system shall be fully controlled from the HMI system.
- e) Load transfer for selection of input DC feeder shall be provided by the Contractor. Load switching must not cause STATCOM trip and minimal disturbance on all systems including STATCOM output.
- f) Once the STATCOM is running it must de-load the Eskom station batteries, because there may be no AC auxiliary supply to charge them, operating under these conditions the STATCOM must be able to withstand any disturbances due to switching or line faults in the network.
- g) This internal supply must be suitable to sustain all the air-conditioning related to the STATCOM. The design of the STATCOM air-conditioners must take the imperfections of this internal supply into account.
- h) The main STATCOM AC supply shall be provided, by the Contractor, via a STATCOM auxiliary transformer connected to the STATCOM LV busbar.
- i) The STATCOM must be able start without any station AC auxiliary supply.

- j) The Contractor must ensure that the insulation quality of the semi-conductor coolant is safe for “black start-up”, after a prolonged outage. Black start means starting without any AC auxiliary supply.
- k) Eskom will provide a 3-phase, 4 wire 50 Hz with a nominal voltage of 400V, backup auxiliary AC supply, rated at 50kVA. The voltage is expected to deviate from the nominal voltage by ±20%. The Contractor shall be responsible for the termination, cubicles and cabling material necessary to take this supply from the substation AC supply point which is the Main AC board, to the Contractors AC distribution board in the STATCOM control building.
- l) The Contractor shall provide all cabling and terminations, interconnections, protection and interlocking for the AC and DC auxiliary systems integration into the STATCOM.

9.8.1 Testing

Apart from general inspection of all components, the Contractor shall prove the reliable operation of the automatic changeover and load transfer functions as well as any other function as required in this specification.

9.9 Power Transformer

The Contractor shall provide a 3-phase power transformer according to Eskom's specification. See Eskom Specification TSP41-87 for transformer requirements. The transformer manufacturer factory must have been evaluated and accredited by the Eskom team prior to commencement of manufacturing. After placing of order with successful Tenderer, a design must be reviewed and approved by Eskom; however the responsibility and the guarantee remain with the Contractor.

Bidders shall provide separate offer for a spare 3-phase transformer. Both STATCOM transformers (including the spare) must be equipped with proper movement system to allow quick exchange of units in case of emergency. The spare transformer shall be kept fully erected.

9.10 Circuit Breakers

Eskom will provide the STATCOM HV circuit breaker; the Contractor shall be responsible for protection coordination and settings.

9.11 Instrument Transformers

Details of VTs and CTs requirements and location shall be detailed by the Contractor and shown on the single line diagram as requested in Schedule B 15&16.

The Contractor shall be responsible for ensuring that all the inputs used for the STATCOM component control, indications, protection and measurement, as well as requirements of Eskom are suitable to ensure their accuracy and satisfactory performance.

10. CIVIL ENGINEERING AND CONTAINER REQUIREMENTS

This part of the specifications deals with information and criteria for design, engineering, supply, fabrication, construction, testing and commissioning of civil and structural works.

The contractor is responsible for all civil works (design specifications and drawings) which shall include the foundations, STATCOM control, valve and cooling rooms; trenches, masonry work, drainage, erosion protection etc. that are required to complete the work.

The *Contractor* shall supply the following information to the *Project Manager* six (6) weeks after *Notification of Acceptance*. This list should not be seen as complete.

- a) All civil work requirements i.e. design specification and drawings
- b) Foundation dimensions and loadings- working loads (un-factored);
- c) The details pertaining to the foundation holding down bolts positioning and sizes;
- d) Trench locations and dimensions; and
- e) Fastening method of equipment, where required.

Eskom will review and comment on the above. Eskom reserves the right to modify the arrangements indicated in the above should they not conform to the essence of the proposed layout and/or if the additional requirements may be necessary to suit the Eskom's needs.

All the civil work requirements (design specifications, drawings, etc.) shall be supplied to the *Project Manager* as stated in the Documentation Section.

10.1 Design Criteria

10.1.1 General Requirements

The detailed design shall include, but not be limited to:

1. Verification of all data, criteria and information contained in Eskom's Requirements.
2. Design and stress analysis of foundation for all equipment support structures, plinth foundations, cable trenches, etc., and preparation of all construction drawings (layout, general arrangement, and structural) required for the complete execution of the work. All necessary layouts and details etc shall be developed keeping in view of functional requirements. Sufficient detailing shall be done in all drawings so that the site engineers face no difficulty during execution.
3. Design and preparation of all construction drawings, bar bending schedules, material selection and material take-off etc., required for the execution of the work.
4. Generation of all criteria and information required for the completion of work including liaison with Eskom and other Authorities.
5. Preparation of field quality control plan.

10.1.2 Scope

As a minimum the following information shall be submitted for review and approval to the Employer:

- STATCOM layout design and drawings
- STATCOM room (container) layout and dimensions – ceiling height, height of floor in relation to STATCOM foundations top of concrete.
- Equipment and panel layout in the rooms
- Design criteria for structural steel and reinforced concrete. The criteria shall comprise the codes and standards used, applicable climatic data including wind loads, assumptions of dead and live loads, including equipment loads, impact factors, safety factors and other relevant information.

- Loads (and foundation dimensions) – working loads
- Details of foundation – bolting arrangements and details
- Structural design calculations and drawings (including construction/fabrication) for all reinforced concrete and structural steel.
- Container design.
- Cooling tower platform size and loadings
- EMF protection requirements
- Amount of cables and sizes foreseen in link tunnel between buildings and containers
- All the civil requirements (design specifications, drawings, etc.).
- The switchyard structures shall include beams and equipment support structures.

In general all the civil works will be carried out by Eskom according to Contractor's requirements:

1. Terrace construction and embankment stabilisation
2. Terrace drainage
3. Supply and erection of structural steel work
4. LV equipment foundations and necessary plinths.
5. Cable trenches including pre-cast covers and road crossings.
6. Placing of yard stone
7. Safety and Live chamber fencing.
8. Laying, connecting and testing of the earth mat.

10.2 General Description of Work

10.2.1 Terrace drainage

Storm water drainage shall be surface drainage and suitably disposed of in such a way as to prevent soil erosion.

10.2.2 Cable Trench (yard)

RCC cable trench with RC pre-cast slab covering. Top level of yard cable trench shall be 150mm above ground level. Ramps shall be provided that allow vehicles to cross over the cable trenches.

10.2.3 Support structures for the LV equipment

Pre-engineered structures of reputed manufacture are preferred. All structural steel members shall be galvanised as per SANS ISO 1461.

10.2.4 Fencing

The following fences are required:

- safety fence 1,8 m high for the yards – see drawing 0.54/4963
- Live Chamber fence 1,8 m high – see drawing 0.54/4963

All fences and gates shall be earthed and labeled according to Transmission's standard TST41-134.

10.2.5 STATCOM Container

The following are the minimum requirements the for container room:

- Shall have a free standing roof with over-hang, bird nests and enough space for ventilation
- The roof and the container combination shall have vermin proofing.
- Shall be maintenance free
- Heat insulated
- Dual redundant air-conditioning, Main and two (fully redundant – 100% each) standby

- The control room must have a space for desk with plug and phone point.
- The control room must have entrance area (dual door entry) in order to limit direct deposit of dust from outside, during maintenance or whenever the door is open for any other reason.
- The containers shall be designed with dust proof seals.
- All cables exiting the STATCOM container must be armoured cables.
- In all design aspects the container shall operate without any problems under harsh environment conditions specified in clause 5.3

10.2.6 Standards

The design, manufacture, fabrication, galvanising, testing, construction, materials used for manufacture, erection of station structures, design & construction of foundations and shall conform to the SANS codes listed in section 2.2.1 and SABS 1200 series of specifications. The latest revisions, with amendments/changes adopted and published, shall be used, unless specifically stated otherwise in the specification.

The material and services covered under these specifications shall be performed as per requirements of the relevant standards / codes. Other internationally acceptable standards, which ensure equal or higher performance than those specified, shall also be accepted with written permission from the Employer's Project Manager.

All changes or modifications will be to the Contractor's cost should any modification be made due to incorrect information or emissions by the Contractor.

11. ENGINEERING STUDIES

The Contractor shall perform the studies at his own facilities to ensure proper design and operation of the STATCOM system and to confirm design rating requirements of all plant and material.

All the engineering studies required in the scope of supply shall be performed by the Contractor. These studies are in addition to the actual STATCOM design studies and performance tests. The studies shall demonstrate that the STATCOM meets all specified performance criteria. Acceptance by the user does not absolve the supplier's overall responsibility for the proper functioning of the STATCOM as specified. The design of the STATCOM shall be such that the STATCOM's operating parameters will still be relevant at the end of its design life. This applies to fault levels, current carrying capacity etc. The data models that are included with this enquiry and the information in section 5 give an indication of the change in system that may be expected. The contractor shall list all engineering studies. Engineering studies shall include, but not be limited to, the studies described in IEEE 1031 clause 11.

All design studies shall take into account all modes of operation specified in this specification and the worst case system conditions up to and including a second contingency outage in the Eskom network.

The titles and scope of the design studies shall be clearly stated in the bid.

Should there be any network or equipment data not included in this enquiry, which is reasonably within the Contractor scope of work, the Contractor shall request such information in writing from Eskom.

The design studies conducted by the Contractor shall result in reports which shall be submitted to Eskom, for review and comments, within 8 weeks from contract award. These reports shall contain assumptions, methodology, study results, conclusions and recommendations.

The following study reports shall be prepared and supplied by the Contractor:

1. System Studies – STATCOM design (rating)
2. Insulation Coordination
3. Control system studies
4. Transient and Stability Studies
5. Valve design studies
6. Harmonic analysis and filter design studies
7. Protection and Protection Coordination Studies
8. Earthmat Design Studies
9. Busbar Design and
10. Civil Design Studies
11. STATCOM Loss Evaluation

Where the above studies have been conducted on PSCAD and or PowerFactory, digital models (case files) shall be supplied to Eskom. The Contractor shall study, design, manufacture, procure, test, deliver to site, erect and commission the works described in this specification.

11.1 Simulator Studies

The Contractor shall conduct the simulator studies on the supplied systems to verify proper operation during all modes of operation and under all credible system conditions and configurations specified in this document. The Contractor shall provide the following digital models to enable simulation of the STATCOM and its control and protective functions during steady-state operation, dynamic, and transient conditions in different timeframes:

1. PSCAD/EMTDC (Windows version) model for time simulations up to 10.0 s.
2. PowerFactory model for time simulations up to 60.0 s.

For each model, the Contractor shall provide an equivalent circuit representing the AC system at the STATCOM point of common coupling, a brief description of the overall structure of the model and an overview of all modules. It shall be possible to modify, change or improve the software model by Eskom personnel and code it directly in the PSCAD/EMTDC and PowerFactory and obtain the same results.

11.1.1 EMTDC Model

The model shall represent the STATCOM in enough details to obtain simulation results, which match field tests and analogue simulator results. The model shall represent the actual digital, analogue control and the main STATCOM. It shall be possible to run the steady state and contingency studies with the operation of the control functions.

11.1.2 Power Factory (DigSilent) Model

The model shall represent the fundamental frequency steady-state and dynamic behaviour of the STATCOM. The model shall be versatile enough to allow representation of additional control upgrades that may be expected during the guarantee period of the project. The DigSilent model shall where possible have similar requirements but, applicable to the PowerFactory principles, to those of PSCAD model.

12. RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)

The STATCOM system is required to provide steady state and transient voltage support, in order to mainly improve voltage unbalance and voltage control. Garona Substation is an unmanned substation and remote from technical maintenance staff. Every endeavor shall be made to ensure high reliability, availability and maintainability of this STATCOM.

12.1 Definitions

See clause 8.7.1 of IEEE 1031 for definitions on SVC availability and reliability.

12.2 Required Availability and Reliability

Reliability performance is required of the STATCOM, as follows:

- e) The annual equivalent availability for forced outages for the STATCOM shall be better than two (2) days in two years.
- f) There shall be not more than one (1) forced outage of the STATCOM for every two years.
- g) The Contractor shall guarantee the quoted availability performance for 2 years from the date of commercial operation. The contractor will be notified of major outages.
- 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 Eskom. The availability guarantee shall then continue for 2 consecutive years of operation until the guaranteed values have been achieved.
- i) An annual maintenance interval (normally in December) coinciding with the scheduled maintenance on the traction systems is expected. The design shall be suitable to operate the STATCOM continuously for two years.
- j) The Contractor shall submit complete RAM calculations in the tender as well as during the contract stage.

It shall contain actual RAM performance figures of comparable utility STATCOM's together with contact details of references.

13 SPARES

The contractor shall provide recommendations for the spares that will be needed for maintenance. This shall include a full complement of essential spare parts, which are to be furnished at the same time and as part of the STATCOM supply. It is the supplier's responsibility, based on the particular design for the STATCOM, to provide adequate spare parts to meet the reliability and availability requirements specified.

The costs, ordering and manufacturing lead times for the spares shall accompany the list. As a minimum one of each type of item is required. In the case of electronic component and sensors, 2 spares are to be provided.

The maintenance and storage requirements for the spares must be clearly laid out in the accompanying documentation.

Eskom may order spare parts in addition to those recommended by the contractor. These spares are intended for Eskom use after the guarantee period has expired and may not be considered when calculating RAM spare part quantities.

The price list for spares shall be valid for ordering within two years after the expiry of the guarantee.

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

13.1 Spares strategy

A strategy for spare parts shall be developed by the contractor to demonstrate that the complement of spare parts will be adequate to meet the reliability requirements specified.

In the spares strategy the contractor shall include the failure rate or the expected replacement rate of the component over a 10-year period.

Each device shall either be:

- Included on an inventory list of all site spares. The inventory list shall show the description, quantity, and storage location of each spare, assuming that any time that a spare is used, the item is reordered.
- Provided with a contingency plan to obtain a replacement on short notice, if a spare is not being kept on hand.

13.2 Spare parts storage

The spare parts for the STATCOM shall be stored on site.

13.3 Spare parts accounting

An inventory of the spare parts shall be prepared at the time when the STATCOM is handed over to Eskom and again at the end of the warranty period. Any shortages shall be replenished by the supplier so that the spare parts inventory is at its 100% level at the end of the warranty period.

13.4 Availability of spares

The availability of spares must be guaranteed for a minimum period of ten years from date of latest delivery. If, during this ten year period, the Contractor or one of his subcontractors intends to discontinue the manufacture of spares or replacement parts, the Contractor shall immediately give written notice to Eskom of such intention, and the offer must be valid for a minimum of six months.

14 TEST AND COMMISSIONING REQUIREMENTS

14.1 General Requirements

All equipment within the Scope of Supply of the Contractor shall be comprehensively tested in order to demonstrate that they meet the specified requirements and fulfil the guarantees. The Contractor shall provide detailed descriptions of test procedures and test program to the Employer.

The *Contractor* is responsible for conducting the tests required in this Specification. The tests shall be conducted at a sufficiently early stage so that rectification of possible non-conformities shall not delay completion of the project.

Testing shall be performed on all individual components, with no additional cost to Eskom and in accordance with the applicable standards such as:

1. Agreed Specifications
2. Applicable IEC (or ANSI) standards

If the requirements of this specification conflict with any of the above standards or practices, ruling shall be sought from Eskom. Where standards are not suitable or applicable, the Contractor shall develop detailed test procedures, which will be subject to review, comments, acceptance modification,

rejection and additions by Eskom. As a minimum all the tests listed in section 12 of IEEE 1031 shall be conducted except where the type tests reports of same SVC technology can be produced by the Contractor and are acceptable to Eskom.

The Contractor shall supply, with the Tender, the list of all routine, factory tests and type tests (if any) to be performed for this project.

No tests as agreed under the test programs shall be waived except upon the instruction or agreement of Eskom in writing.

The Employer reserves the right, in collaboration with the Contractor, to make alterations in the test program.

The Contractor shall provide all instruments, equipment and wirings, as well as the necessary skilled personnel, for carrying out these tests. Details of the test equipment and instruments used shall be noted in the test sheets.

The procedures and results obtained from tests shall be recorded and compiled in writing. The test report must be provided to Eskom within 2 weeks of the completion of tests.

The Contractor, at all times, must obtain permission from Eskom to perform field verification tests that require the STATCOM to be connected to the Eskom transmission system, such test shall be done under the supervision of Eskom personnel. Eskom Safety requirements and operating regulations shall be adhered to. These tests may have to be performed during night or low load periods. Energised system testing shall be kept to a minimum.

If any piece of equipment provided as a part of the STATCOM does not pass a test, show that is not in accordance with the contract or is damaged, the Contractor must replace the failed or damaged equipment and modify the equipment design, if necessary. The Contractor shall also redo all the tests. All expenses for the material, re-installation and re-testing will be the responsibility of the Contractor.

In addition to tests required by the specification, for which the cost shall be included in the contract, Eskom may require other tests done which may deem necessary to Eskom,. If such tests comply with the requirements of the contract, Eskom will bear the costs. However if any of the tests results are not in accordance with the contract, the costs shall be borne by the Contractor.

Eskom reserves the right to witness Routine, Type, Factory Acceptance, Simulator and Customer Acceptance Tests. The costs incurred by Eskom for witnessing of these tests will be carried by Eskom.

Type testing maybe waived by Eskom if the Contractor can submit valid Type Test Certificates for tests done previously. All required Type Testing cost and time shall be an integral part of the contract at no extra cost to Eskom.

The tests shall be divided into four main groups:

1. Factory Acceptance Tests
2. Factory Simulator Tests (RTDS).
3. Site Acceptance tests.
4. Commissioning Tests

14.2 Notification of Tests

The Contractor shall give the Customer advance notice of type, routine and factory acceptance, simulator tests eight (8) weeks before the actual testing date.

The Contractor shall submit a list of the Master Test Plan (MTP) with a preliminary time schedule for all tests including acceptance tests and the final MTP within 16 weeks of contract award. The test programs shall be approved by the Employer.

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

14.3 Factory Acceptance Tests

To the extent possible, all the equipment to be supplied by the Contractor shall be tested prior to shipping. The test reports shall be forwarded to Eskom 2 weeks upon completion of the tests. The Employer's acceptance shall be obtained prior to shipping of the equipment.

14.4 RTDS Tests

RTDS Test shall be conducted to demonstrate the proper operation of the control and protection systems where all functions shall be tested thoroughly. The actual plant to be supplied shall be connected to a RTDS simulator with an adequate representation of the Eskom network. The contractor shall furnish Eskom with simulator setup, general description of the RTDS, test program and equivalence Eskom network model for review and comments. These tests shall provide an initial verification of performance before the control equipment is shipped to site.

The simulator shall include saturation effects of transformers located in the substation, the operation of mechanically switched capacitors and reactors both under and not under the STATCOM control.

14.5 Site Acceptance Tests

This test shall be performed on a fully assembled STATCOM, without having the STATCOM connected to the power system. The purpose of this is to ensure that no damage occurred on the plant and material during shipping or erection, to check the quality of equipment and workmanship in general and to test the operation of the subsystems individually. It shall be carried out prior to the final testing of the complete STATCOM system. The test shall include but not be limited to the following items:

1. Insulation check of auxiliary cables.
2. Verification of operation of station auxiliary power distribution.
3. DC distribution system.
4. Testing of relay protections and protective control functions (by secondary injection).
5. Testing of control and monitor system and thyristor valves.
6. Verification and tuning of cooling system.
7. Check of operation and indications of circuit breakers, disconnect and earthing switches.
8. Capacitance check of capacitor banks.
9. Verify proper operation of all pumps fans and motors.
10. Verify proper operation of heating, ventilation and lighting systems.
11. Check of current and voltage transformers.
12. Overall check of trip operations from protections to breaker.
13. Check of circuits through interface.

14.6 Commissioning Tests

Upon completion of the Site Acceptance Tests, energizing and commissioning tests of the STATCOM shall be performed. These tests shall be performed on the fully assembled STATCOM with the STATCOM operating and connected to the Eskom power system. The tests shall include but not be limited to the following items:

1. Measure and verify the STATCOM operation at nominal power system properties.
2. Verify start, stop, de-block, block and trip sequences.
3. Verify change of reference point and slope setting.
4. Verify the function of the manual control mode, the secondary voltage limiter and the current limiter.
5. Verify the dynamic response of the voltage regulator and the gain supervision/optimization functions.
6. Harmonic voltage measurements on the 275 kV and LV side.
7. Measurements of audible noise.
8. Measure temperature rise at maximum available load.
9. Check of supplementary control functions

Tenderers shall note that Eskom's requirements for commissioning are described in the standard "TPC41-141 Check sheets for HV substation work to be taken over by the asset owner". The plant will not be taken over unless this standard is complied with, in all respects.

15 TRAINING REQUIREMENT

The *Contractor* shall organize and conduct a formally structured training, as part of the Scope of Supply, thorough training programs for operating, maintenance and engineering personnel prior to the commercial operation date. The training shall be sufficient that Eskom staff will be able to operate the STATCOM, do fault finding, diagnostics and repairing or replacing of failed components. The maintenance people must be able to do all necessary maintenance on the plant, as per OEM recommendations. The training shall include both theoretical and hands on training.

The course outline and a schedule shall be submitted to Eskom for review and comments 6 weeks prior to start of classes.

Eskom requires 3 distinct levels of training for the people who will operate and maintain the STATCOM, namely:

1. National Controllers
2. Substation operators
3. Technicians and engineers in the field of Protection, Measurements and Control, Telecommunications (substation control) and Maintenance staff.

The material presented for each level must be applicable to the group's responsibilities i.e. part of level 3 should include in-depth protection technology applied on this specific STATCOM.

The trainees shall be certified as being competent to work on the equipment after successful completion of the training.

The courses shall also include training in the factory during the testing of the complete STATCOM control system and Factory System Tests.

Appropriate training documentation shall be provided.

It is anticipated that the technical and maintenance personnel shall take part during contract period. Eskom representatives will work in cooperation with the *Contractor's* personnel for training purposes during the design, testing, installation and commissioning period. The *Contractor* will however remain responsible for the work.

Trainees' travel and living expenses will be borne by the *Employer*.

The *Contractor* must provide a simulator for ongoing training and retaining as part of this *Contract*. Simulator shall be in the form of software.

15.1 Training Schedule

In all types of training, two sessions shall be held. The Contractor shall provide training material for at least 10 trainees per session and one (1) set of training manual shall be included in the complete STATCOM documentation. First training session shall start for Level 1 personnel at least 4 weeks prior to first energisation of the STATCOM, subject to co-ordination with Eskom. The theoretical training for Level 2 and Level 3 personnel shall take place before the equipment is commissioned. The practical training shall happen during the commissioning stage.

The second session of classroom and practical training shall take place every two years for the next five years, after the equipment is been in operation.

The following durations are given purely as a guideline. The Contractor must make provision for adequate training of the groups. As a minimum the length of each course shall be as follows:

- National Controllers – 2 days.
- Substation staff – 5 days.
- Level 3 – 10 days.

The Contractor shall suggest course dates such that it does not interfere with commissioning or installation program. The suggested dates will be depend upon Eskom's approval.

15.2 Course Objectives

Clear objectives should be set for each course module in terms of purpose of the module, what will be studied, expected knowledge gain at the end of each module.

The trainees shall be trained on the following:

- Theory, operation, and maintenance of the STATCOM hardware and software components to be furnished by the Contractor.
- All aspects of the operator/maintenance interface subsystems used in the STATCOM system.
- Orientation to documentation (manuals and drawings) structure for the purpose of gaining maximum use of information contained therein.
- In-depth instruction on troubleshooting tools available in the STATCOM. Orientation and interpretation of all alarms, warnings etc., measured

variables, trend data; followed by a detailed study of the meaning and use of the various tools available in the system to isolate hardware failures.

- The training course shall include hands-on-demonstrations on the STATCOM covering routine servicing, testing, adjusting and calibrating, fault diagnosis, use of special tools and instruments and replacement of faulted components. Practical training shall be recorded on video.

15.3 Training Content

A suggested structure is:

1. A STATCOM overview and basic operations course.
2. A detailed operation and maintenance course.

The course content shall include but not be limited to the following topics:

1. STATCOM - basic theory and design
2. Main STATCOM Components
 - 2.1 Thyristors, thyristor modules, snubber circuits, prevention of overvoltages & Cooling System
 - 2.2 Reactors
 - 2.3 Capacitors
 - 2.4 Transformer
 - 2.5 Circuit breaker, earth switches and disconnectors
 - 2.6 Instrument transformers and measuring circuits
3. Control Systems principles – operation, control functions, schematic diagram
4. Protection principles – operation logic diagrams, relays, main components, protective control functions, protection calculations, settings and testing.
5. STATCOM Operation
6. STATCOM Operator Interfaces
7. Control and communication – alarms, signals and indications.
8. Auxiliary equipment AC/DC supplies – schematic diagrams.

9. Use of special tools and test equipment.
10. Fault Finding
11. Routine Maintenance
12. Switching and Interlocks
13. Manuals and Drawings
14. Simulator model for testing of control functions and STATCOM performance

15.3.1 Course Content for Level 1 (National Controllers)

Minimum training for Eskom's National Controllers shall include but not be limited to the following, but should form the basis of the training for SCADA staff:

1. What is a STATCOM?
2. An overview of the STATCOM function and theory of operation.
3. Purpose of a STATCOM. What does the STATCOM achieve in this application?
4. Describe a single line diagram of the STATCOM and detailed description of each component and their purpose.
5. How does STATCOM support the network during contingencies i.e. line fault
6. Alarms and trips, and annunciations.
7. Interpretation and changing of voltage set points, slope and gain.
8. Changing of voltage set point relative switching of external devices and their switching regimes.
9. Optimum utilization and operating practices
10. Describe the operating philosophy with particular attention to:
 - 5.1 HV and LV configuration.
 - 5.2 Isolating and earthing of each capacitor branch, reactors and transformers on the LV including the HV side.
 - 5.3 Spare transformer connection.
11. Safety and Switching.
12. Operating philosophy where single phase transformers are used.

13. Negative phase sequence and voltage control.
14. Operation of AC and DC auxiliary systems
15. General protection block diagram.
16. Protection: settings, operation and discussion of faults
17. Level of information available on SCADA.
18. STATCOM operating modes i.e. normal and degraded.
19. Overload capabilities and limitations of STATCOM.
20. Demonstration of STATCOM performance and all possible functions with a simulator model.

15.3.2 Course Content for Level 2 (Substation Personnel)

Minimum Training for Eskom Substation staff shall include but not be limited to the following:

1. An overview of the STATCOM function and theory of operation covering all functions provided.
2. Instruction shall use all provided documentation on the installation, operation, and maintenance of the system including reading and understanding of drawings.
3. Safety and Switching
4. Interpretation of all alarms and trips, and action required.
5. Use of mimic, printers, DFR/TFR, SER, security, and fire alarm protection.

15.3.3 Course Content for Level 3

The training course will be attended by professional engineers, technical officers and technicians and the presentations should be aimed at this level. Minimum training shall include the following:

1. Description of the objective and all functions of the STATCOM.
2. An overview of the function and theory of operation of the STATCOM including all functions.
3. Instruction on installation, setup, and calibration procedures.

4. Operation of all system features and operator interfaces, including the development of programs, databases, and documentation tools.
5. Maintenance and testing procedures, both as a whole and on a module basis.
6. Instruction shall use all provided documentation on the installation, operation, and maintenance of the system including reading and interpretation of drawings.
7. Background and instruction on software operation and development tools used for this application.
8. Instruction on reconfiguring or modification techniques used in devices or systems that utilise programmable controllers.
9. Eskom engineers, if required in the future shall be able to do reprogramming, modifications or changes to the software and hardware in all the microprocessor based systems.
10. Discussion questions and answers.

The following training scheme is common for level 2 and 3. The only difference is depth of discussion for each topic.

1. What is a STATCOM?
2. Purpose of a STATCOM. What does the STATCOM achieve in this application?
3. STATCOM Main Components.
4. Describe a single diagram of the STATCOM and detailed description of each component and their purpose.
5. Describe the operating philosophy with particular attention to:
 - 5.1 HV and LV configuration.
 - 5.2 HV and LV disconnectors.
 - 5.3 Earthing.
 - 5.4 Transformer.
 - 5.5 Capacitors.
 - 5.6 Reactors.
 - 5.7 change-over for spare transformer phase.
6. STATCOM operator interface - mimic panel, diagnostics

7. Disturbance/Transient Fault Recorder, Dynamic System Monitor, Power Quality Monitor and Sequence of event recorder (SER).
8. Using the SER to isolate device, locate fault, and determine solution to the problem.
9. Documentation, drawings and manuals
10. Structure of manuals and methodology in gaining maximum use of information contained therein.
11. Overview on thyristors, Thyristor modules, Snubber circuits and cooling system
12. Open and Closed loop control:
 - 12.1 Control Concept
 - 12.2 Software
 - 12.3 Hardware
 - 12.4 Software / Hardware Integration
 - 12.5 Testing and calibrating of components / plant
13. Protection systems:
 - 13.1 Operation
 - 13.2 Logic diagrams
 - 13.3 Relays and associated apparatus
 - 13.4 Discussion of faults
 - 13.5 Settings/calculations
 - 13.6 Testing
14. Auxiliary supplies:
 - 14.1 AC Systems
 - 14.2 DC Systems
15. Routine maintenance of STATCOM: on line and off-line
16. Use of special tools and test equipment
17. Safety and Switching
18. Security monitoring and controlled access
19. Fire alarm protection systems
20. Air conditioning

16 DOCUMENTATION

Eskom requires adequate information to be able to operate, fault find and maintain the STATCOM effectively. The supplier shall provide sufficient information. Some guidelines are given below but the lists are indicative only and are not exhaustive.

The documentation shall be assembled, cross referenced and packaged in a way that allows easy access by users. Eskom reserves the right to copy and distribute this information within its own organisation.

All documentation shall be provided in electronic form (3 sets) and in paper copies (3 sets). Drawings shall be compatible with the MicroStation 2004 edition, version 8 package. Note the requirements with respect to drawings in Transmission standard TPC41-246. The schematic diagrams must be a true reflection of equipment layout on site.

All text documentation shall be provided on either Microsoft Office XP packages or Acrobat (.pdf) format.

Any listed information must also be provided in Excel format.

The Contractor shall submit all design documents for review, modification and comment by the Employer. Eskom will actively participate with the Contractor during the design review meetings. The Contractor shall include all these activities in his Accepted Programme including the preliminary one and any subsequent revised submissions. All travel and subsistence costs for Eskom during the design review meetings are not for the Contractor's account.

The *Contractor* shall resubmit the revised documents within 30 calendar days from receipt of the comments from the *Employer*.

All plant and material, components, including spares shall be marked clearly and cross-referenced in the documentation and drawings.

16.1 Design documentation

Some of the main design documents to be sent for review include:

- Single line diagram
- Basic STATCOM design
- General layout and architecture, (all civil and building designs).
- Technical reports (this should contain all plant concepts & final designs, philosophies and strategies and system study reports).
- Auxiliary AC and DC system design

- Equipment specifications for HV and LV apparatus
- Transformer special requirements
- Dimension drawings for HV and LV apparatus
- RAM Engineering
- STATCOM loss evaluation

The manual documents for the equipment shall contain all information needed for operation and maintenance of the system. They shall be delivered at the commencement of installation of each equipment.

The "as-built" plant documentation shall be delivered in a structured fashion no later than 3 months after start of commercial operation.

16.2 Other Documents and Activities

- Project Program
- Interfaces with and integration of existing systems
- Type test reports
- Routine test reports
- Master Test Plan (MTP)
- Factory acceptance tests
- RTDS tests
- Site acceptance testing and commissioning

16.3 Pre Commissioning Documentation

The documentation that accompanies the equipment shall cover at least the following:

- Testing and Commissioning program
- Commissioning and installation practices and check sheets
- Spares lists
- Maintenance practices and procedures and fault finding techniques
- Operating and Operation manual for the STATCOM
- Complete sets of drawings (primary and secondary plant). Manually updated drawings are acceptable.

- Nameplate drawings for HV and LV apparatus
- Routine and Type Test certificates for all major components of the STATCOM.
- Reports of the studies done as part of the design.
- Protection and Control Settings and the Settings Guide

These items shall be available 16 weeks before commissioning starts. Eskom may choose to not permit the commissioning to start unless this information is made available, and is of acceptable standard.

NOTE: The STATCOM will not be put into service unless the commissioning check sheets are completed in full.

16.4 Post Commissioning Documentation

The documentation shall include at least the following:

- Commissioning and installation practices and completed commissioning check sheets
- Spare parts list
- Complete sets of 'as built' drawings (primary and secondary plant)
- Fault finding procedures
- Complete plant information and specifications
- Protection and Control Settings and the Settings Guide

The documentation shall be acceptably bound and cross referenced.

17. DESIGN AND CONSTRUCTION REQUIREMENTS

17.1 Plant and Material Characteristics

All plant and material shall be entirely suitable for continuous operation under the conditions specified in this specification without any restriction to the operating range of the STATCOM. All plant and material shall include everything necessary for safe and convenient installation, operation and maintenance of the plant and material whether directly specified or not. The STATCOM is expected to last and continue operating with minimal maintenance for at least 30 years over its entire range under the most severe conditions described in this specification.

No components shall be overloaded or disconnected under any STATCOM operating condition, in particular the wide range of auxiliary AC and LV operating voltages and levels of harmonics.

17.2 Layout and Design

The proposed layout for the transformer position is attached to this document. Eskom's drawing are proposed layouts for transformer positions.

The STATCOM layout and design shall be of modular with each branch section separated with fencing and having suitable access control (fence with lockable gate and interlocking). The Contractor may provide alternatives that are compliant with the need for accessibility. Sufficient space shall be provided between the plant and material and the fence to allow safe maintenance and repair access. Refer to Annexure D for safety and working clearances. The area available for the STATCOM is shown in the Substation Key Plan diagram.

17.3 Maintainability

All applicable redundant systems shall allow maintenance and repair on one system with the other system in service. The layout shall be arranged in such a manner that access to any plant and material is possible and may be removed without disconnecting other plant or apparatus first.

17.4 Polychlorinated Biphenyls (PCB)

All plant and material shall be free of any PCB.

17.5 Vermin Proofing

STATCOM container including valve & cooling system rooms; main busbar system, capacitor racks, air insulated reactors, fences, control cables and optic cables shall be designed and constructed to prevent snake, rodent, civet cat, bird, bees, moths, insects and other wildlife from inadvertent contact with energised plant and material or access to the building and areas where damage may be inflicted to plant.

The design shall also ensure that birds that roost on the filter bank cannot short out the terminals of the units. This may require the use of shields. Anti-bird nesting devices shall be utilised where practical. Note that the measures to prevent bird faults must not limit the effectiveness of the Infra-red scanning that will be done on a regular basis.

Vermin insect proofing must be provided in the valve room. The screens, if used, to the valve room must be of a small mash to prevent vermin.

For out door circuits the minimum insulation for 36kV in Annexure D shall be applied for the purpose of vermin proofing.

18. SAFETY REQUIREMENTS AND ENVIRONMENTAL IMPACT

18.1 Safety Requirements

The supplier is responsible for the compliance with ESKOM Operating Regulations for High Voltage Systems and the statutory requirements of South African law at all times.

Any safety requirements (entrance to the valve container, etc.) shall be monitored and included in the protection of the STATCOM. The Contractor shall supply a key interlock system (mechanical) for the TCR valve chambers and each of the external LV yard plant and material (TCR and filters) that are individually fenced. All these interlocks shall be monitored and indicated.

The supplier shall provide all supervision needed for his/her people and any sub-contractors he/she may use.

Only people who have been authorized by the Grid GMR 2.1 appointee as Responsible Persons may supervise contractor and sub-contractor staff. The GMR2.1 appointee requires 14 working days notice to process any applications for authorizations as Responsible Persons. The requirements for authorization are:

- Details of the scope of work
- Duration of stay on site
- First Aid certificate
- Proof of successful completion of pre-requisite ORHVS modules
- Letter of appointment from his employer as Safety representative on the site
- ID Document
- Compensation of injury and diseases (COID) registration number
- Completed Risk assessment

Tenderers are reminded that full compliance with the Construction regulations GNR1010 (18th July 2003) of the OHS Act is required. Tenderers are advised to contact the Grid Safety Advisors to establish the details of this compliance before submitting the tender.

18.2 Environmental Impact

The plant and material shall be constructed such that it has insignificant risk to the environment from the oil contained in the bank, bushing and other equipment in the yard. It must also be protected against environmental conditions as stated in this specification that may be damaging to the plant during its operation or life-cycle.

The plant design shall ensure that no spillage of hazardous material can enter the environment under normal operating conditions. This applies to all plant and buildings.

The supplier shall ensure that all environmental precautions are taken at all times during the construction phase to avoid damage or contamination to the surrounding air, ground and water. The supplier shall rehabilitate any damage caused by the activities of his people or of his subcontractors.

Note that Waste disposal is an important part of responsible environmental management.

The supplier shall ensure that all requirements of the Record of Decision for the project are strictly complied with.

19. GENERAL PLANT REQUIREMENTS

19.1 Secondary Equipment Design and Construction Standards

ESKOM Standards TST41-1062 and TST41-627 will be used as the standards that are applicable to the details of the design on the secondary equipment. Items such as acceptable wiring, terminations, panels etc. are defined in these Standards.

In addition all equipment and material shall comply with IEC Publication 60255.

The secondary plant and material shall comply with the relevant standards of the IEEE Surge Withstand Specification. Full details of all relays and instruments offered shall be included in the contract.

Full details of the system that is used shall be presented in the A/B Schedules and will be comprehensively examined at the Design Review meetings.

The Contractor shall submit a detailed type test report of the protection & control scheme and equipment conducted by a third party. Eskom may elect to witness the repeat of any or all of the type tests as per TST41-1062.

The design shall ensure that all outdoor cables (that are exposed to sun light) are suitably protected against Ultra-violet damage or shall be specified in such a way that the high South African levels of ultra-violet radiation will not cause damage to the cable sheathing and internal wires.

19.2 Special Tools

The supplier shall indicate what tools and software packages are required for commissioning, maintenance, fault finding and operations on the STATCOM.

Any special tools, capacitance measuring devices, fibre optic system tester, software and diagnostic instruments that are needed for commissioning, maintenance, fault finding or operation shall be supplied as an integral part of the contractual deliverables and shall be available from the beginning of commissioning. The cost of such tools shall not be included in the Main offer, but shall be shown as a separate item in the costing schedule.

Software shall be “free ware” and shall be compatible with present and future releases of standard Windows operating systems.

The following tools are excluded from this requirement.

- Multimeters
- Oscilloscopes
- Conventional current injection test sets (Omicron, Pulsar, etc.)
- Usual hand tools
- Standard Personal computers (Pentium 4 processors)

The Eskom technician will have the usual basic tools. Oscilloscopes with a bandwidth of 20 MHz will be available as part of the technician’s equipment. If a higher bandwidth is called for, the supplier shall state this fact and justify the requirement.

The programmable current injection test sets mentioned above are the standard equipment of the field staff. If a different current injection test set is required, the supplier shall state this fact and justify the requirement.

19.3 Mechanism, junction boxes and terminals

Lights shall be installed inside every breaker and Isolator mechanism box and in every Junction box. The lights shall be of the low energy type and shall be switched on or off by a door operated micro switch.

Heaters shall be provided in each mechanism box and in each junction box. The heater shall be permanently energized. These heaters are required to keep the temperature in the cubicle above the dew point.

Gland plates shall be properly sealed and all unused holes shall be securely closed off (PVC plugs are not acceptable). Gland plates shall be adequately protected against rust and oxidation.

Door rubber seals shall be made from rubber and be securely glued into place.

Terminals shall comply with Eskom Standard TST41-1062, clause 2.2.14.

19.4 Statutory, labeling and labeling of Primary Plant

All the labels shall be in accordance with Transmission Specifications TST41-134 and TST41-655. A schedule of labels shall be submitted for acceptance at least 3 months before commissioning.

19.5 Special design requirements for fibre optic cables

Especial care shall be taken to ensure that no damage can occur to Fibre optic cables that are laid in trenches (or conduits or other similar constructions) with other cables (power, protection, control etc). This means that fibre optic cables shall be housed in a dedicated protective covering of Class 6 HDPE, stainless steel "Sprague" tubing or Optex or equivalent.

19.6 Painting Specification

Eskom's preference for paint colour is Light Grey to SABS 1091 colour code G29 (semi gloss) for exterior finishes. The finish shall be semi mat (polyurethane or epoxy coating). Galvanised surfaces shall not be painted. Minimum thickness of the paint shall be 85 micrometers.

20. ELECTROMAGNETIC INTERFERENCE

20.1 Radio Interference

20.1.1 Conducted Noise

Requirements in respect to interference in the power line carrier frequency band:

The level of interference produced by the STATCOM under any operating condition, in the power line carrier frequency band of 50 to 500 kHz, shall not exceed a noise power of -10dBm, measured over a bandwidth of 4 kHz, across a 75 ohm resistive termination connected to the centre phase line matching plant and material on any line connected to the same busbar as the STATCOM.

20.1.2 Radiated Noise

Means shall be taken to eliminate all risk of interference to Substation plant and material due to radiated sound generated by the STATCOM.

Susceptibility of STATCOM electronics to withstand Radio-Frequency Interference:

The plant and material shall not maloperate in any way when subjected to radiated field strength of 10V/m over the frequency range of 27 MHz to 1000 MHz. The plant and material shall be tested in accordance to IEC 61000-4-3.

20.1.3 Radio / Television Interference

The limit value for RI and TVI shall be between 50 $\mu\text{V/m}$ and 100 $\mu\text{V/m}$ at a distance of 500 m radius of the centre of the STATCOM for all operating conditions and all frequencies between 150 kHz and 30 MHz.

20.1.4 Magnetic and Electric field strengths

The clearances shall be such that no person outside the fenced area can be exposed to magnetic field strengths greater than 0.5 mT (5.0 Gauss) and electrostatic field strengths greater than 10 kV/m. Refer IEEE PC95.6-2002 Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields.

21. AUDIBLE SOUND LEVEL

Permissible audible sound levels shall be between 40 and 45 dB(A). Refer to SABS 10103 and applicable IEC standard.

22. STATCOM LOSS EVALUATION

The Contractor shall calculate the total operating losses of the total proposed STATCOM system. The losses shall be calculated at nominal voltage at each operating point of the STATCOM. These losses shall be calculated based on each STATCOM component in accordance with IEEE 1031 method.

The total losses calculated over the complete STATCOM range, shall not exceed the guaranteed losses as stated in the tender and no credit will be given for losses below the guaranteed figures.

ANNEXURE A: SYSTEM CONTINGENCIES

System Contingencies

1.	Ferrum – Olien 275kV line1 out
2.	Mecury – Ferrum 400kV line out
3.	Lewensaar (MTSE) – Garona 275kV line out
4.	Garona – Gordonia 132kV line out
5.	Garona 275/132 kV Transformer out
6.	Garona 275/50 kV traction transformer out
7.	One traction transformer out

Shunt Bank States

1.	132kV, 1x36 MVAR filter bank out at Olien
2.	132kV, 1x36 MVAR standard bank out at Olien
3.	275kV, 1x72 MVAR standard bank out at Ferrum
4.	275kV 1x45 MVAR shunt reactor out at Ferrum
5.	132kV 1x 36 MVAR bank out at Garona

ANNEXURE B: TSC REQUIREMENTS

General Requirements

1. The oscillations occurring at TSC energization with the capacitor voltage differing from the system voltage should be efficiently suppressed. In case of operation without harmonic filters the oscillations must be practically damped out in not more than 5 cycles.
2. The TSC branch shall have the ability to be switched off and successfully block the transient voltages up to 1.5 p.u primary voltage, taking into account the commutation overshoot associated with this overvoltage.
3. The thyristor valve shall be connected in series with a capacitor bank and a current limiting reactor. The current limiting reactor shall be designed to limit the current rate of rise during fault conditions and misfirings.
4. The control and valve firing system shall be designed to minimize the risk for generation of spurious firing pulses at normal or disturbed mode of operation. The system shall be insensitive to variations in, or complete loss of, the station auxiliary AC supply voltage.
5. The thyristors must be protected against harmful voltage during their recovery period at partial turn off situations, i.e recovery protection.
6. The valve firing system shall be designed to prevent blocking of the thyristors in case the capacitor voltage exceeds a certain voltage level. This level shall be set to a value exceeding the capacitor voltage occurring immediately following valve blocking at 1.5 pu system voltage.
7. In case of severe power grid disturbances resulting in difficulties to maintain proper firing pulse synchronization, the valve must not misfire to such a degree that thermal valve overload leading to reduced thyristor blocking capability are caused. Voltage build up on the capacitors exceeding 2.0 times their voltage rating is not allowed.

In case the misfiring cannot be prevented, but the negative effects thereof are limited by unlinear resistors, the system must be designed to handle multiple misfirings on the worst point of wave at 1.5 pu primary voltage. The build up of the capacitor voltage at each misfiring must be accounted for.

8. Undervoltage Strategy:

If the voltage in all three phases goes below 0.3 p.u a special undervoltage strategy shall be activated that blocks the firing pulses to the TSC-valves and controls the SVC output to 0 Mvar or settable reference. As soon as the voltage in one of the phases goes higher than 0.3 p.u the undervoltage strategy is deactivated and the normal control will be in operation.

Protection Requirements

1. Each TSC branch shall have its own protection
2. Main and backup protections shall be provided

The following is a list of minimum protection requirements:

3. Capacitor Overload Protection
4. Overcurrent protection
5. Capacitor bank Unbalance Protection
6. Differential protection
7. Capacitor Unit Protection
8. Surge Protection
9. Valve and Thyristor Protection, shall include, but not be limited to:

9.1 Overvoltages Protection:

The valves of the TSC branches shall be protected against overvoltages by a surge arrester or a combination of surge arresters. Protective firing initiated by thyristor level voltage or by valve voltage exceeding a pre-determined level is not permitted as the main overvoltage protection of the valves. If VBO/EOP protection is provided at each thyristor level, the break-over level shall be set sufficiently high such that the arrester or combination of arresters provide the primary protection for the valves while the VBO/EOP protects mainly the individual thyristor levels from overvoltages, taking into account redundancy and uneven voltage distribution along the valve. Valve transient overvoltage detection and the blocking system shall be monitored and an alarm annunciated.

9.2 Overcurrent Protection

The thyristors shall be protected against currents of excessive magnitude and duration. Overcurrent protection shall prevent the thyristors from blocking after a very high surge current, e. g. due to false firing of the thyristors.

9.3 Thermal Overload Protection:

The simulation shall take account of the actual waveshapes of the overcurrents in the TSC branches, the thyristor heatsinks and the cooling circuit conditions. This protection device shall be designed to meet the requirement set out in this specification. The device shall monitor the voltage blocking capability of the valve in each polarity as a function of the thyristor junction temperature and initiate continuous conduction of the valve and tripping of the SVC only if the blocking capability of the thyristors is determined to be inadequate. Alternative schemes may be proposed that utilise the TSC thermal capability, protecting the valve against overcurrents and the system against overvoltages. This protection device shall be duplicated.

ANNEXURE C: EQUIPMENT INSULATION LEVELS

					Electrical clearance in mm	
Highest line-to-line voltage for equipment U_M	Rated lightning impulse withstand voltage at sea level	60-s power frequency withstand voltage at sea level	Minimum creepage distance for external insulation Mm		Phase-to-earth	Phase-to-phase
kV r.m.s.	kV peak	kV r.m.s.	IEC pollution classification			
			Medium	High		
3,6	45	16	70	90	80	110
7,2	75	22	140	180	150	200
12	95	28	240	300	200	270
17,5	110	38	350	400	230	310
24	150	50	480	600	320	430
36	200	70	720	900	430	580
48	250	95	960	1200	540	730
72	350	140	1400	1800	770	1050
100	380	150(185)	2000	2500	840(1000)	1150(1350)
145	550	230(275)	2900	3600	1200(1450)	1650(1950)
245	850	360	4900	6100	1850	2300
300	1050	460	6000	7500	2350	2950
362	1300	570	7200	9000	2900	3600
420	1425	630	8400	10500	3200	4000

* Up to $U_N= 330kV$, $U_M= 1,1 U_N$

** The creepage insulation values are based on line-to-line maximum system voltage.

Note: 25mm/kV (U_m basis) shall be used

ANNEXURE D: STANDARD ELECTRICAL AND WORKING CLEARANCES

System Nominal Voltage	System Highest Voltage	Minimum Electrical Clearance in mm		Working Clearance in metres	
		Phase-to-earth	Phase-to-phase	Vertical	Horizontal
3,3	3,6	80	110	2,5	1,2
6,6	7,2	150	200	2,6	1,2
11,0	12,0	200	270	2,7	1,3
22	24	320	430	2,8	1,4
33	36	430	580	2,9	1,5
44	48	540	730	3,0	1,6
66	72	770	1050	3,2	1,8
88	100	840 (1000)	1150 (1350)	3,3 (3,5)	1,9 (2,1)
132	145	1200	1650	3,7	2,3
220	245	1850	2300	4,3	2,9
275	300	2350	2950	4,8	3,4
330	362	2900	3600	5,4	4,0
400	420	3200	4000	5,7	4,3

ANNEXURE E

SCHEDULE A: ESKOM'S PARTICULAR REQUIREMENTS

A.1: General Requirements

Item	Description	Units	Schedule A
1.1	Summary of requirements		
b)	Design, manufacture, deliver, build, erection and commissioning		Yes
1.2	Access and completion dates		
a)	Delivery not before		as per project schedule
b)	Erection and commissioning completed not later than		as per project schedule
1.3	Site details		
a)	Site location (approximate) GPS coordinates		100 km southeast of Uppington Alt -28,74" Lon 21,995"
c)	Transport to site		Dread Road
d)	Contractor responsible for off loading from transport vehicle		Yes
e)	Crane facilities available on site		No
f)	400/230 volt, 3 phase, 4 wire, 50 Hz construction supply available on site		Yes, hand tools only
1.4	Site and service conditions		
a)	Ambient temperature		
	i) Maximum	°C	50
	ii) Minimum	°C	-10
b)	Daily average temperature	°C	30
e)	Pollution		Heavy – dusty
f)	Altitude above sea level	M	501 – 1000
g)	Maximum solar radiation	kW/ m ²	1,2
h)	Maximum steady wind velocity	m/s	40
i)	Dry corrosivity		Moderate
j)	Maximum relative humidity	%	95

Item	Description	Units	Schedule A
k)	Isokeraunic level – flashes per km ² per year	days/yr	less than 10 flashes/km ² /year See clause 5.1
1.5	Transmission system details		
a)	Nominal voltage (U _N)	kV _{r.m.s.}	275
b)	Maximum continuous operating voltage (U _M)	kV _{r.m.s.}	290
c)	Frequency	Hz	50
d)	Number of phases		3
e)	System effectively earthed		Yes, at the terminal stations
1.6	Routine test certificates to be supplied		4 copies
1.7	Spares to be delivered to		Site

ESKOM'S SCOPE OF SUPPLY HV & EQUIPMENT INFORMATION

A.2 STATCOM HV Circuit Breaker

Item	Description	Units	Schedule A
1	Nominal Voltage (U _n)	kV _{rms}	275
2	Rated Normal Current (I _r)	A _{rms}	3150A
	Rated short-time withstand breaking current (I _k)	kA	50
	Rated peak withstand current (I _p)	kA _{rms}	125
	Type of operating mechanism		Spring
3	Quantity		Three single phase units i.e. 1ph-Auto Reclosure
	Operating duty cycle where:		O-t-CO-t'-CO
	- t	ms	0.3
	- t'	min	3
	Cooling time before duty is repeated	min	5
4	NOTE: The operating times are:		
	Closing time	ms	<65
	Opening Mechanical time	ms	<22
	Total Breakage time	ms	33

A. 3 STATCOM HV Isolators

Item	Description	Units	Schedule A
1	Rated Nominal Voltage (U_n)	kV	275
2	Rated Nominal Current (I_n)	A	3150
3	Rated short time current for 1s	kA	50
4	Type of Isolator		Pantograph with trapeze contact
5	Method of operation		Motor
6	Specific creepage distance	mm/kV	31
7	Peak dynamic withstand	kA crest	125
8	Rated insulation level	kV crest	1050

A.4 275kV Surge Arresters Isolators

Item	Description	Unit	Schedule A	Schedule B
1.	Refer to Eskom's Standard Specification TSP41-363.			

ANNEXURE F

SCHEDULE B: GUARANTEES AND TECHNICAL DETAILS OF EQUIPMENT OFFERED

The performance of the STATCOM, when working under the specified conditions, and subject to the stated tolerances where applicable, is guaranteed to be as follows:

B.1 STATCOM Performance

Item	Description	Units	Schedule A	Schedule B
1.1	STATCOM Performance and Rating			
a)	Nominal Voltage (Un) HV	kV_{rms}	Specify	
1.2	Nominal Voltage (Un) LV	kV_{rms}	Specify	
1.3	Rated Frequency	Hz	Specify	
1.4	STATCOM Maximum Continuous energising voltage			
a)	HV	$\text{kV}_{\text{r.m.s.}}$	Specify	
b)	LV	$\text{kV}_{\text{r.m.s.}}$	Specify	
1.5	STATCOM Minimum Continuous Operating Voltage			
a)	HV	$\text{kV}_{\text{r.m.s.}}$	Specify	
b)	LV	$\text{kV}_{\text{r.m.s.}}$	Specify	
1.6	Maximum Transient Voltage Variation during STATCOM Energisation	%	Specify	
1.7	STATCOM ON Transient Duration	ms	Specify	
1.8	Maximum duration to fully energised (Voltage Controller Active)	ms	Specify	

Item	Description	Units	Schedule A	Schedule B		
1.9	STATCOM output at maximum capacitive current					
a)	Operating voltage range	pu	Specify			
b)	Maximum output	MVAR	Specify			
c)	Duration	s	Specify			
1.10	STATCOM output at maximum inductive current	MVar	Specify			
a)	Operating voltage range	pu	Specify			
b)	Maximum output	MVAR	Specify			
c)	Duration	s	Specify			

B.2 STATCOM Performance: Losses

Item	Description	Units	Schedule A	Schedule B
2.1	STATCOM Losses at maximum inductive continuous rating at nominal STATCOM HV Bus voltage			
2.1.1	Total STATCOM Power transformer (including auxiliaries)	kW	Specify	
2.1.2	Total STATCOM valve losses, including auxiliaries, cooling, RC circuits, etc	kW	Specify	
2.1.3	Series Reactor Losses	kW	Specify	
2.1.4	Auxiliary and Other Service equipment losses (List individual equipment)	kW	Specify	
2.1.5	Total auxiliary and other losses	kW	Specify	
2.1.6	Total STATCOM Losses (maximum inductive)	kW	Specify	
2.2	STATCOM Losses at 0 Mvar output at nominal STATCOM HV bus voltage:			
2.2.1	Total STATCOM Power transformer (including auxiliaries)	kW		
2.2.2	Total STATCOM valve losses, including auxiliaries, cooling, RC circuits, etc	kW		
2.2.3	Series Reactor Losses	kW	Specify	
2.2.4	Auxiliary and Other Service equipment losses (List individual equipment)			
2.2.5	Total Auxiliary and other losses	kW	Specify	
2.2.6	Total STATCOM Losses (0 Mvar Output)	kW	Specify	
2.3	STATCOM Losses at maximum capacitive continuous rating at nominal STATCOM HV Bus voltage:			
2.3.1	Total STATCOM Power transformer (including auxiliaries)	kW		
2.3.2	Total STATCOM valve losses, including	kW		

Item	Description	Units	Schedule A	Schedule B
	auxiliaries, cooling, RC circuits, etc			
2.3.3	Series Reactor Losses	kW	Specify	
2.3.4	Auxiliary and Other Service equipment losses (List individual equipment)	kW		
2.3.5	Total Auxiliary and other losses	kW	Specify	
2.3.6	Total STATCOM Losses (Maximum Capacitive)	kW	Specify	

B.3 STATCOM Performance: Rated Values

Item	Rated Values	Units	Value
3.1	Short term inductive overload capability of STATCOM		
3.1.1	1 hour	Mvar	
3.1.2	½ hour	Mvar	
3.2	Overvoltage withstand capabilities of the STATCOM		
3.2.1	100 ms	pu	
3.2.2	3 Seconds	pu	
3.3.3	Continuous	pu	
3.3	Minimum operation:		
3.3.1	Voltage capability	pu	
3.3.2	Duration	ms	
3.4	Range of frequencies over which the STATCOM is capable of continuous normal operation:		
3.4.1	Maximum Frequency	Hz	
3.4.2	Minimum Frequency	Hz	

Item	Rated Values	Units	Value
3.5	Range of temporary frequency excursions (less than 15 seconds) over which the STATCOM is capable of continuous operation, but outside specified tolerances:		
3.5.1	Maximum Frequency	Hz	
3.5.2	Minimum Frequency	Hz	
3.6	Associated voltage deviation at:		
3.6.1	Maximum Frequency	kV	
3.6.2	Minimum Frequency	kV	

B.4 STATCOM Voltage Control

Item	Description	Units	Schedule A	Schedule B
4.1	Response time			
4.1.1	Maximum time required for reactive output to change from full inductive absorption to full capacitive generation following a step input	ms	Specify	
4.1.2	Maximum time required for reactive output to change from full capacitive generation to full inductive absorption following a step input	ms	Specify	
4.1.3	Settling Time	ms	Specify	
4.1.4	Maximum Voltage Overshoot	%	Specify	

B.5 Audible Noise Levels

Item	Description	Units	Schedule A	Schedule B
1.	Maximum audible noise levels inside the STATCOM container:			
1.1	Valve Room	dB(A)	Specify	
1.2	Control Room	dB(A)	Specify	
1.3	Other Accessible rooms	dB(A)	Specify	
2.	Maximum Audible noise level outside the STATCOM container:			
2.1	Reactors at a distance of 3m	dB(A)	Specify	
2.2	Mechanical Equipment	dB(A)	Specify	
2.3	STATCOM boundary fence	dB(A)	Specify	

B.6: Air-Core Reactors

Provide separate schedule for each type and rating of air core reactor

Item	Description	Unit	Schedule B
1	Rated Values		
1.1	Voltage	kV	
1.2	Um Voltage	kV	
1.3	Continuous Current	A	
1.4	Short circuit current rating	A	
1.5	Duration of rated short circuit current	s	
2	Current		
2.1	Maximum inrush current	kA	
2.2	Maximum current surge without mechanical damage	kA	
2.3	Harmonic content of reactor current		
2.4	Current density of windings at rated current	A/mm ²	
3	Rated impedance per phase at 50Hz		
3.1	Rated inductance	mH	
3.2	Tolerance of rated inductance	% (-,+)	
3.3	Rated resistance	Ω	
3.4	Temperature at rated resistance	$^{\circ}\text{C}$	
4	Insulation of reactor windings		
4.1	Insulation level BIL	kV _{peak}	
4.2	Switching impulse withstand voltage at sea level	kV _{peak}	
4.3	60s power frequency withstand voltage	kV _{rms}	
4.4	Inter-turn voltage withstand	kV	
4.5	Insulation resistance	Ω	
4.6	External voltage grading	kV/mm	
5	Post Insulators		
5.1	Rated Voltage	kV	

5.2	Lightning Impulse withstand, BIL	kV _{peak}	
5.3	Switching impulse withstand voltage at sea level	kV _{peak}	
5.4	60s power frequency withstand voltage	kV _{rms}	
5.5	Total creepage distance	mm	
5.6	Steady mechanical load safety factor		
6	Losses		
6.1	Total losses at rated current	kW	
7	Temperature rise at site altitude at maximum continuous current		
7.1	Hot spot temperature	°C	
7.2	Maximum temperature rise of windings	°C	
8	Reactor details		
8.1	Type of cooling		
8.2	Number of coils per phase		
8.3	Mass of one coil	kg	
8.4	Coil dimensions:		
	i) Diameter	mm	
	ii) Height	mm	
8.5	Dimensions of unit including pedestals:		
	i) Diameter	mm	
	ii) Height	mm	
8.6	Winding capacity of one coil	pF	
8.7	Arrangement of coils:		
	i) spacing between coils of same phase	mm	
	ii) spacing between coils of different phases	mm	
8.8	Maximum audible sound level of individual Reactors at a distance of 3m	dB(A)	
8.9	Protection schemes		
8.10	Manufacture		

8.11	Country of manufacture			
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B.7: Air-cooled Resistors

Provide separate schedule for each type and rating of resistor

Item	Description	Unit	Schedule A	Schedule B
1	Rated voltage	kV _{rms}		
2	Um (rms) (terminal-to-terminal)	kV _{rms}	Specify	
3	Rated current	A	Specify	
4	Maximum continuous rating	kW	Specify	
5	Time rating at rated current	s		
6	Resistance at 20°C	Ω	Specify	
7	Insulation level			
7.1	BIL	kV _{peak}	Specify	
7.2	Power frequency withstand	kV _{rms}	Specify	
7.3	Maximum short-time rating of resistor	kW-s		
8	General			
8.1	Manufacturer			
8.2	Country			
8.3	Type or model			
8.4	Resistance material			
8.5	Temperature co-efficient at resistance	Ω/°C		
8.6	Dimensions (length x depth x height)	mm		
8.7	Mass	kg		
8.8	Total creepage distance	mm	Specify	
8.9	Housing details		Specify	
	Drawing no.			
8.10	Vermin proofing		Specify	
8.11	Standard to which equipment conform		Specify	

B.8: IEGT Valves for each phase

Item	Description	Unit	Schedule A	Schedule B
1	General valve characteristics			
1.1	Rated voltage per valve	kV	Specify	
1.2	Um per valve	kV	Specify	
1.3	Rated current per valve	kA	Specify	
1.4	Number of valve sections per valve			
1.5	Number of IEGT levels per valve section		Specify	
1.6	Total number of IEGT pairs in a valve		Specify	
1.7	Continuous MVA rating of each valve at 50 Hz	MVA	Specify	
2	Specific Valve Characteristics:			
2.1	Method of valve firing		Specify	
2.2	Redundancy: Number of redundant IEGT levels		Specify	
2.3	Type of voltage grading:			
2.3.1	DC	Ω		
2.3.2	AC	Ω/μF		
2.4	Maximum thyristor firing angle unbalance	degrees	Specify	
3	IEGT units (Supply standard data sheets on all IEGT types used containing values such as VSM, ITAVM, ITRMS, VTO, rT, etc.)			
4	General			
4.1	Manufacturer and country		Specify	
4.2	Type or model number		Specify	
5	Insulation level			
5.1	Valve section BIL	kV _{peak}	Specify	

5.2	Power frequency withstand	kV _{rms}	Specify	
5.3	Air clearance distance	mm	Specify	
6	Bushings (if required)			
6.1	Insulation level BIL	kV peak		
6.2	Total creepage distance	mm		
6.3	Manufacturer		Specify	
7	Mass			
7.1	Valve section	kg		
7.2	Total valve	kg		
8	Dimensions			
8.1	Valve section (length x depth x height)	mm		
8.2	Total valve (length x depth x height)	mm		
9	Maintenance and repair			
9.1	Time to replace complete valve	Hrs		
9.2	Time to replace / repair IEGT level	Hrs		

B.9: Valve Cooling System

Item	Description	Unit	Schedule A	Schedule B
1	Type of Cooling		Specify	
2	Heat Exchanger			
2.1	Number of Units		Specify	
2.2	Manufacturer and Contractor		Specify	
2.3	Design Duty			
2.3.1	Water Flow rate	l/s	Specify	
2.3.2	Inlet Temperature	°C	Specify	
2.3.3	Outlet Temperature	°C	Specify	
2.3.4	Power Dissipation	kW	Specify	
2.4	Material – type of stainless steel			
2.5	Redundant Capacity	%	Specify	
3	Pumps			
3.1	Number of Pumps		Specify	
3.2	Type			
3.2.1	Pumps			
3.2.2	Motors			
3.3	Manufacturer / Country			
3.3.1	Pumps			
3.3.2	Motors			
3.4	Speed of Pumps	rpm		
3.5	Rated Power	kW	Specify	
3.6	Material in Contact with water			
3.7	Mounting (Horizontal / Vertical)			
4	Fans			
4.1	Number of Units		Specify	
4.2	Manufacturer and Country			
4.2.1	Fan			

4.2.2	Motor			
4.3	Redundancy		Specify	
4.4	Rated Power	kW	Specify	
4.5	Variable Speed Drive Included	Yes/No		
5	Water Purification Plant			
5.1	Maximum Conductivity	µS/cm		
5.2	Maximum Conductivity (trip)	µS/cm		
5.3	Maximum Total Dissolved Solids	ppm		
5.4	pH			
5.5	Type of Resin			
5.6	Mass kg	kg		
5.7	Approximate intervals between recharging days		Specify	
5.8	Material in Contact with coolant			
6	Coolant			
6.1	Composition			
6.2	Coolant flow-rate at 40°C and maximum load	ℓ/m		
6.3	Minimum flow-rate (alarm)	ℓ/m		
6.4	Minimum flow-rate (trip)	ℓ/m		
6.5	Maximum valve inlet temperature (alarm)	°C		
6.6	Maximum valve inlet temperature (trip)	°C		
6.7	Volume of Coolant	ℓ		
7	Pipe work Material			
7.1	Type of stainless steel piping used			
7.2	Thyristor Valve Cooling Pipes			
7.2.1	Material			
7.2.2	Maximum Operating Temperature	°C		
7.2.3	Design Life years			
8	Material used for other components in contact with coolant			
9	Maintenance and Repair			

9.1	Maintenance Frequency months		Specify	
9.2	Time to Repair or Replace major Cooling System Components	Hrs	Specify	
10	Years of Experience with proposed cooling system equipment		Specify	

B.10: Control and Monitoring

Item	Description	Unit	Schedule A	Schedule B
1	Control System Fully digital	Yes/No	Specify	
2	Transmission system impedance range with stable STATCOM operation with parameter adjustment (on 100 MVA base)			
2.1	minimum	pu	Specify	
3	Voltage set point control			
3.1	Resolution	pu	Specify	
3.2	Range (+, -)	pu	Specify	
4	Input to regulator (measurant)			
5	Droop adjustment			
5.1	Range	%	Specify	
6	Maximum deviation from set voltage level under balanced conditions	%		
7	Range of MVar limits adjustable for voltage balancing	+/- MVar		
8	Adaptive control used	Yes/No		
8.1	Description			
9	Manufacturer of control system			
9.1	Country			
10	Control System Time Code Compliant with IRIG-B	Yes/No		
11	Closed and Open loop Control System spare capacity (estimate)	%		
12	Maximum ambient temperature for control system normal operation	°C		

B.11: Protection

Provide a separate schedule for each relay and instrument type in the protection system.

Item	Description	Unit	Schedule A	Schedule B
1	Manufacturer		Specify	
2	Protection scheme used (detailed description of relay type & setting, protection layout and logics)		Drawing Nos.	
3	Type designation		Specify	
4	Dual redundant		Comply	
5	Type of fibre optic cable		Specify	
6	DC drain under quiescent conditions:			
6.1	Main 1 scheme	A	Specify	
6.2	Main 2 scheme	A	Specify	
7	Standards:			
7.1	TST41-627	-	Comply	

B.12: Measuring Current Transformer

Item	Description	Unit	Schedule A	Schedule B
1	Application		Specify	
2	Number per phase per bank		Specify	
3	Ratio		Specify	
4	Rated voltage	kV		
5	Rated primary current	A		
6	Rated secondary current	A		
7	Insulation level	kV _{peak} / kV _{rms}		
8	Rated Frequency	Hz		
9	Rated Burden	VA		
10	Accuracy Class			
11	Accuracy limit factor			
12	Drawing number of			

	i) outline drawing	Dwg nos		
	ii) magnetizing curves			
13	Knee-point voltage	V		
	Magnetising current, I _{mag}	A		
14	Total creepage distance	mm		
15	Name of manufacture and country		Specify	

B.13: Measuring Voltage Transformer

Item	Description	Unit	Schedule A	Schedule B
1	Application		Specify	
2	Number per phase per bank		Specify	
3	Ratio		Specify	
4	Rated voltage	kV		
5	Rated primary voltage	kV		
6	Rated secondary voltage	kV		
7	Insulation level	kV _{peak} / kV _{rms}		
8	Rated Frequency	Hz		
9	Rated Burden	VA		
10	Accuracy Class		Specify	
11	Total creepage distance	mm		
12	Name of manufacture and country		Specify	

B.14: Isolators

Item	Description	Unit	Schedule A	Schedule B
1	Manufacturer			
2	Type			
3	Type of operating mechanism			
4	Insulation	kV		
5	Insulation level between terminals			
5.1	Impulse withstand	kV	230	
5.2	1 min wet power frequency withstand	kV	77	
5.3	Creepage distance	mm		
6	Insulation level to earth			
6.1	Impulse withstand (BIL)	kV	200	
6.2	1 min wet power frequency withstand	kV	70	
6.3	Creepage distance	mm	1116	
7	Rated continuous current	A_{rms}		
8	Type of operation:			
8.1	rated voltage	V_{dc}		
8.2	rated power	kW	Specify	
8.3	starting current	A	Specify	
9	Isolator drawings to be submitted		Yes	
9.1	Circuit diagrams for operating mechanism		Specify	
9.2	Circuit diagram for assembly		Specify	
10	Heating (230V, 50Hz) provided for the Isolator mechanisms	Yes/No		
11	Series Isolator Integral Earth Switches			
11.1	Number of Earth switches required (bank side) per isolator	kA	1 each	
11.2	Short time current rating	kA	Specify	
12	Bypass Isolator Integral Earth Switches			
12.1	Number of Earth switches required		2	
12.2	Short time current rating	kA	Specify	

12.3	Auxiliary switches: Number of contacts for isolator i) Type G ii) Type M iii) Type N		Specify Specify Specify	
12.4	Auxiliary switches: Number of contacts for earth switch Type M Type N		Specify Specify	

B.15: Power Transformer

Item	Description	Unit	Schedule A	Schedule B
	Winding Arrangement		Core: LV/HV	
1	Delivery and off-loading		GARONA SUBSTATION	
1.1	Transformer delivered to		TBA	
1.2	Delivery effected not before		Yes	
1.3	Off-loaded from transport vehicle by supplier	Yes/No	Yes	
1.4	Transformer transferred to intended operating position by supplier	Yes/No	Yes	
2	Erection and oil filling			
2.1	Erected ready for service		Yes	
2.2	Erection completed not later than		TBA	
2.3	Place 6 ply Malthoid mat under transformer on plinth		Yes	
3	Site details			
3.1	· Access to site		Road	
3.2	· Distance from off-loading position	m	15 M	
3.3	· Rise or fall to off-loading position	m	1,5M	

Item	Description	Unit	Schedule A	Schedule B
4	Operating environment			
4.1	Corrosion protection:	Yes/No	As per Eskom specification TSP41-220	
4.2	Pollution level: Medium/ Very Heavy		25mm/kV	
5	Type of unit required			
5.1	Number of units required		1	
5.2	Single/ 3-phase		3-phase unit	
5.3	Auto/ Double wound transformer		Double Wound	

6	Rated power			
6.1	· HV		65/	
6.2	· MV (with LV unloaded)	MVA	N/A	
6.3	· LV (with HV fully loaded)	MVA	65/	
7	Nominal system voltage "Un" (Um as per IEC)			
7.1	· HV	kV _{r.m.s}	275	
7.2	· MV	kV _{r.m.s}	N/A	
7.3	· LV	kV _{r.m.s}		
	"Um" Maximum system voltage should be as per IEC (1.05 x Un continuously)			
8	Vector group			
8.1	· Type YNd1/YNyn0/Yna0d1		YNyn0	
9	Tap-changers			
9.1	· Type OLTC/OCTS		N/A	
10	Bushing			
10.1	· Type RIP Outdoor/Cable boxes		RIP Outdoor	
10.1.1	· HV		xxxxxxxxxx	
10.1.2	· MV		N/A	
Item	Description		Schedule A	Schedule B
10.1.3	· LV		xxxxxxxxxx	
10.1.4	· HV Neutral		xxxxxxxxxx	
12	Maximum continuous ratings on any tapping with rated cooling OFAF/ONAF/ODAF		ONAF	
12.1	· HV	MVA	65/	
12.2	· MV (LV unloaded)	MVA	N/A	
12.3	· LV (with HV fully loaded)	MVA	65/	

13	Continuous ratings on any tapping with ONAN cooling			
13.1	· HV	MVA	45.5/	
13.2	· MV (LV unloaded)	MVA	N/A	
13.3	· LV (with HV fully loaded)	MVA	45.5/	
14	Maximum current density in windings			
14.1	· HV	A/mm ²	<4	
14.2	· MV	A/mm ²	N/A	
14.3	· LV	A/mm ²	<4	
15.1	Geomagnetic induced Currents: 10 amps on the neutral for 30 minutes			
15.2	Harmonics content from TCR		Yes	
15.2.1	3rd Harmonic content		2%	
15.2.2	5th harmonic content		5%	
15.2.3	7th harmonic content		5%	
16	Short-circuit current that the transformer is designed to withstand, in per unit of r.m.s. rated current			
16.1	· HV	p.u.	Infinite busbar	
16.2	· MV	p.u.	N/A	
16.3	· LV	p.u.	Infinite busbar	
Item	Description		Schedule A	Schedule B
17	No-load loss on principal tapping (Note - No plus tolerance allowed)			
17.1	at 1,00 Un	kW	XXXXXXXXXX	
17.2	at 1,10 Un	kW	XXXXXXXXXX	
18	Core design			
18.1	Manufacturer of core steel		XXXXXXXXXX	
18.2	Grade and thickness of core steel		XXXXXXXXXX	

	grade/mm			
18.3	Number and length(height) of limbs no/mm		XXXXXXXXXX	
18.4	Core diameter	mm	XXXXXXXXXX	
19	Cross sectional area of:			
19.1.1	Wound limbs	mm ²	XXXXXXXXXX	
19.1.2	Yoke	mm ²	XXXXXXXXXX	
19.1.3	Unwound limbs	mm ²	XXXXXXXXXX	
19.2	Distance between core limb centres	mm	XXXXXXXXXX	
19.3	Total core mass	kg	XXXXXXXXXX	
19.4	The design flux density at Un for:			
19.4.1	Yoke	T	1,7	
19.4.2	Wound limbs	T	1,7	
19.4.3	Unwound limbs	T	1,7	
19.5	Volts per turn at the above flux densities		XXXXXXXXXX	
19.6	Magnetizing current, at rated frequency, on principal tapping, in percent of rated current at maximum HV rating			
19.6.1	· at 0,90 Un	%	XXXXXXXXXX	
19.6.2	· at 1,00 Un	%	XXXXXXXXXX	
19.6.3	· at 1,10 Un	%	XXXXXXXXXX	

Item	Description	Unit	Schedule A	Schedule B
19.7	Load loss (I²R + stray) at 75 °C and at maximum HV rating with MV fully loaded but LV unloaded.			
	(Note - No plus tolerance allowed)			
19.7.1	· On principal tapping	kW	XXXXXXXXXX	

19.7.2	· On extreme plus tapping	kW	XXXXXXXXXX	
19.7.3	· On extreme minus tapping	kW	XXXXXXXXXX	
20	Input to coolers for maximum rated output in service		Three phase induction motors - standard frame design - impellers to comply to TSP41-588	
20.1	Fans		XXXXXXXXXX	
20.1.1	· Power	kW	XXXXXXXXXX	
20.1.2	· Current	A	XXXXXXXXXX	
20.2	Oil pumps			
20.2.1	· Power	kW	XXXXXXXXXX	
20.2.2	· Current	A	XXXXXXXXXX	
21	IEC impedance at 75 °C and rated frequency based on maximum rated power of HV winding		IEC	
21.1	HV/MV			
21.1.1	· On principal tapping Normal	%	N/A	
21.1.2	· On extreme plus tapping	%	N/A	
21.1.3	· On extreme minus tapping	%	N/A	
21.2	HV/LV			
21.2.1	· On principal tapping	%	15%	
21.2.2	· On extreme plus tapping	%	N/A	
21.2.3	· On extreme minus tapping	%	N/A	

Item	Description		Schedule A	Schedule B
21.3	MV/LV			
21.3.1	· On principal tapping	%	N/A	
21.3.2	· On extreme plus tapping	%	N/A	

21.3.3	· On extreme minus tapping	%	N/A	
21.4	Tolerances applicable to guaranteed impedances			
21.4.1	HV/MV		xxxxxxxxxx	
21.4.1.1	· On principal tapping	%	N/A	
21.4.2.2	· On extreme plus tapping	%	N/A	
21.4.3.3	· On extreme minus tapping	%	N/A	
21.4.2	HV/LV			
21.4.2.1	· On principal tapping	%	+/- 7.5%	
21.4.2.2	· On extreme plus tapping	%	+/- 7.5%	
21.4.2.3	· On extreme minus tapping	%	+/- 7.5%	
21.5	Zero sequence impedances in percent of Un²/M		As per IEC	
21.5.1	HV/LV			
21.5.1.1	· On principal tapping	%	xxxxxxxxxx	
21.5.1.2	· On extreme plus tapping	%	xxxxxxxxxx	
21.5.1.3	· On extreme minus tapping	%	xxxxxxxxxx	

Item	Description	Unit	Schedule A	Schedule B
21.5.2	HV/ Neutral			
21.5.2.1	· On principal tapping	%	xxxxxxxxxx	
21.5.2.2	· On extreme plus tapping	%	xxxxxxxxxx	
21.5.2.3	· On extreme minus tapping	%	xxxxxxxxxx	
21.5.3	LV/ Neutral			

21.5.3.1	· On principal tapping	%	XXXXXXXXXX	
21.5.3.2	· On extreme plus tapping	%	XXXXXXXXXX	
21.5.3.3	· On extreme minus tapping	%	XXXXXXXXXX	
22	Temperature rises at altitude of 1 800 m			
22.1	· Top oil		50	
22.2	· Windings (by resistance)		55	
22.3	· Hotspot		68	
22.4	· Percentage of total losses that will be supplied		100%	
22.5	Maximum temperature rise for metal surface in contact with oil under any conditions		75K	
23	Maximum noise level at no-load with cooling equipment for full load operation in service / dBA / 80		< 80	
24	Winding design			
24.1	Indicate per coil the following:			
24.1.1	· Type (i.e. multilayer helix)		XXXXXXXXXX	
24.1.2	· Number of turns		XXXXXXXXXX	
24.1.3	· Conductor size, number and configuration		XXXXXXXXXX	

Item	Description	Unit	Schedule A	Schedule B
24.1.4	· Number and width of support spacers per turn		XXXXXXXXXX	
24.1.5	· Total conductor mass	kg	XXXXXXXXXX	
24.1.6	· Dry insulation mass	kg	XXXXXXXXXX	
25	Minimum insulation for windings			

	(Provide detailed test plan for evaluation)			
25.1	Impulse withstand test voltage for:		As per IEC	
25.1.1	· HV	kV _{peak}	As per IEC	
25.1.2	· MV	kV _{peak}	As per IEC	
25.1.3	· LV	kV _{peak}	As per IEC	
25.1.4	· Neutral	kV _{peak}	As per IEC	
25.2	Sixty-second, separate source			
25.2.1	· HV	kV _{r.m.s}	As per IEC	
25.2.2	· MV	kV _{r.m.s}	As per IEC	
25.2.3	· LV	kV _{r.m.s}	As per IEC	
25.2.4	· Neutral	kV _{r.m.s}	As per IEC	
25.3	Induced-overvoltage withstand test voltages			
25.3.1	· HV to earth	kV _{r.m.s}	As per IEC	
25.3.2	· MV to earth	kV _{r.m.s}	As per IEC	
25.4	Between line terminals			
	· HV	kV _{r.m.s}		
25.4.1			As per IEC	
25.4.2	· MV	kV _{r.m.s}	As per IEC	
25.4.3	Test frequency	Hz	As per IEC	
25.4.4	Test duration	s	As per IEC	

Item	Description	Unit	Schedule A	Schedule B
26	Main terminal bushings (BIL to be 10% above transformer windings BIL level), RIP		RIP Bushings	

26.0.1	· HV		xxxxxxxxxx	
26.0.2	· MV		N/A	
26.0.3	· LV		xxxxxxxxxx	
26.0.4	· HV Neutral		xxxxxxxxxx	
26.1	Impulse withstand test voltage at sea level (1,2/50 ms)			
26.1.1	· HV	kV _{peak}	1050	
26.1.2	· MV	kV _{peak}	N/A	
26.1.3	· LV	kV _{peak}	TBA	
26.1.4	· HV/MV Neutral	kV _{peak}	TBA	
26.2	Sixty-second, power-frequency withstand test voltage to earth			
26.2.1	· HV	kV _{r.m.s}	As per IEC	
26.2.2	· MV	kV _{r.m.s}	As per IEC	
26.2.3	· LV	kV _{r.m.s}	As per IEC	
26.2.4	· HV/MV Neutral	kV _{r.m.s}	As per IEC	
26.3	Total creepage distance		25mm/kV	
26.3.1	· HV	mm	As per IEC	
26.3.2	· MV	mm	As per IEC	
26.3.3	· LV	mm	As per IEC	
26.3.4	· HV/MV Neutral	mm	As per IEC	

Item	Description	Unit	Schedule A	Schedule B
26.4	Protected creepage distance			
26.4.1	· HV	mm	As per IEC	

26.4.2	· MV	mm	As per IEC	
26.4.3	· LV	mm	As per IEC	
26.4.4	· HV/MV Neutral	mm	As per IEC	
26.5	Type, ratings and dimensions (attach data sheets)		Yes	
26.5.1	Service bushings stem dimensions			
26.5.1.1	· HV (38 mm diameter x 125 mm)		38 mm Dia , 125 mm long	
26.5.1.2	· MV (38 mm diameter x 125 mm)		N/A	
26.5.1.4	· LV (38 mm diameter x 125 mm)		38 mm Dia, 125 mm long	
	·Neutral (38 mm diameter x 125 mm)		38 mm Dia, 125 mm long	
26.5.2	Test bushings		N/A	
26.5.3	Give particulars of special turrets etc. that will be used		XXXXXXXXXX	
26.5.4	Special test items be supplied as part of the contract			
	Special test agreed to:			
26.5.4.1	Accoustic noise as part of contract		Yes	
26.5.4.2	1 hour over excitation test 1.10p.u as part of the contract		Yes	
27	Transformer general information			
27.1	· Manufacturer		XXXXXXXXXX	
27.2	· Place of manufacture		XXXXXXXXXX	
27.3	· Type of transformer		Core	
Item	Description		Schedule A	Schedule B
27.4	· Number of limbs		XXXXXXXXXX	
27.5	· Type of cooling		XXXXXXXXXX	

28	Oil quantities:			
28.1	· Transformer tank		XXXXXXXXXX	
28.2	· Radiators		XXXXXXXXXX	
28.3	· Conservator tank		XXXXXXXXXX	
28.4	· Tap-changer		XXXXXXXXXX	
28.5	· Total		XXXXXXXXXX	
29	Masses:			
29.1	· Mass of core and windings	kg	XXXXXXXXXX	
29.2	· Mass of core steel	kg	XXXXXXXXXX	
29.3	· Mass of winding copper (insulation excluded)	kg	XXXXXXXXXX	
29.4	· Mass of tank and fittings	kg	XXXXXXXXXX	
29.5	· Mass of coolers incl. Pipes and supports	kg	XXXXXXXXXX	
29.6	· Mass of oil	kg	XXXXXXXXXX	
29.7	· Total mass	kg	XXXXXXXXXX	
29.8	· Greatest transportation mass	kg	XXXXXXXXXX	
30	Filling medium for transport		Dry Air	
31	Overall dimensions of tank only :			
31.1	· Length	mm	XXXXXXXXXX	
31.2	· Base plate thickness		XXXXXXXXXX	
32	Transport dimensions:			
32.1	Length	mm	XXXXXXXXXX	
32.2	Width	mm	XXXXXXXXXX	
32.3	Height	mm		
Item	Description		Schedule A	Schedule B
32	Height over HV bushings		XXXXXXXXXX	
33	Tank and cooler material thickness:		XXXXXXXXXX	

33.1	.Tank - sides/ top/ bottom		mm	
33.2	. cooler tubes		mm	
33.3	. pressed-sheet radiators		mm	
33.4	. Hot dipped galvanised - no paint		> 70 microns average	
34	Safe withstand vacuum at sea level	kpa	full vacuum	
35	Motors (Forced cooling)		Three phase induction motors standard frame design impellers to comply to TSP41-588	
35.1	. Make fans		XXXXXXXXXX	
35.2	.Type fans		XXXXXXXXXX	
35.3	.Make pumps		XXXXXXXXXX	
35.4	.Type pumps		XXXXXXXXXX	
36	On-load tap-changers			
36.1	Type and design:			
36.1.1	. Manufacturer and type designation		N/A	
36.1.2	. Precise electrical location of tappings		N/A	
36.2	Tapping range of HV/MV ratio % of the ratio on the principal tapping:			
36.2.1	.Max	%	N/A	
36.2.2	.Min	%	N/A	
36.2.3	Number of steps	No	N/A	
36.2.4	Size of steps	%	N/A	
36.2.5	Reversing/ Linear Switch		N/A	
36.2.5	Number of positions (including transition positions)		N/A	
Item	Description		Schedule A	Schedule B
36.3	Nominal 50 Hz ratings of tap-changer:		N/A	

36.3.1	· Voltage	kV	N/A	
36.3.2	· Current	A	N/A	
	Temporary over voltages		N/A	
			N/A	
36.4	Insulation levels of tap-changer:			
36.4.1	· Lightning impulse level (1,2/50 ms full wave)		N/A	
36.4.2	· phase-to-ground	kV _{peak}	N/A	
36.4.3	· phase-to-phase	kV _{peak}	N/A	
36.5	Tap-changer 50 Hz withstand:			
36.5.1	· phase-to-ground	kV _{r.m.s}	N/A	
36.5.2	· phase-to-phase	kV _{r.m.s}	N/A	
36.5.3	· Nominal voltage and current rating of tap-changer		N/A	
36.6	Tap-changer contacts:			
36.6.1	· Selector	kV/A	N/A	
36.6.2	· Selector switch	kV/A	N/A	
36.6.3	· Diverter switch	kV/A	N/A	
36.7	Tap-changer transition resistor	kV/A	N/A	
36.8	Tap-changer driving motor:			
36.8.1	· Type of driving motor 3 Phase		N/A	
36.8.2	· Power	kW	N/A	
36.8.3	· Current	A	N/A	
	· Motor Voltage	VAC	N/A	
	· Control voltage	VDC	N/A	

Item	Description		Schedule A	Schedule B
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37	Resulting no-load voltage appearing:		
37.8.1	· On principal tapping	kV	275
37.8.2	· On extreme plus tapping	kV	N/A
37.8.3	· On extreme minus tapping	kV	N/A
38	Supply of contract drawings		Yes
	Type test certificates shall be submitted with the tender for approval, otherwise it will be assumed that no type tests for identical units are available		yes
39			
40	Indicating and protective devices:		
40.1	Winding temperature thermometer(s)		As per Eskom specification TSP 41-620
40.2	Oil temperature thermometer		As per Eskom specification TSP 41-620
40.3	Rapid pressure relay - Quantity of 1 required		As per Eskom specification TSP41-898
40.4	Oil- and gas-actuated relay		As per Eskom specification TSP 41-60
40.5	Pressure relief device (Messko or Qualitrol)		As per Eskom specification TSP 41-900
40.6	Tap-changer protective device (detail)		RS2001
40.7	Dehydrating breathers		As per Eskom specification TSP 41-623
40.8	Conservator bag (Pronal, Treborg, Musthane)		Yes
40.9	Oil level indicators		As per specification TSP41- 899
40.1	Gas monitor relay and conservator bags		As per specification TSP41- 903

Item	Description	Schedule A	Schedule B
	<p>Oil Specification</p>	<p>As per ESP32-406. OEM to approve oil specified and take ownership and responsibility for oil during the guarantee period</p>	
<p>41</p>			
<p>42</p>	<p>Special Requirements:</p>		
<p>42.1</p>	<p>Testing: Heat run test as per IEC to be performed and not repeated again on same design. – overload testing at 130% for 1 hour to be performed during heat run. – Acceptance criteria will be as per IEC loading guide 60076-7 – long term emergency loading.</p>	<p>yes</p>	
<p>42.2</p>	<p>Dielectric test to be performed as per IEC. Induced over voltage test refers to IEC long duration test.</p>	<p>yes</p>	
<p>42.3</p>	<p>In accordance with IEC – latest version as per contract date, routine test specification – manufacturers routine test certificate will be provided for all results for individually supplied units, type test certificates will be accepted for all type tests</p>	<p>yes</p>	
<p>42.4</p>	<p>SFRA test to be done at factory and again on site when unit is full of oil.</p>	<p>yes</p>	
<p>42.5</p>	<p>Water based paint information to be submitted to Eskom for approval as per specification TSP 41-220</p>	<p>yes</p>	
<p>42.6</p>	<p>HV bushing test tap to face inwards and oil level gauge to face outwards</p>	<p>yes</p>	
<p>42.7</p>	<p>Bucholzs Relays to be fitted with 10-mm copper sample pipe only from the top of the Bucholzs with needle and seat valve only. No gas sampling device.</p>	<p>yes</p>	
<p>42.8</p>	<p>Core and clamps to be earthed separately by external bushings and labelled accordingly.</p>	<p>yes</p>	
<p>42.9</p>	<p>For storage / transportation conditions,</p>	<p>yes</p>	

	test bushings to be installed.		
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Item	Description	Unit	Schedule A	Schedule B
42.10.	Units must be painted as per specification TSP41-220.		yes	
42.11	Fiber optic sensors to be fitted on every transformer		yes	
42.12	Copper Conductors to be enamelled		yes	
42.13	Short circuit test results of similar unit or design calculations		yes	
42.14	Factory Test			
42.14.1	Main test required as per IEC:			
42.14.1.1	Temperature rise test		Type	
42.14.1.2	Short time heat run test		Yes, on subsequent units	
42.14.1.3	Short circuit test		Special	
42.14.1.4	Lightning impulse test		Routine	
42.14.1.5	Switching Impulse test		Routine	
42.14.1.6	Induced over voltage test		Routine	
42.14.1.7	Chopped impulse test		Routine	
42.14.1.8	Accoustic noise level measurement		Type	
42.14.1.9	Overload test		Type	
42.14.1.10	Dielectric loss angle test and capacitance (Doble instrument)		Routine	
42.14.1.11	Vibration test		Type	
42.14.1.12	SFRA (Doble instrument)		Routine	
42.14.2	Special tests:			
	1 hour over excitation test 1.10 p.u		Routine	

Item	Description	Schedule A	Schedule B
42.14.3	Any other test		
42.15	Agreements on clarifications and deviations:		
1	Tertiary winding to be suitably rated to withstand short circuits but may only be loaded to 2MVA. Details to be provided on nameplate.	N/A	
2	Bushings to be fitted with shock indicators for transport purposes	yes	
3	Unit will only be prepared for Sergi Protection system	yes	
4	Valves and mounting brackets to be installed for Drykeep and Drykeep to be fitted on site before commissioning.	yes	
5	On-line gas analyser, Transformer to be prepared ONLY, for the fitment of the Kelman Transfix type unit.	yes	
6	Magnetisation of the curve of core	yes supply curve	

Eskom Transmission Design Information: Annexure to A&B Schedules

Technical information required for tender evaluation:

A	Core design:	
A.1	Core sheet material	
A.2	Method of joints	
A.3	Number of limbs / wound limbs	

A.4	Core diameter	mm
A.5	Window height	mm
A.6	Centre leg distance main limb – main limb	mm
A.7	Centre leg distance main limb – return limb	mm
A.8	Cross section of wound limbs	m ²
A.9	Cross section of yoke between wound limbs	m ²
A.10	Cross section of unwound limbs	m ²
B	Total core mass:	kg
B.1	Flux density in wound limbs	Tesla
B.2	Flux density in yoke between wound limbs	Tesla
B.3	Flux density in unwound limbs	Tesla
B4	Volt per turn at the above wound limb flux density	V

C	Winding design:	
C.1	Provide a cross-sectional diagram of the windings showing relative position to the core	
C.2	Provide from each winding the following information: Wound limb	
C.2.1	<u>Exciting Winding</u> (next to the core)	
C.2.1.1	Type of winding (layer, helical, disk, interleaved	

	disk, inter-shielded disk)	
C.2.1.2	Number of turns	
C.2.1.3	Inner diameter	mm
C.2.1.4	Outer diameter	mm
C.2.1.5	Radial build	mm
C.2.1.6	Electrical height	mm
C.2.1.7	Magnetic height	mm
C.2.1.8	Conductor size, number and configuration	mm
C.2.1.9	Conductor insulation	mm
C.2.1.10	Current density	A/mm ²
C.2.1.11	Gradient winding - oil	°C
C.2.1.12	Total copper mass	kg
C.2.1	<u>PW Winding</u>	N/A
C.2.1.1	Type of winding (layer, helical, disk, interleaved disk, inter-shielded disk)	
C.2.1.2	Number of turns	
C.2.1.3	Inner diameter	mm
C.2.1.4	Outer diameter	mm
C.2.1.5	Radial build	mm
C.2.1.6	Electrical height	mm
C.2.1.7	Magnetic height	mm
C.2.1.8	Conductor size, number and configuration	mm
C.2.1.9	Conductor insulation	mm
C.2.1.10	Current density	A/mm ²
C.2.1.11	Gradient winding - oil	°C
C.2.1.12	Total copper mass	kg

C.2.1	<u>SW Winding</u>	
C.2.1.1	Type of winding (layer, helical, disk, interleaved disk, inter-shielded disk)	
C.2.1.2	Number of turns	
C.2.1.3	Inner diameter	mm
C.2.1.4	Outer diameter	mm
C.2.1.5	Radial build	mm
C.2.1.6	Electrical height	mm
C.2.1.7	Magnetic height	mm
C.2.1.8	Conductor size, number and configuration	mm
C.2.1.9	Conductor insulation	mm
C.2.1.10	Current density	A/mm ²
C.2.1.11	Gradient winding - oil	°C
C.2.1.12	Total copper mass	kg

C.2.1	<u>Regulating Winding</u>	N/A
C.2.1.1	Type of winding (layer, helical, disk, interleaved disk, inter-shielded disk)	
C.2.1.2	Number of turns	
C.2.1.3	Inner diameter	mm
C.2.1.4	Outer diameter	mm

C.2.1.5	Radial build	mm
C.2.1.6	Electrical height	mm
C.2.1.7	Magnetic height	mm
C.2.1.8	Conductor size, number and configuration	mm
C.2.1.9	Conductor insulation	mm
C.2.1.10	Current density	A/mm ²
C.2.1.11	Gradient winding - oil	°C
C.2.1.12	Total copper mass	kg
C.2.1	<u>LV Winding</u>	
C.2.1.1	Type of winding (layer, helical, disk, interleaved disk, inter-shielded disk)	
C.2.1.2	Number of turns	
C.2.1.3	Inner diameter	mm
C.2.1.4	Outer diameter	mm
C.2.1.5	Radial build	mm
C.2.1.6	Electrical height	mm
C.2.1.7	Magnetic height	mm
C.2.1.8	Conductor size, number and configuration	mm
C.2.1.9	Conductor insulation	mm
C.2.1.10	Current density	A/mm ²
C.2.1.11	Gradient winding - oil	°C
C.2.1.12	Total copper mass	kg
C.3.1	<u>Current limiting reactor</u>	
C.3.1.1	Type of winding (layer, helical, disk, interleaved disk, inter-shielded disk)	
C.3.1.2	Number of turns	
C.3.1.3	Inner diameter	mm

C.3.1.4	Outer diameter	mm
C.3.1.5	Radial build	mm
C.3.1.6	Electrical height	mm
C.3.1.7	Magnetic height	mm
C.3.1.8	Conductor size, number and configuration	mm
C.3.1.9	Conductor insulation	mm
C.3.1.10	Current density	A/mm ²
C.3.1.11	Gradient winding - oil	°C
C.3.1.12	Total copper mass	kg
C.4.1	Winding arrangement	

ANNEXURE G: SCHEDULE A/B2 ADDITIONAL ITEMS

Item	Description	Units	Schedule A	Schedule B
1	Has the list of special tools that will be supplied with the STATCOM been included in this tender?		Yes	
2	Has a recommended spares list (including recommendations, maintenance requirements etc) been provided?		Yes	
3	Are the drawings compatible with MicroStation version 8?		Comply	
4	Does the Control scheme provide emergency switching or Dual redundant HMIs?		Specify	
5	Are adequate details on Environmental protection provided?		Yes	
6	Metric nuts and bolts used in design		Comply	
7	Has adequate technical detail been provided with respect to insulation co-ordination, earthmat and all other studies and specifications		Yes	

ANNEXURE I: SCHEDULE B3 STATEMENT OF COMPLIANCE

The Table below lists the clauses in the specification. The Tenderer shall indicate whether his tender complies with the requirements in each clause, or not. If the tender does not comply, full details shall be given. If the clause contains information rather than requirements, the tenderer shall indicate that he has noted the contents. This table shall be reproduced for other sections.

Section	Subsection	Clause	Comply/Not comply/Noted	Explanation
2				
4	4.1			
	4.2			
	4.3			
	4.4			
	4.5			
	4.6			
	4.7	4.7.1		
		4.7.2		
		4.7.3		
		4.7.2		
		4.7.3		
		4.7.4		
		4.7.5		
5	5.1	5.1.1		
		5.1.2		
		5.1.3		
	5.2			

