

	Standard	Technology
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Title: **TECHNICAL SPECIFICATION
FOR MAKHATHINI SUBSTATION
2 X 3MVAR, 22KV SHUNT
CAPACITORS & C-TYPE FILTER**

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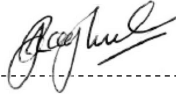

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1. Introduction

Eskom Distribution (*the Employer*) Central East Cluster in Kwa-Zulu Natal has severe voltage constraints on certain sections of the high voltage network being supplied from Normandie 400/132/88kV Transmission Substation. The voltages experienced on the 132kV busbars at Candover, Makhathini, Nondabuya, Ndumo and Mkuze substations are below NRS-048 acceptable limits. It is therefore required that two (2) 3MVAR 22kV shunt capacitor banks with C-Type 3rd Harmonic Filters be installed for VAR compensation on the 22kV Busbar at Makhathini 132/22kV Substation, which will assist with reactive power injection thus improving the HV Busbar voltages on the system.

The requirement is the complete switching studies, design, manufacture, fabrication, delivery, installation and commissioning of two (2) 3MVAR 22kV shunt capacitor banks with C-Type 3rd Harmonic Filters. This specification describes the required features of the capacitor banks and also defines the interconnection requirements to the Eskom System. The plant and material shall be supplied complete with damping / filter reactors, main and coupling capacitors, surge capacitors, damping resistors and resistor current transformers, unbalance and restricted earth fault current transformers, racks, earthing points, auxiliary equipment, supporting platforms and porcelain insulators. The Contractor shall be responsible for all specified plant and providing all materials, studies done to choose equipment, settings, design, installation, training, documentation, RAM requirements and commissioning of the functional 22kV shunt capacitor installations (*The Project*).

All capacitors, resistors and reactors offered must be supported with the reference list describing the supplier's performance over the past five years. The Type Testing of each Capacitor Unit, Damping Resistor and Filter Reactor type and rating offered will be required as part of the main offer. The cost of type testing of each type and rating of equipment shall be an integral part of the contract and not listed as an additional cost to Eskom. *Should the cost of the type testing not be financially justifiable (based on the total cost of the project), type test certificates of similar equipment that are less than 5 years old and within the same ratings as specified may be accepted.*

The Employer's requirements are for the shunt capacitor banks to be equipped with internally fused or fuseless capacitor units. Simplicity in design, performance and maintenance ease is the driving factors for this requirement.

This specification is to be sent out together with the reactors, CT, surge arrestor and post insulator specifications [2][5][8][10].

2. Supporting clauses

2.1 Scope

This specification outlines Eskom Distribution Central East Cluster (Kwa-Zulu Natal) technical requirements for two shunt capacitor banks to be installed at Makhathini Substation on the 22kV system voltage, with reactors, capacitors, CTs, surge arrestors and post insulators covered separately by each equipment's specification [2][5][8][10].

2.1.1 Purpose

This specification is compiled to list the requirement for the capacitor bank medium voltage equipment required for the installation of two shunt banks at Makhathini Substation on the 22kV system voltage.

2.1.2 Applicability

This specification shall apply to Eskom Distribution Central East Cluster (Kwa-Zulu Natal).

2.2 Normative/informative references

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

2.2.1 Normative

- [1] ER00024-00-P05#A1.8-00 Technical Evaluation Standard for Shunt/Filter Capacitor (Makhathini)
- [2] 240-76429758: Specification For Capacitor Units
- [3] 240-42587021: Specification for air core reactors
- [4] 240-89963721: Technical Evaluation Standard for Air Core Reactors
- [5] 240-56062864 Current Transformers Eskom Specific Requirements for Voltages up to 132kV in Accordance with NRS 029
- [6] IEC 61869-2: Instrument transformers - Part 2: Additional requirements for current transformers
- [7] PDRP_2013-287 Technical Evaluation Criteria For Post Type Instrument Transformers
- [8] 240-75540566 CORP3076 Station Class Surge Arrester Specification
- [9] 240-79570028 CORP3076 Station Class Surge Arrester Technical Evaluation Criteria
- [10] 240-56030435: Outdoor Ceramic Station Post Insulators for Systems with Nominal Voltages up to 765kV Specification
- [11] 240-79707491: Technical Evaluation Standard for Outdoor Ceramic Station Post Insulators for Systems with Nominal Voltages up to 765kV
- [12] 240-56063756: Outdoor Circuit Breakers for System with Nominal Voltages From 6.6KV up to and including 765KV Standard
- [13] 34-1439: Standard For The Labelling of Substations And Networks
- [14] 240-120804300: Standard For The Labelling Of Electrical Equipment Within Eskom Wires Networks
- [15] 240-75660336: Substation And Network Equipment Label Specification
- [16] 240-55922824: Substation Layout Design Guideline
- [17] 240-53113927: Specification for Substation Clamps for Stranded Aluminium Conductors
- [18] 240-76624507: Standard For Neutral Earthing Of Transmission And Distribution Networks
- [19] NRS 029: Current Transformers
- [20] ISO 9001: Quality Management Systems Occupational Health and Safety Act, Act no. 85 of 1993 of the Republic of South Africa or the latest updated and approved sections
- [21] Regulations under the Environmental Conservation Act, 1989 (Act no. 73 of 1989) of the Republic of South Africa
- [22] IEC 60871-1: Shunt capacitors for a.c. power systems having a rated voltage above 1000 V, Part 1: General performance, testing and rating - safety requirements - Guide for installation and operation.
- [23] IEC 60871-2: Shunt capacitors for a.c. power systems having a rated voltage above 1000 V, Part 2: Endurance testing, (including Amendment 1 of 1991).
- [24] IEC 60871-3: Shunt capacitors for a.c. power systems having a rated voltage above 1000V, Part 3: Protection of shunt capacitors and shunt capacitor banks.
- [25] IEC 60060-1: High voltage test techniques, Part 1 General definitions and test requirements.
- [26] IEC 60060-2: High voltage test techniques, Part 2 Measuring systems (including Amendment 1 of 1996).
- [27] IEC 60071-1: Insulation co-ordination, Part 1 Definitions, principles and rules.
- [28] IEC 60071-2: Insulation co-ordination, Part 2 Application guide.
- [29] IEC 60137: Insulating bushings for alternating voltages above 1000V.
- [30] IEC 60160, Standard atmospheric conditions for test purposes

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- [31] IEC 60168: Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 000 V.
 - [32] IEC 61869-1: General requirements for instrument transformers
 - [33] IEC 60518: Dimensional standardisation of terminals for high-voltage switchgear and control gear.
 - [34] SANS 60815: Guide for the selection of insulators in respect of polluted conditions.
 - [35] IEEE Std 693: Recommended Practices for Seismic Design of Substation.
 - [36] BS 1615: Method for specifying anodic oxidation coatings on aluminium and its alloys.
 - [37] BS 1872: Specification for electroplated coatings of tin.
 - [38] BS 449-2: Specification for the use of structural steel in building – Part 2 Metric units.
 - [39] SANS 121 Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods (supersede SABS 763)
 - [40] SANS 1019: Standard voltages, currents and insulation levels for electricity supply.
 - [41] SANS 10162: The structural use of steel (supersede SABS 0162).
 - [42] SANS 1574: PVC insulated electrical cables and flexible cords (supersede SABS 150).
 - [43] SANS 1200: Standardized specification for civil engineering construction.
 - [44] SANS 1091: National colour standard

2.2.2 Informative

- [45] 32-9: Definition of Eskom documents.
- [46] 32-644: Eskom documentation management standard.
- [47] 474-65: Operating Manual of the Steering Committee of Technologies (SCOT)
- [48] NST 39-60: Rev 1, Contract Quality Requirements
- [49] 240-56030674: Corrosion Protection and Maintenance of New and In-Service Transformers and Reactors Standard
- [50] 240-120804300: Standard For The Labelling Of Electrical Equipment Within Eskom Wires Networks
- [51] 240-57649119: Approval of drawings submitted by contractors and consultants.
- [52] E 32/846: Rev 3, Operating regulations for high voltage systems.
- [53] DDT-5240: Earthing Standard
- [54] ESP 32-406, Management, Procurement and Maintenance of Mineral Insulating Oil
- [55] TPL 327-727 Safety Health Environment & Quality Policy (SHEQ)
- [56] TST 41-120 Environmental requirements for procurement of asset, goods and services
- [57] NEMA CP-1: Shunt capacitors

2.2.3 Statutory Regulations and Other Regulations

- [58] Occupational Health and Safety Act, Act no. 85 of 1993 of the Republic of South Africa or the latest updated and approved sections.
- [59] Regulations under the Environmental Conservation Act, 1989 (Act no. 73 of 1989) of the Republic of South Africa

2.3 Definitions

2.3.1 General

Definition	Description
Back-to-Back Capacitor Bank Switching	Switching a capacitor bank with and in close electrical proximity to one or more other capacitor banks.
Capacitor Unit	Collection of capacitor elements connected in parallel and series arrangements fitted inside a metal enclosure and vacuum sealed with an insulation fluid. Internal connections made to a bushing situated on the outside of the unit enclosure.
Contractor	The successful bidder being appointed to deliver scope of work as specified
Employer	These refer to Eskom and it is interchangeably used to refer to the customer
Filter Bank:	A filter bank is a combination of a high voltage shunt capacitor bank and a reactor (usually connected in series) chosen such that they form a resonant circuit for a specific frequency that needs to be filtered out of the power system grid. The resonant circuit is usually tuned for a specific frequency (harmonic) and forms a low impedance path for this harmonic energy to flow to earth.
Fuseless Unit	A capacitor unit with capacitor elements with no internal or external fuses
Project Manager	The Employer appointed person to manage the project i.t.o scheduling, resources and quality.
Service Life	This refers to the expected lifetime of the bank operating incident free
Shunt Capacitor Bank	A device with a combination of capacitor units connected in parallel and series connections that are connected between live potential and ground to provide reactive support.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
μF	Micro Farads [10^{-6}]
Cn	Rated nominal capacitance
CT	Current Transformer
HCT	High Voltage H type current transformer
kV	Kilovolts
MVAR	Mega Volt Ampere Reactive
ORHVS	Operating Regulations for High Voltage Systems
PCB	Polychlorinated biphenyls
Pi	Number of internal parallel connected elements inside a capacitor unit
REF	Restricted earth fault

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Abbreviation	Description
Si	Number of internal series connected elements inside a capacitor unit
TX	Transmission
UM	System maximum continuous operating voltage (line-to-line)
VT	Voltage Transformer

2.5 Roles and responsibilities

Not applicable.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

Not applicable.

3. General Requirements

- The shunt/filter capacitor installation shall be designed and manufactured to provide reliable operation for a period of not less than 25 years with minimum maintenance under service conditions as specified in the AB schedules and RAM requirements.
- The shunt/filter capacitor equipment shall be manufactured under strict quality control using the highest quality of material and workmanship.
- Vermin proofing: All plant and material shall be designed and constructed to prevent inadvertent contact by snakes, rodents, cats, birds and other wildlife with energized plant or material or areas where damage may be inflicted to the plant. Anti-bird nesting devices shall be used. How this is delivered must be clearly described in the Contractors tender submission.
- Fire retardant material shall be used in the shunt/filter capacitor installation.
- All plant and material shall be free of any Polychlorinated Biphenyls (PCB).
- Shunt/Filter capacitor components shall be interchangeable between the banks where more than one bank is installed.
- All units shall be SI-units (metric). The Contractor shall be consistent in the units used throughout the contract.

4. Scope of Works supplied by the Employer and the Contractor

4.1 Contractor Scope of Work

4.1.1 General

- All civil works including cable trenches, concrete foundations, holding down bolts and any civil work to suit the bank and auxiliary equipment, according to the Contractor's requirements;
- Design of the earthmat for the shunt/filter capacitor as well as the overhead lightning protection and supporting structures;
- Isolators (disconnectors), and earth switches

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- d) Main circuit-breaker with point on wave functionality and relay, drawn from the Eskom National Contract. The *Contractor* shall supply the main circuit breaker that is capable of capacitor switching. The circuit breaker shall be class C2 and capable of switching single capacitor bank as well as back to back capacitor banks. The circuit breaker shall be drawn from the Eskom National Contract [12].
- e) Bay current transformers
- f) Overhead conductors, droppers, clamps for external high voltage connections between the primary equipment including connections between damping reactors/resistors and circuit breaker – standard clamps as per specifications to be used;
- g) Safety and security fencing around the bank, access gates and lighting;
- h) The dates by which the equipment assembly shall be completed, commissioned and ready for commercial operation, will be specified in schedule A of the enquiry document;
- i) All control and relaying equipment and the secondary cabling (including the cabling between the bay junction box and the secondary terminals of the unbalance instrument transformer(s);
- j) The earthing connections, earth tails, from the station earth mat to the shunt/filter capacitor support frames footing and to the unbalance transformers bushing and neutral earthing point.
- k) The equipment components to be supplied by the Contractor for the complete shunt/filter capacitor installations shall include but not be limited to:
- The Filter (tuning) reactors with their supporting insulators and pedestals;
 - Damping Resistors;
 - Damping resistor current transformers;
 - Main, Coupling and Surge Capacitors units as per IEC 60871 - 1 and IEC 60076- 6
 - Type Testing of Capacitor units, Damping Resistors and Filter Reactors. *Type test certificates of similar equipment that are less than 5 years old and within the same ratings as specified may be accepted.*
 - Supporting frame insulators with creepage distance calculated at Um;
 - Buswork;
 - All necessary connections (electrical and mechanical);
 - Steel supporting racks;
 - Capacitance meter(s);
 - Safety earthing numbering and connection points;
 - Restricted earth fault current transformers;
 - Insulated cable for neutral point earthing;
 - Capacitor lifting device
 - Special tools;
 - Current transformers for out-of-balance protection for H type configurations
 - Neutral cable connections to common rail including copper connection bar to steel pedestals
 - Safety Earthing kit;
- l) All necessary connections (electrical and mechanical);
- m) Spares.

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- n) The work and services to be supplied by the Contractor for the complete shunt/filter capacitor Supply shall include but not be limited to:
- Documentation;
 - Commissioning reports
 - Maintenance Manuals;
 - Training;
 - Reliability, Availability and Maintainability (RAM) program, studies and guarantees;
 - Seismic studies and analysis
 - Quality assurance;
 - Inspection and Test Plans
 - Maintenance Requirements; and
 - Maintenance during the guarantee period with the involvement of Eskom staff.
 - Design and Design Review
 - Manufacture
 - Tests
 - Installation
 - Monitor and report
 - Commissioning bay
- o) The Contractor shall supply drawings detailing positioning and size of all bolts, equipment, and total weight of capacitor supporting racks including the assembled equipment. Any special clearance requirements for fitting the bolts and fixing nuts, locknuts and washers shall be detailed on the drawing. *This will be for Eskom information and future reference only.*
- p) All MV insulation to be a minimum of 31 mm/kV.
- q) The Contractor shall be responsible for engineering, equipment design, manufacture, inspection and testing, supply, transport to site, unloading from transport at site, erection and field acceptance testing of all equipment supplied, commissioning, coating and painting works and ensuring that the equipment supplied complies with this specification including the RAM monitoring and reporting.

4.1.2 Safety Earthing Kit

The Contractor is to supply one safety earthing kit to earth each capacitor bank installation (2 in total). The safety earthing kit is to be according to Distribution standard and safety earthing **procedure** and shall include the following minimum equipment to safely earth all three phases for each installation (i.e. capacitor banks 1 & 2):

- a) Lightweight induction earthtails with bottom and top connectors to make all the necessary connections for earthing all three phases including the neutral point earthing;
- b) One link stick with adapter head;
- c) One pair of insulated gloves;
- d) Container(s) to house all the safety earthing gear;
- e) Safety earthing studs/balls fitted to accommodate all the safety earthing connection points
- f) Safety earthing points, numbering and labelling.

4.1.3 Erection and Regulations

- a) The Contractor shall provide an experienced and competent erection foreman to supervise the erection work on site on a full time basis. This person shall be certified by Eskom for the relevant sections of the Eskom High Voltage Regulations before the commencement of any site work by the Contractor whatsoever [52].
- b) Erection shall include moving from the off-loading position or storage, lifting, handling and positioning onto the supporting platform.
- c) All necessary staging, lifting tackle and tools shall be provided as part of the contract and these items shall be removed from site on completion of erection.
- d) The contract work, working conditions and safety shall be subject to the statutory regulations of the Republic of South Africa and as per Eskom High Voltage Regulations [52].
- e) Should any erection work be undertaken on or near the Employer's installations which are already in service, the Contractor's work and the Contractor's personnel shall comply with Eskom High Voltage Regulations for work on or near live equipment [52].

4.2 Employer Scope of Work

The *Employer* will provide the following:

- a) Site with access roads;
- b) Shunt/Filter capacitor bay layout and positioning information;

4.3 Service Conditions

All shunt/filter capacitor components shall be suitable for outdoor operation and use under the service conditions specified in schedule A of the enquiry document. The unavailability of point on wave functionality must not affect the performance of the shunt/filter capacitor bank. The *Contractor* shall verify with the Employer that the nominated circuit breaker is suitable for capacitor switching duties. Vermin proofing design must not limit the effectiveness of the Infra-red scanning that will be done on a regular basis.

4.4 Termination Points

- a) The Contractor shall terminate all connections to the plant and material supplied under this contract as well as the connections to the Employer's plant and material, as indicated in this specification.
- b) Shunt/Filter Capacitor MV (Medium Voltage) termination point: The MV termination point for the filter/shunt capacitor shall be the terminal pad onto the filter/damping reactors or capacitor rack connection. The *Contractor* will provide the MV connections between the MV circuit breaker and the damping circuit terminal pad. The terminal connection between the damping reactors and the connection to the capacitors shall be the responsibility of the *Contractor* to the requirements of the *Employer*. Connections between all the MV yard primary equipment shall be supplied by the *Contractor*.
- c) Earthing: The termination points for the filter/shunt capacitor plant to the earthmat shall be to the earthing point of the unbalance transformers bushing and to the support footing of the capacitor supporting structures. The *Contractor* shall supply the earthing tails between the station earthmat and these earthing connection points. The *Contractor* shall make provision on the supporting frame footing and on the unbalance transformers bushing for the terminations of the earthing tails. See DDT-5240.
- d) Shunt Bank Neutral terminal points: The neutral voltage termination points shall be between the unbalance current transformer rails and the common rail. The *Contractor* is to provide and make the connection including the common rail at both ends. Insulated MV cable is to be used to achieve the connection (if required). The *Contractor* is to supply the footing foundations and support rails and live chamber for the common neutral to earth connection.

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- e) Shunt Capacitor secondary termination points: The secondary termination points shall be between the bay junction box and the unbalance current transformer(s) terminal strip inside the instrument transformer(s) secondary terminal box. The *Contractor* will be responsible for all the secondary connections (needed for protection and control) to all the primary bay equipment and the bay junction box, including the secondary connections to the unbalance instrument transformer(s).
- f) Shunt/Filter capacitor civil works shall be the Contractor responsibility:
- Foundation and plinths for power plant and material supplied by the *Contractor*;
 - Shunt/filter capacitor safety fence; and
 - Containment area for spillage of capacitor insulation fluid.

4.5 Cable Trenches and Drainage

4.5.1 Civil Construction

The *Contractor* will construct all civil work, including cable trenches, trenches, foundations and drainage. The Contractor shall supply the Project Manager with complete requirements. This shall include the total layout, sections, design loads (plant and material), drawings, etc.

4.5.2 Construction Tolerance

The *Contractor* will construct all the civil works in accordance with the SANS 1200 series of specifications. All changes and modifications shall be to the Contractor's cost if any modification is required due to incorrect information or omissions by the Contractor [43].

4.5.3 Civil Requirements

The Contractor shall supply the following information to the Project Manager four (4) weeks after Notification of Acceptance and after the Design review. This list should not be seen as complete.

- a) Shunt/Filter capacitor bank layout design and drawings;
- b) Foundation dimensions and loadings- working loads (un-factored) including terminal and wind loading;
- c) The details pertaining to the foundation holding down bolts positioning and sizes;
- d) Trench locations and dimensions (if required);
- e) Fastening method of equipment, where required and
- f) Vermin proofing methods.

The *Project Manager* will review and comment on the above. The *Project Manager* 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 *Employer's* needs.

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

4.6 Safety Requirements

Refer to the *Employer's* High Voltage Regulations [52], and OHSA [20].

4.7 Foundations and Supporting Steel Racks

- a) The capacitor bank shall be mounted on post insulators fixed to concrete foundations. The *Contractor* will supply the foundations.
- b) The *Contractor* shall provide the foundations. The Contractor to supply and install the holding down bolt assemblies for equipment supplied under the scope of this specification. The Contractor shall supply drawings detailing the positioning of all bolts, holes or fixing pockets to be provided in the structure or plant and material or foundations. Any special clearance requirements for fitting the bolts and fixing nuts and washers shall be detailed on the drawing as well as the grade of the bolts.
- c) The supporting steel racks shall be designed with a minimum safety factor of 2.5 to support all of the equipment and to incorporate methods for safe access to all of the major components for inspection and maintenance.
- d) Supporting racks for the capacitor units shall be supplied by the Contractor in accordance with this specification and shall be designed to provide natural air cooling of the capacitor units and vermin proofing.
- e) Capacitor units shall be readily accessible and replaceable without removing adjacent units.
- f) Steelwork, gratings, bolts, nuts and washers shall be hot-dip galvanised in accordance with SANS 121 and shall be completely weatherproof.
- g) Working stresses for steel supporting structure shall be in accordance with BS 449-2. If supporting structures are of aluminium, details of the design and the safety factors employed shall be submitted to the Project Manager for acceptance prior to manufacture.
- h) The design of all steelwork shall be such as to avoid corona discharge (less than 500pD) at the maximum operating voltages.
- i) Supporting structures and insulators shall be designed to have a factor of safety of at least 2,5 when subjected to a wind loading of 1200 Pa on the projected area of all associated apparatus. Creepage distance to be 31 mm/kV calculated at maximum operating voltage.

5. Design Requirements


5.1 General

- a) The filter (tuning) reactor and damping resistors (where applicable) shall be constructed in such a fashion that it forms an integral single-phase damping circuit.
- b) The number of damping resistors used per single-phase damping circuit shall be clearly indicated by the *Contractor* during the tender stage.
- c) Filter (tuning) reactors and damping resistor(s) shall be the single-phase dry type with a fixed inductance rating suitable for connection to the MV side of the shunt/filter capacitor bank.
- d) Damping resistors shall be of the non-inductive type with linear characteristics.

5.2 General Layout

The required shunt/filter capacitor bank installation is to be designed to fit the below detailed dimensions.

Table 1: Layout dimensions

Maximum space available for shunt/filter capacitor banks including safety fence for a three phase installation.	
 <p>The diagram shows a square layout within a larger rectangular frame. The horizontal dimension is labeled 'A' and the vertical dimension is labeled 'B'.</p>	
Dimension A in metres	Dimension B in metres
5	5

5.3 Components

5.3.1 Capacitor Units

5.3.1.1 General

- The capacitor units shall be designed, manufactured and tested in accordance with IEC 60871 and the 240-76429758 (Capacitors).
- Each capacitor phase shall consist of equal series capacitor groups/strings and shall be provided with its own supporting galvanised steel structures and all necessary insulators.
- The number of capacitor series groups shall be such that the voltage drop across the individual capacitors does not exceed the rated capacitor voltage.
- The capacitor installation shall be of open rack construction, and shall be naturally air-cooled.
- Vermin proofing to be provided to eliminate the possibility of insulation flash over from occurring as a result of vermin contact

5.3.1.2 Rating Requirements

The kVAr and voltage ratings of capacitor units, and hence the number of these units to be connected in series and parallel, shall be chosen to meet the ratings specified for the bank as a whole. In addition, the arrangement and ratings of series/parallel units and shall ensure that when a unit fails it does not cause a voltage rise in excess of 5% across healthy units for which they will be rated (IEC-60871), while applying the rated current and voltage to the bank.

5.3.1.3 Over voltage and Over current Capability

Capacitor units shall be capable of repeated operation in the bank under the following conditions during the expected 30 year life of the bank as per IEC 60871 [22]:

- Maximum r.m.s. power frequency voltages based on the bank voltage ratings
 - 1,00 p.u – Continuous
 - 1,10 p.u. – 12 h in a 24 h period
 - 1,15 p.u. – 30 min in a 24 h period
 - 1,20 p.u. – 5 min, 200 times
 - 1,30 p.u. – 1 min, 200 times
 - 1,5 p.u. – 5 seconds, 200 times
 - 1,75 p.u. – 1 second, 200 times

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- b) In addition to the normal load requirements and over voltages associated with fault currents the capacitors shall be capable of withstanding the over voltages associated with the presence of system harmonics in the local system.
- c) The capacitor shunt/filter bank installations will be switched daily by the user. A minimum of at least 4 switching in operations per day and 4 switch out operations per day will occur. The installation will be designed to handle this switching requirement for the overall expected life of the installation.

5.3.1.4 Losses

The losses of each capacitor unit including losses due to the internal discharge resistors, including internal connections shall not be more than 0,1 watt per kVAr when measured at rated voltage, rated frequency and at 20°C ambient temperature.

5.3.1.5 Reactance Tolerance

The reactance tolerance for each unit shall not exceed $\pm 5\%$ over the ambient temperature range -10°C to +45°C. The reactance tolerance for the whole segment and bank shall be as specified in IEC 60871.

5.3.1.6 Capacitor Unit Mass

Capacitor units may have an output not exceeding 550kVAr per unit. The Contractor shall include a lifting device (ground to platform and into bank position) to be approved by the Project Manager. The lifting device to be light weight in design. Details of this shall be supplied with the Contractor's Works Information.

The mass of each unit to be limited as far as possible and ideally not weigh more than 65 kg.

5.3.1.7 Capacitor Unit Built-in Discharge Resistors

Capacitor units shall be fitted with an internally mounted discharge resistor, which will reduce the residual voltage to 50 V or less within 5 min after the capacitor bank is de-energised.

5.3.1.8 Container and Bushings

- a) Only stainless steel containers with a suitable protective coating and a light grey finish will be acceptable to the *Project Manager*. When filled with insulating fluid and sealed, no bubbles shall remain trapped in the container. The container shall be fitted with brackets suitable for mounting on the supporting frames. The full dimensions of the container and its overall height including bushings, the thickness of the stainless steel and the details of the brackets and their positions shall be supplied as specified in schedule A of the enquiry document. The clamping arrangement and its material shall be detailed and any limitations in the compatibility with copper or aluminium conductors shall be pointed out and determined.
- b) Only capacitor units designed with two bushings will be accepted.
- c) The bushing flange shall not be welded or soldered to the containers. The use of alternative attachment methods shall be stated in the tender as a deviation from this specification and shall be subject to approval by the *Project Manager*. The bushing characteristics shall be in accordance with NEMA CP -1 and IEC 60871.
- d) The capacitor unit bushings shall have a BIL and creepage as required by capacitor unit voltage rating as specified in schedule A and in compliance with and Table 5.
- e) Earthing studs to be supplied on the individual capacitor unit studs for the purpose of safety earthing of shunt/filter capacitor banks. The earthing studs shall be made out of copper. This is required to accommodate the earthing of each capacitor unit on both connection points. Alternative safety earthing positions to be submitted with the tender and shall be for the *Project Manager's* approval.

5.3.1.9 Insulating Fluid

The capacitor insulating fluid used shall be biodegradable and nontoxic. In the event of accidental spillage, the biological concentration and effect on the environment shall be minimal. Polychlorinated biphenyls (askarels) are not acceptable as insulating media. All characteristics of the fluid to be used shall be submitted, with the tender, to the *Project Manager* for evaluation (partial discharge inception/extinction properties, PD extinction time, gas absorption properties, etc.).

Instructions for fluid disposal shall be submitted to the *Project Manager* for approval. Tan delta and moisture content test results to be supplied as per list.

Mineral insulating oil must comply with ESP 32-406.

5.3.1.10 Balancing

To prevent excessive voltages from being applied to capacitor units under normal conditions, and to facilitate the application of sensitive out-of-balance protection relay, the positions of the capacitor units in a bank shall be carefully selected to provide the best possible balance between series groups/strings of each capacitor module in a phase. For this purpose the following information shall be submitted to the *Project Manager* for the capacitor bank before its delivery:

- a) Serial numbers of all capacitor units and corresponding measured capacitance;
- b) Recommended position in the bank of every capacitor unit (in drawing or schedule form);
- c) Resulting total capacitance of each parallel group of units, of each module and of each phase.
- d) Care must be taken to standardise designs as to eliminate tedious testing and balancing

The maximum acceptable unbalance in healthy banks shall be such that the r.m.s. unbalance current at rated line current, assuming all units at the same temperature, does not exceed the permissible unbalance inherent limit that is relevant to the design. The maximum out of balance shall not exceed 20% of the unbalance alarm setting,

5.3.2 Filter (Tuning) Reactors

The filter (tuning)/damping reactors shall be designed, manufactured and tested in accordance with 240-42587021 [2] and IEC 60076. The damping/filter reactor ratings shall comply with the requirements listed in schedule A of the enquiry document and confirmed during the Design Review.

5.3.3 Damping Resistors

The damping resistors shall be designed, manufactured and tested as specified in this specification.

5.3.4 Unbalance Current Transformers (HCT or Unbalance CT)

5.3.4.1 General

One post type unbalance current transformer per phase each fitted with three secondary core shall be supplied in accordance to this specification for connection between each half of the H per phase. This neutral installed current transformer shall be used for the purpose of current unbalance protection detection of each shunt/filter capacitor bank. The unbalance current transformer shall be designed, manufactured and tested in accordance with IEC 61869.

5.3.4.2 Ratings

The unbalance current transformers shall be rated as specified in schedule A of Annex A.

5.3.5 Restricted Earth Fault Current Transformers

5.3.5.1 General

Unless otherwise specified one separate ring type, air-core current transformer fitted with two secondary cores shall be supplied in accordance with this specification for connection in the neutral connection to the common rail. This neutral installed current transformer shall be used for the purpose of restricted earth fault protection detection on the shunt/filter capacitor bank. The restricted earth fault current transformers shall be designed, manufactured and tested in accordance with IEC 61869.

5.3.5.2 Ratings

The current transformer shall be rated as specified in schedule A of Annex A.

5.3.6 Post Insulators

The post insulators shall be designed, manufactured and tested in accordance with 240-56030435 [10].

5.3.7 Surge Arrestors

The surge arrestors shall be designed, manufactured and tested in accordance with 240-75540566 [8].

5.4 Nameplates

5.4.1 General

The labels shall be designed to maintain legibility of data during the expected 30 years life of the installation while exposed to the South African climatic conditions with its high ultra-violet radiation and acid rain. The method of fixing the label to the capacitor shall be commensurate with the life of the capacitor. Cable tie fixing and double sided tape are not acceptable to Eskom.

The words "Eskom Contract No...." and "Eskom Serial No...." shall appear on the plates. The information to be provided on the plates for different types of equipment shall be in compliance with the details listed below.

5.4.2 Capacitor Units

The information shall be given on nameplates for each individual capacitor unit as required in IEC 60871-1. In addition, the insulating fluid used in capacitor units shall be identified on the rating plate of each unit and the percentage measured capacitance shall be given.

The series/parallel arrangement of the internal elements shall also be indicated on the nameplate, for example, 2P/8S.

5.4.3 Current Transformers

Current transformers shall have rating plates fitted in accordance with the requirements set out in N29 and IEC 61869. The information shall be engraved on, or stamped into the plate(s). The plate(s) shall be mechanically affixed e.g. screwed or riveted, to the equipment. Mounting by means of adhesives is not acceptable. The plate(s) shall be manufactured from anodized aluminium or stainless steel. The plate(s) shall be externally fixed on a vertical surface of the main body of the CT, in close proximity to the terminal box and not to any removable part [17].

The size of the characters shall be not less than 4 mm.

The rating plate shall display the following information as specified in IEC 61869-1 and 61869-2:

- a) The applicable version of NRS 029;
- b) The purchase order number, the date of manufacture and a blank space for the purchaser's reference number;
- c) The volume of oil, in litres, for oil-filled CTs;

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- d) The gas type and the density for gas-filled CTs;
 - e) The terminal markings and the relative physical arrangement of the CTs' secondary windings with respect to the primary terminals; the P1 terminal indicated as being isolated from the CT;
 - f) The dielectric dissipation factor (tangent delta), expressed as an absolute value and capacitance (C12) expressed in picofarads, as measured at 10 kV, with the ambient temperature (Tamb) at the time of measurement, recorded either on the main rating plate or on a separate plate mounted under the main rating plate; this plate, if separate, shall be manufactured from the same material, and mounted by the same method as the main rating plate.

5.4.4 Filter (Tuning) Reactor

Reactors shall have rating plates fitted in accordance with the requirements set out in 240-42587021 and IEC 60076.

5.4.5 Post Insulator

Post insulator shall have rating plates fitted in accordance with the requirements set out in 240-56030435 [10].

5.4.6 Surge Arrestor

Surge arrestors shall have rating plates fitted in accordance with the requirements set out in 240-75540566 [8].

5.4.7 Capacitor Banks

A rating plate, mounted at a convenient point on the centre phase of the bank, shall be provided for the bank as a whole. The plate shall provide the following information:

- a) Manufacturer;
- b) Year of manufacture;
- c) Rated output in MVAR at nominal distribution system voltage, written as, for example, 3 MVAR at 22 kV;
- d) Rated capacitor bank voltage in kV;
- e) Rated capacitance of each leg of each phase in μF ;
- f) Insulation levels in terms of the r.m.s. power-frequency test voltage and the peak impulse test voltage;
- g) Connection symbol;
- h) Minimum time required between disconnection and reclosure of the bank; and
- i) Eskom's order and serial number.

5.4.8 Capacitor Bushings

The tenderer shall give adequate information about the bushings in Schedule B and in supporting documentation in the tender.

The 50 Hz test voltage of any insulator should not be less than 2.75 times its working voltage

Tenders should be asked to submit a complete schedule of all insulators in the bank showing working voltages, rest voltages and creepage stress in mm/kV stated at UM conditions.

5.4.9 Capacitor Supporting Rack Numbering and Phasing

The capacitor supporting racks shall be numbered to indicate the required earthing connection points as shown in the standard earthing procedures for fuseless capacitors. The actual number and positioning of each numbering plate shall be in accordance to the numbering sequence used in figures 1 and 2. These plates shall be easily readable from ground level.

Each capacitor supporting rack shall be equipped with phasing discs. The phasing discs shall be placed in such a way that they are easily visible from ground level when the bank is in operation.

5.5 General Plant and Materials Requirements

5.5.1 Main Terminals and Connections

- a) All primary connections between equipment and phases on the capacitor bank shall be made in aluminium or tinned copper of appropriate area.
- b) The capacitor bank shall be supplied with the main terminals fitted with clamps suitable for connecting flexible busbars to the terminals.
- c) The main terminals on the high-voltage side of the damping reactor/resistor units shall be a copper or aluminium terminal pad having the dimensions specified in **schedule A** of the enquiry document and also electro-tinned according to BS 1872 classification Sn 12c without subsequent heat treatment or aluminium.
- d) The connections from Eskom's equipment to the bank will be made horizontally and the main terminals of the bank shall be oriented and positioned to suit this arrangement. The terminals shall support a pulling force of at least 3 000 N without distortion.
- e) Eskom accepts capacitor units with two terminal bushings incorporating a terminal bolt with clamps for conductors suitable for continuous current rating, ranging between 20 A and 80 A.
- f) The interconnections between capacitor units and between various sections of the bank shall be insulated copper. The type of conductor used for the interconnection of capacitors shall be suitable for repeated connection/disconnection duty. Connecting conductors shall run in gentle curves and care shall be taken to ensure that shrinkage due to clamping of braided or stranded conductors does not cause connections to deteriorate. Reaction due to different chemical compositions between the terminal stems of the capacitor units and the interconnections shall be prevented. Connections shall be such that the capacitor bushings are not subjected to excessive cantilever forces. Support shall be provided for all connections to prevent excessive movement due to wind or to electromagnetic forces associated with charging and discharging the bank.
- g) The interconnections between two different potentials shall be connected in such a fashion that the minimum looping is experienced from one terminal connection of an individual capacitor unit to the other terminal of the same potential as to facilitate for the maximum BIL clearance at U_M for which the capacitor units are rated. The interconnections will stay in this position for the total expected life of the capacitor installation.

5.5.2 Neutral Earthing Cable

The neutral earthing cable for the connection between the neutral star point and the common rail earthing point to be of the single core, insulated type. The cable to be rated for 22 kV BIL to have a minimum area of 185 mm² and to be of the trailing type. The connection to the common rail to be supplied and the material used to be such that no Electro corrosion occurs between materials used.

5.5.3 Materials

Materials shall be of recent manufacture, unused and free of defects and irregularities.

5.5.4 Surface Finishes

- a) All interiors and exteriors of tanks and enclosures, which are not galvanised, or of corrosion-resistant metal shall be thoroughly cleaned and painted. Cleaning shall be by degreasing and abrasive blasting or other equivalent means to remove all grease, scale, corrosion and foreign substances. The proposed cleaning method shall be submitted to the *Project Manager* for review and comments.
- b) All surfaces to be painted shall be given at least one priming coat and one finish coat of paint or enamel. The surfaces of interior components, where applicable, may be painted in accordance with the manufacturer's standard practice.
- c) All surfaces to be painted shall have a finish coat of paint Light Grey to SANS 1091 colour code G29 (semi-gloss), except as indicated otherwise in the respective plant and material specification. The base frame shall be painted Black Gloss [44].
- d) Galvanising shall be in accordance with SANS/*Eskom* standards, as applicable [39].
- e) Structural steel members that are not feasible to galvanise shall be given at least two coats of zinc-rich paint having a total dry thickness of not less than 0,1 mm.
- f) Following installation of the plant and material, all painted surfaces shall be touched-up as applicable. The paint shall be the same type and colour used originally on the plant and material.

5.5.5 Labels

- a) Labelling shall be in accordance with Eskom standard [13] **Error! Reference source not found.** [15].
- b) All items of outdoor primary plant and material, marshalling kiosks, mechanism cubicles, terminal boxes, etc., shall be identified by means of a label which shall be of the vitreous enamel type on a 1,6mm mild steel plate base. The labels shall have black letters on a deep orange (No. 591) background.
- c) The labels shall be mounted in such a manner that they cannot be easily damaged or distorted and where necessary shall be fixed by means of a strong galvanized steel frame supplied by the *Contractor*. Any mounting holes shall be drilled in the label before enamelling, the hole diameter shall be suitable for the insertion of brass eyelets and label fixing shall be in accordance with [14].

5.5.6 Corrosion Protection

All plant and material shall be treated to prevent corrosion in accordance with SANS 1200 and SANS 121.

5.5.7 Secondary Terminals

5.5.7.1 Current Transformer Terminals

- a) The terminal blocks shall be mounted on 'G' type mounting rails in the terminal boxes.
- b) The terminal blocks shall be spring retained on the assembly rail and closely mounted. End sections and circuit separators between units of different secondary core terminals shall be provided. It shall be possible to replace any unit in an assembly without dismantling adjacent units. No joints are allowed in the wiring.
- c) A rail mounted spring loaded / screw clamp type terminal block for hooked blade lugs shall be provided. The terminals shall be suitable for fitting a rated wire size of 6 mm² and be able to accommodate 2 hooked blade type lugs.
- d) The terminal blocks shall be the type, which compress the terminations between two plates using terminal screws. The terminals shall be spring loaded with the spring action independent of the terminals screw action.

- e) The terminal screws shall be captive within the moulding and the heads shall not project above the moulding when fully released. Terminal entries shall be shrouded such that no current carrying metal is exposed when fitted.
- f) Cross connection facilities shall be provided for combining two or more adjacent terminal blocks, without interfering with the terminals openings.
- g) The following terminals for use in secondary terminal boxes have been approved:
- Entrelec – Type M10/10-RS

5.5.8 Rating and Diagram Plates

All items of plant and material of the capacitor bank shall be fitted with rating and diagram plates in accordance with the relevant Standard Specification. The rating and diagram plates shall at least comply with the following:

- a) They shall be permanently etched or engraved stainless steel;
- b) At least 1 mm thick;
- c) Located so that they can be read safely and conveniently while the plant and material is energised.
- d) The following information shall be included:
- The number of the appropriate standard specification;
 - Service voltage;
 - Normal current;
 - Frequency;
 - Reactance and resistance (where applicable);
 - Short time over current rating, and time;
 - Manufacturer's serial number;
 - The *Employer's* name, the number of this specification, and the *Employer's* reference number which will be supplied to the *Contractor* (character height at least 5 mm).

5.6 Bank Insulation levels

5.6.1 General

The insulation levels of the various components of a bank shall be based on the highest line-line r.m.s. voltages to which these components are normally subjected to as a consequence of the layout adopted and shall comply with the levels as specified in Table 2. If there are differences between the levels given in Table 3 and the IEC 60871 levels refer to Annex A of the enquiry document for the specified system voltage [22].

Table 2: 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		

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			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	2000	2500	840/1100+	1150/1350+
145	550	230	2900	3600	1200	1650
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 $U_N = 330\text{kV}$, $U_M = 1,1 U_N$ + Values for non-effectively earthed 88kV system. ** The creepage insulation values are based on line-to-line maximum system voltage.						

5.6.2 Precautionary Insulation of Live Plant and Material

Table 3: Standard electrical and working clearances [15]

System Voltages		Minimum Electrical Clearance		Minimum Working Clearance	
System Nominal Voltage (kV)	System Highest Voltage (kV)	Phase to Earth (m)	Phase to Phase (m)	Vertical (m)	Horizontal (m)
3,3	3,6	0.08	0.11	2,58	1,18
6,6	7,2	0.15	0.20	2,65	1,25
11	12	0.20	0.27	2,7	1,3
15	17,5	0.23	0.31	2,73	1,33
22	24	0.32	0.43	2,82	1,42
33	36	0.43	0.58	2,93	1.53
44	48	0.54	0.73	3,04	1,64
66	72	0.77	1,05	3,27	1,87
88	100	0.84 (1.00)	1,15 (1.35)	3,34 (3.5)	1,94 (2.1)
132	145	1,20	1,65	3,7	2,3
220	245	1,85	2,30	4,35	2,95
275	300	2,35	2,95	4,85	3,45
330	362	2,90	3,60	5,4	4,0
400	420	3,20	4,00	5,7	4,3
765	800	5,50	8,00	8,0	6,6

Note: Bracketed figures for 88 kV are for full insulation and are to be used only if the system is not effectively earthed.

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5.7 Capacitor Rack and Miscellaneous Insulators

- a) The strength of the capacitor rack frame insulators shall provide a safety factor of not less than 2.5 when subjected to the maximum continuous steady mechanical load.
- b) Other important features of these insulators shall be a high cantilever strength, long creepage distance and good anti-pollution performance.
- c) The insulators used for some of the equipment mounted on the supporting frames, for example, capacitor inter-rack insulators shall be the cap and either pin or post type. The bases of these insulators shall be supplied with bolts or clamps to fasten them firmly to the supporting frames.
- d) All buswork required on the supporting frame shall be provided by the supplier.
- e) The mechanical strength of the frame support equipment shall be capable of withstanding the maximum wind loading including stresses induced by an electrical short-circuit at the same time. Factors of safety to be included and shown in the calculations.

5.8 Shunt/Filter Capacitor Bank**5.8.1 General**

The shunt/filter capacitor bank shall comprise individual capacitor units connected in series/parallel groups, supporting frames for the capacitor units, post insulators between frames, damping/filter reactors, and the necessary interconnections to provide a bank of the type and rating specified in the Schedules. Creepage distance and vermin proofing requirements to be included in the design as per specified requirements.

5.8.2 Ratings and Bank Configuration

The continuous three-phase output at nominal distribution system voltage shall be as specified in schedule A of the enquiry document.

5.8.3 Safety Earthing Procedures

The *Contractor* shall submit an alternative safety earthing procedure for earthing the shunt/filter capacitor as an alternative other than the safety earthing procedure used by the *Employer*. The *Project Manager* will review this procedure and will decide if it will be included in the order.

Table 4: Capacitor bank voltage and maximum over voltage duration in pu of maximum distribution system voltage

TYPE	BANK VOLTAGE RATING in p.u. OF SPECIFIED NOMINAL DISTRIBUTION VOLTAGE	MAXIMUM OVERVOLTAGE DURATION	OBSERVATION
Power Frequency	1,00	Continuous	Highest average value during any period of capacitor energization. For energization periods less than 24 h exceptions apply in accordance with the values below.
Power Frequency	1,10	12 h continuous in every 24 h	System voltage regulation and fluctuations
Power Frequency	1,15	30 min continuous in every 24 h	System voltage regulation and fluctuations

TYPE	BANK VOLTAGE RATING in p.u. OF SPECIFIED NOMINAL DISTRIBUTION VOLTAGE	MAXIMUM OVERVOLTAGE DURATION	OBSERVATION
Power Frequency	1,20	5 min x 200 times (life time)	Voltage rise at light load
Power Frequency	1,30	1 min x 200 times (life time)	
Power Frequency	1,50	5 seconds	
Power Frequency	1,75	1 second	

The shunt/filter capacitor bank and each capacitor unit shall be capable of continuous operation at up to 135% of the rated R.M.S. current including fundamental and harmonic currents. Depending on the actual capacitance value, which may be at a maximum of 1,15 CN, the maximum current can reach 1,5 CN.

6. Reliability, Availability and Maintainability (RAM Programme)

6.1 General

The *Contractor* shall provide a RAM Programme Manual within 2 months after *Notification of Acceptance*.

6.2 Reliability

The reliability programme shall include:

- An evaluation of the shunt/filter capacitor equipment throughout the design, the production and the test procedures used;
- An estimate of the failure rates expected for the various system devices during their useful life based on component history of factory failure rates, in service failure rates and references.
- An assurance that the material and the components selected for this application enable the shunt/filter capacitor installation to perform in compliance with the specified requirements;
- De-rating and safety factors used in the design of each item to enhance the reliability of the entire system; and
- Test data that support the performance capability as well as the quality of parts and materials supplied.

6.3 Availability

The shunt/filter capacitor bank shall be designed to meet the following guaranteed values of availability:

- Scheduled outages, which involves planned inspection and maintenance, not be more than once per year; and
- Forced outage also not to be more than once per year.
- The overall shunt/filter bank availability to be 99,8 % per year per bank. This availability to be calculated on a yearly basis.

The maximum outage time to be limited to 8 hours with the understanding that only one shunt/filter bank to be switched out at a time for scheduled maintenance activities. The outage time allowed for scheduled maintenance might only be during weekends.

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6.4 Maintainability

The shunt/filter capacitor bank shall be designed to meet the following maintainability requirements:

- a) The *Contractor* shall design the equipment system to minimise both repair and maintenance effort and the need for special skills and tools;
- b) The *Contractor* shall include as a minimum the following factors in the maintainability design plan:
 - analysis and allocation of scheduled maintenance effort required to keep the equipment in proper working order;
 - for each repair or maintenance work, quantitative estimates shall be made of repair frequency, duration, manhours and parts requirements;
 - spare parts provision and logistic support;
 - personnel safety requirements;
 - recommendation on the quantities of spare parts or units required. Technical information concerning spare parts shall include reasons for selection, information on storage and supply of parts for the repair and maintenance of equipment during the nominal operating life; and
 - provide installation, operation, repair and maintenance manuals in compliance with the *Employer's* requirements. The manuals shall include details of special skills, training, or tools needed for maintenance operations.

6.5 Station Reliability and Availability

Reliability and performance are key factors that will be considered in the evaluation of the bidder's proposal. Unavailability of the shunt/filter capacitor will have corresponding reduction in power flow at the substation which will have economic consequences to the *Employer* that are proportional to the scheduled load flow.

The design shall provide adequate reliability by incorporating sufficient redundancy and equipment spares. The *Contractor* shall indicate the targeted level of planned (maintenance) and unplanned (forced) unavailability of the capacitor bank in hours per annum.

The *Contractor* shall also indicate the expected Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) the significant components.

An assessment value of R 100 000,00 per day (24 h), will be made against the *Contractor* for non-availability of service for the shunt/filter capacitor bank.

6.6 Availability Guarantee

6.6.1 Definitions

Accountable Outages are outages caused or necessitated by the Work which may result in reduced capacity or loss of essential functions of the system. These outages may be initiated by failure of components. Such outages include both forced outages due to equipment problems and scheduled outages for maintenance.

6.6.2 Accountable Outage Duration

Accountable Outage Duration is the elapsed time of accountable outages from the instant the Plant experiences reduced capacity or is out of service to the instant it is returned to full service or full capacity. If the system is out of service, but is determined by the *Employer* to be ready and available to return to full service, such time will be discounted from the outage duration.

6.6.3 Availability Guarantee Period

The *Contractor* shall achieve the Availability Guarantee for 36 consecutive full months of operation. The availability guarantee period shall only start after the successful completion of the System Commissioning tests and after one year's normal guarantee period. The *Contractor* may install the necessary communication equipment to monitor the system remotely and respond to outages. On request the *Employer* will provide the *Contractor* with the details of major alarms received via RTU - SCS interface (SCADA).

Quarterly outage reports will be provided by the *Contractor* and verified by the *Employer*.

6.6.4 Availability

Availability in % is the percentage of hours that the Plant is available during the Availability Guarantee Period (36 months), calculated as follows:

$[1 - \Sigma \text{accountable shunt/filter capacitor outage durations in hours} / 8760] \times 100$.

6.6.5 Availability Guarantee

The annual availability required of the Plant shall be no less than 99,8 %. Failure of auxiliary equipment and any other parts of the shunt/filter capacitor bank and other Work as specified in this specification as being the responsibility of the *Contractor*, shall be included in the determination of availability.

6.6.6 Guaranteed RAM Rates

The *Contractor* shall, based on the failure of plant and material within his contract responsibility, deliver a shunt capacitor system which shall perform equal to or better than the values specified above. The *Contractor* shall state guaranteed values in the Schedule which are better than this specification requirement if better rates are proposed.

The *Contractor* will monitor the actual performance in accordance with this specification, and will inform the *Employer* whether or not the specified guaranteed levels have been met. If these values are not met, the procedures outlined in this specification and the Conditions of Contract will apply.

The RAM measurement will be calculated after a period of 12 months on the Completion of the *Contractor's* Works.

The *Employer* requires that the shunt/filter capacitor shall be fully operational without experiencing initial failures attributed to commissioning, learning, new technology or bath-tub type failures.

The *Contractor* shall at his cost repair or replace defective components and auxiliary items for a period of 3 years from the date, after one year of Completion, in order to fully satisfy reliability and availability requirements for the shunt/filter capacitor. The *Contractor* shall warrant that the shunt/filter capacitor bank will conform to the applicable performance guarantees set forth in the Technical Specification.

- a) The 3 year guarantee period for Reliability Availability Maintainability (RAM) performance shall be extended from the time of identification of the need for such corrective action until the action is completed, but in no event for a total cumulative extension period of more than 3 years. The corrective action shall raise the performance level of the Plant and Material so that the accumulative average RAM performance over the guarantee period will equal or better the values specified in the contract. The total RAM monitoring and guarantee period, with extensions, shall not exceed 6 years.
- b) To maintain system availability, the *Contractor* shall ensure timeous turnaround of repaired or replaced parts. The *Contractor* shall adjust the spare parts (recommended spare parts) inventory and add necessary items and quantity to achieve specified availability performance levels. The dedicated spare parts at the shunt/filter capacitor site and all additions to the inventory of spares determined to be necessary to achieve RAM performance levels shall, at the end of the guarantee period, be at the full inventory of types and quantity.
- c) All RAM spare parts shall be the property of the *Employer*.

- d) If the guarantee period is extended in accordance with paragraph (b), above, the *Contractor* shall bear the expense of removal, correction, or replacement, and reinstallation and re-testing, whether incurred by or on behalf of The *Employer* or the *Contractor*, including transportation charges; provided that any later installed material or plant not supplied by the *Contractor* which degrades the originally accepted maintainability, which must be removed to give access to the material or plant supplied by the *Contractor* will be removed and replaced by the *Employer* without cost to the *Contractor*.
- Capacitor units with faulty internal elements shall be replaced with new and repairs shall not be allowed as part of the guarantee period.
 - Unless the *Contractor* can and will promptly correct or replace the deficiencies in RAM performance, the *Employer* will:
 - Correct the deficiencies or order the same to be done, or
 - Procure or obtain similar supplies elsewhere and hold the *Contractor* liable for excess cost and damages caused thereby.

6.7 Spare Parts

If the *Employer's* stock of spare parts purchased with the system is used for repairs during the Availability Guarantee Period, the *Contractor* shall restock such spare parts within 5 working days or advise the *Employer* in writing, within 5 working days, when such parts will be delivered. All such spare parts shall be replaced as soon as practical. In the event that the *Contractor* proposes to replace the spare parts in more than 30 days, approval from the *Employer* shall be required.

6.8 Non Performance

If actual availability is below the specified level, the *Contractor* shall promptly, at no cost to the *Employer*, analyse the situation and provide corrections and modifications to prevent the failure or malfunction from occurring again. System commissioning tests may be required by the *Project Manager* at the *Contractor's* expense. The Availability Guarantee Period shall then restart and 12 consecutive months of operation within which the Availability Guarantee must be achieved.

6.9 RAM Programme Requirements

6.9.1 General

6.9.1.1 Scope

This specification establishes requirements for a Reliability, Availability, and Maintainability (RAM) Program that shall be developed and maintained by the *Contractor*.

6.9.1.2 Contractual Intent

The programme requirements set forth herein are consistent with those of the *Employer's* Quality Program Requirements as well as ISO 9001. Nothing in this specification shall be construed as a requirement of duplication of effort. Overlapping Quality Programme and Reliability elements shall be clearly delineated in the RAM Program and cross referenced in the Quality Programme Manual or other pertinent technical programme documents. The RAM Programme requirements shall have preference over the Quality Assurance in case of conflict.

6.9.1.3 RAM Programme Reviews

The *Contractor's* programme shall be subject to review and approval by the *Project Manager*. If the *Contractor's* RAM programme has not been previously approved by the *Project Manager*, the *Contractor* shall submit his programme manual to the *Project Manager* for review and comments as specified in this specification.

6.9.1.4 Information Feedback

The *Employer* will supply periodic field performance, maintenance and failure data of the equipment supplied that is reasonably available. Alternately the *Employer* will provide access to the equipment, failed units and records for *Contractor* acquisition of data where practical. The *Contractor* shall report to the *Employer* periodically (at least quarterly) on the field service performance, maintenance and failure statistics of his equipment.

6.9.1.5 Documentation

The *Contractor* shall establish and maintain written procedures defining his RAM Programme. The *Contractor's* written documentation shall include, but not be limited to, the requirements of the specification. The *Contractor* is encouraged to utilise any additional programme elements that, in his judgement, will increase the effectiveness and efficiency of the programme.

The RAM Programme Documentation shall prescribe:

- a) Thorough planning and effective management of the reliability effort.
- b) Definition of the Major RAM tasks and their place as an integral part of the Design and Development process.
- c) Assurance of reliability through a programme of production, test, and evaluation.
- d) A Retention System to ensure control improvement and feed forward to future projects.

6.9.1.6 Programme Management

To ensure timely and effective management, the *Contractor* shall:

- a) Clearly define management policies, objectives and responsibilities for RAM and associated functions.
- b) Clearly identify the group within the organisation which will be responsible for management of the RAM Programme.
- c) Make functional assignments to implement each element of the total programme. Personnel performing program functions shall have sufficient, well-defined responsibility, together with adequate authority and organisational freedom to fulfil the responsibility.
- d) Describe the RAM organisation and its relationship to Management, Design, Manufacturing, Testing, Installation, Commissioning, Marketing, and QA.
- e) Prepare a RAM Program Plan to serve as a master planning and control document for the reliability programme for individual projects. Individual plans shall include:
 - Identification of the necessary tasks,
 - Define and schedule milestones,
 - Delineate responsibilities, and
 - Provide for timely documentation.
- f) Conduct scheduled quarterly reports to evaluate programme progress and effectiveness. The Schedule of Reviews shall be given in the RAM Programme Plan. Such reviews shall verify that:
 - The required levels of RAM are being achieved.
 - RAM contract requirements are being achieved.
 - Necessary follow-up and corrective action are being implemented effectively.
- g) Provide for effective RAM training for all personnel who are involved in the programme.

6.9.2 RAM Engineering

6.9.2.1 General

The RAM Programme is considered an integral part of the Design and Development process. The co-ordination and integration of the various RAM tasks are of key importance in the growth and development of product capabilities. The *Contractor* Programme shall utilise RAM Engineering to ensure that the equipment meets the *Contractor* generated design specifications after establishing that the set of these documents covers all contract requirements.

6.9.2.2 Design Specifications

General and detailed design specifications shall be prepared covering the end item, system, subsystem and component. The specifications shall define functional and physical interfaces, environmental, performance, operational, safety, transportability, test criteria, safety margins, de-rating factors, and RAM goals. Such Specifications shall guide the design of the equipment and shall be updated to reflect changes during the design and development cycle.

6.9.2.3 Field Data

The *Contractor* shall acquire, maintain, and use field service performance, maintenance, and failure statistics in the engineering of the equipment.

6.9.3 Failure Analysis

The *Contractor* shall perform availability block diagram (ABD) analysis to identify all significant failure modes and their effects on the equipment and its operation. Estimated failure rates shall be supported by data. Failure analysis shall be a major consideration in design reviews and provide criteria for:

- a) Design improvement, Quality Assurance, and testing by the *Contractor*.
- b) System improvement by the customer
- c) 20 % overrating on voltage

6.9.4 Reliability Prediction

The *Contractor* shall develop a reliability model and a reliability predication. The model and the input data shall be consistent with the failure analysis. The reliability predications shall be used as:

- a) Timely means to identify problem areas and guide design trade-offs.
- b) As evidence that the reliability requirements will be met.
- c) A basis for test programme planning.

6.9.5 Human Error

The design shall minimise sources of human error in assembly, tests, installation, maintenance and operation of the equipment. A systematic effort shall be directed toward making proper and safe use of the equipment convenient, and toward making improper and unsafe use very difficult.

6.9.6 Maintainability in Design

The *Contractor* shall design the system equipment to minimise both repair and maintenance effort and the need for special skills and tools. The *Contractor* shall include as a minimum the following factors in the maintainability design plan:

- a) Analysis and allocation of scheduled maintenance effort required to keep the equipment in proper working order.
- b) Identify all known non-scheduled repair tasks.

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- c) Scheduled maintenance and repair tasks shall be broken down into job components and identified as test, inspection, disassembly, assembly, and component replacement or adjustment.
- d) For each job, quantitative estimates shall be made of repair frequency, duration, man-hours and parts requirements.
- e) Spare parts provisions and logistic support.
- f) Technical safety requirements.
- g) Works Instructions

6.9.7 Maintenance Support

The *Contractor* shall have a local service organisation with suitable programmes to provide assistance in installation, operation, maintenance and repair. The following functions shall be included:

- a) Advanced preparation of procedures in anticipation of events which cause significant or frequent outages.
- b) Recommended quantities of spare parts required. Technical information concerning spare parts shall include reason for selection (wear, corrosion, etc.) and information concerning storage and re-order lead times.
- c) Maintain the supply of parts for the repair and maintenance of equipment for the normal life of the equipment.
- d) Maintain configuration documentation of each customer unit for the life of the item to enable correct spare part provisioning. The *Contractor* shall, if no longer able to supply spares, supply drawings for items that the customer may wish to procure elsewhere.
- e) Provide installation, operation, repair, and maintenance manuals in compliance with contract requirements. The manuals shall include details of special skills, training, or tools as needed for maintenance work.

7. Design Review Programme

7.1 General

The *Contractor* shall conduct a formal programme of planned, scheduled and documented design reviews of the end item system, sub-system and component level to assure all design specification requirements are met. These reviews shall be comprehensive and critically examine all pertinent aspects of the design. These reviews shall be conducted on a periodic basis starting at the concept phase and at appropriate stages thereafter.

Participation shall be interdepartmental to assure design integration, RAM integration, QA integration and co-ordination with other project functions. Participation shall include representatives from Design, RAM, marketing, manufacturing, QA, test, and other concerned areas of the *Contractor's* organisation. The Design Review Programme Plan shall be included in the RAM Programme Plan. The design review should be concluded before any material is purchased, unless the employer agreement can be acquired beforehand. The ITP must be signed and signed off at the design review.

7.2 Design Review Programme Plan

The *Contractor* shall prepare a Design Review Programme Plan including:

- Practices and procedures employed.
- Check lists of design aspects to be covered at individual reviews.
- Reviews to be accomplished with category definitions.
- Inspection and Test Plan Sign Off

- Chairperson and participants.
- Recording, Publishing and follow-up minutes of Design Reviews.
- Maintaining files of records and documentation of Design Reviews.

7.3 Customer Participation

Participation in Design Reviews shall be required. Design Review documentation and Reports shall be available for customer review at the *Contractor's* facility or at The *Employer's* facility. The *Project Manager* and the Technical Specialist shall have the right to participate in the Design Review Programme. The Employers participation in the Design Review will in no way release the Contractors accountability and responsibility for the Plant.

7.4 Standardization of Design Practices

The application of proven design practices is a key factor affecting reliability. The *Contractor* shall maintain a continuous effort to standardise and formalise its prior practices in manuals for use by design, drafting, fabrication, processing and testing personnel. Deviations from standard practices shall be the subject of particular scrutiny in design reviews. International (IEC) codes and standards shall be used whenever they are practical. The *Employer* has a preference for IEC, codes and standards.

7.5 Parts and Materials Application

The *Contractor* shall implement a programme to ensure that components selected enable the equipment system to meet its requirements to standardise, as well as to minimize the quantity and types of components used on the equipment system. The parts and materials programme shall consist of:

7.5.1 Organisation

Scope of program, function assignments, and procedures for selection, specification, qualification, testing, source selection and control, documentation, application guidance, application review, and field support.

7.5.2 Selection Criteria

Criteria shall be established to control selection of parts and material. The *Contractor* shall establish preferred parts and materials lists. Reapplication of previously qualified items shall require particular attention to correctness of data, applicability of original qualification and adequacy of the specification. The selection effort will determine requirements for additional qualification testing.

7.5.3 Specification

Complete and adequate specifications shall be the basis for the standards for parts and material qualification.

7.5.4 Qualification Testing

The performance capability as well as the quality of parts and materials shall be supported by test data. The results of qualification test shall be used to develop the criteria to be used in acceptance testing. Requalification of parts and materials shall be conducted to insure control over changes in items after initial qualification.

7.5.5 Approved Parts and Materials List

Based on the above selection studies and qualification tests the *Contractor* shall prepare lists of approved parts and material for use in each project.

7.5.6 Parts and Materials application review

Prior to the finalisation of each component, the *Contractor* shall conduct a thorough applications review to determine applicability of each part and material on the design.

Reviews shall:

- Evaluate the completeness of data upon which each part and material selection has been made.
- Evaluate safety margins represented by the latest design data or measurements.

Note: All discrepancies, omissions or data estimates which are considered unlikely or not sufficiently verified.

7.5.7 Documentation

The Parts and Materials Programme shall document performance and environmental capability of parts and materials and usage stresses under which the parts and materials must function in the equipment system. Selection work sheets shall be used to summarise usage requirements for each part and associated materials application in a component.

8. Quality Assurance, Documentation, Quality Control & Tests

8.1 Documentation and Drawings

8.1.1 General

- a) The *Contractor* shall supply to the *Project Manager* complete documentation which will be used for the engineering, construction, testing, operation and maintenance of the shunt/filter capacitor bank. At a minimum, *Contractor's* documentation shall consist of:
 - Construction and Installation Drawings.
 - Construction Materials Submittal.
 - Equipment Drawings.
 - QITP's
 - Operation and Maintenance Manual.
 - Maintenance Schedule.
 - Accepted Programme.
 - Master Test Plan and Procedures.
 - Quality Assurance Manual.
 - Test Reports and Results.
 - Training Manuals.
 - Operating Framework
- b) The *Contractor's* documentation shall provide clear and detailed information to the extent that the maintenance operations, equipment internal to the shunt/filter capacitor supporting frames and the bank upgrading can be easily performed without the manufacturer's intervention.
- c) All documents supplied shall be written in British English and identified in a single document by numbers or by appropriate codes. All dimensioning shall be in the metric system.
- d) The documents shall be correlated in such a fashion that each item and its position in the bank configuration is easily identified by the *Employer* personnel during the project development, maintenance and modifications, and as a permanent record of the system.

- e) Documents and drawings shall be clearly identified and structured for easy reference by the *Employer* personnel responsible for the operation and maintenance of the shunt/filter capacitor bank.
- f) The *Employer* shall have the right to reproduce and use all documentation supplied.

8.1.2 Quantity of Submissions

All documents shall be submitted for the *Project Manager* review and comment. The quantity of documents required for the *Project Manager* shall be in accordance with the following Table: (N of A: Notification of Acceptance).

Table 5: Document submission outline

Title	Review Quantity	Final Quantity	Revision
Const. & Inst. Dwgs.	1	3	As Required
Const. Matl. Submittal	1	3	As Required
Equipment Dwgs.	1	3	As Required
O & M Manual & CD	1	3	As Required
Maintenance Schedule	1	3	30 Days after N of A
Accepted Programme	1	3	Monthly
Master Test Plan and Procedures	1	3	2 Months after N of A
Quality Assurance Manual	1	3	20 Days after N of A
Test Reports	1	3	As Required
Training Manuals	1	3	30 Days Before Start of Class
Electrical Wiring Diagrams	1	3	
Operating Framework			

8.1.3 Drawings

8.1.3.1 Drawings and Diagrams

The *Contractor* shall provide the required sets of outline drawings and wiring diagrams to the *Project Manager* for approval by the *Project Manager*. Where applicable, drawings shall include the information requested below and as described in the section: 8.1.4 Drawings and Diagrams Information:

- a) Outline drawings of the capacitor banks shall show the overall dimensions, location of and all other critical dimensions.
- b) Outline drawings of the capacitor units shall show the dimensions, weights, voltage ratings, kvar rating, BIL and creepage distance over the bushings. They must also include the forces; vertical and horizontal both in the stable and dynamic state.
- c) Outline drawings of the high-voltage insulators shall show all critical dimensions, voltage rating, BIL, cantilever strengths, creepage distance, manufacturer and catalogue number.
- d) Outline drawings of the major components and the complete installation shall be provided.
- e) *Contractor's* drawing number, revision number, sheet number and total number of sheets shall appear on each drawing.
- f) Drawings shall be identified by the drawing identification system endorsed by Eskom.

8.1.3.2 Drawing Review and Approval

The *Project Manager's* review and approval of drawings will be general only and shall not relieve the *Contractor* of responsibility for compliance with the Specification. Drawings will not be reviewed for technical correctness or design concept. (Refer to section:8.1.4 Drawings and Diagrams Information)

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- a) The *Contractor* shall be consistent in his usage of the units selected (Metric) throughout the contract.
- b) All schematic and wiring diagrams shall be Eskom standard drafting symbols.
- c) All drawings shall be carefully checked by the *Contractor* for accuracy, completeness of notes, clearness, continuity of wiring, correctness of phasing and equipment to be installed. The *Contractor* shall be responsible for the correctness of all details of the drawings.
- d) During the construction and testing, the *Contractor* shall make a record of all field changes or corrections. After completion of the testing of the project, the *Contractor* shall revise all drawings so that they accurately reflect the as-constructed facilities.
- e) Review of Drawings: In order to co-ordinate the progress of the project design and to verify that the designs comply with these specifications, the *Contractor* shall submit to the *Project Manager* design review drawings at the 35%, and 75% completion level.
- f) The preliminary drawings submitted shall be accompanied by design memoranda which shall provide, when applicable, all data, calculations and information necessary for an engineering review and understanding of the proposed design. The *Contractor* shall continue with design work while preliminary drawings are being reviewed.
- g) It is anticipated that a design review meeting will be held with the *Contractor* in the *Project Manager's* offices following review of drawing submittals. The *Project Manager* or the *Contractor* may request additional meetings as required.
- h) The *Project Manager* shall have the right to require the *Contractor* to make design alterations for conformance to the design requirements of these specifications without additional costs to Eskom. The review of such alterations shall not be construed to mean that the drawings have been checked in detail, shall not be accepted as justification for an extension of time, and shall not relieve the *Contractor* of the responsibility for the correctness of the drawings.
- i) The *Contractor* shall submit for review a set of final drawings ready for construction. After the design review, the *Contractor* shall stamp the final drawings "Approved for Construction" to indicate that these drawings will be the official drawings used for construction activities.
- j) A final set of signed "Approved for Construction" drawings shall be available on site before construction may proceed.
- k) Computer Aided Design Format: The *Contractor* shall submit in digital form, in addition to the specified drawing requirements, all construction, installation and equipment drawings pertaining to civil, mechanical and electrical activities. Bills of materials and interconnection diagrams shall be included. Drawings shall be Computer Aided Design format, stored on compact disk to suit Eskom CAD workstations with CD ROM drives. CAD drawings shall be compatible with Microstation SE format. In addition, all documentation such as manuals, etc. shall be supplied in a CD ROM format.
- l) Interconnection Diagrams: The interconnection diagrams for major equipment shall be on an individual sheet (or in a drawing series) for each major piece of equipment. The interconnection diagrams shall be complete within themselves and not require reference to another drawing. The physical arrangement of devices and terminals shall be shown as seen when wiring these devices and shall match the equipment layout.
- m) Bill of Materials: The *Contractor* shall prepare complete Bills of Materials covering all material to be supplied by the *Contractor* for the construction of the Project. Bills of Material shall be sufficiently complete so as to allow the future purchase of any single part or assembly as replacement parts.
- n) The description of an item shall be complete but concise, listing only those things which are pertinent; such as, rating, type, catalogue number, and manufacturer. A unit of equipment is not required to be broken down into more than one item on the parts lists.

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- o) Assembly Drawings: Assembly drawings shall be submitted for each type of structure or equipment. Each piece shall be identified by its proper mark number and at each connection the gasket material, if required, the number, type and length of bolts required and the number and type of washers required for proper assembly of the structure or equipment, shall be shown. Torque values for each bolt type shall be specified.
 - p) On each installation drawing there shall also be shown a complete tabulation listing all the material needed for assembly shown thereon, including all bolts, nuts, washers and locknuts. The tabulation shall show the number of pieces required in the structure, the mark number of each piece and the description of each piece.
 - q) Nameplate Drawings: Nameplate drawings of components, where it is general practice in the industry to supply nameplates shall be provided.
 - r) One-Line Diagram: The *Contractor* shall provide a one-line diagram showing the major project layout and electric circuit. Equipment shall be identified in a manner that assists in the review of test plans and is consistent with other drawings.

8.1.4 Drawings and Diagram Information

8.1.4.1 Outline Drawings

They shall include:

- a) The general layout of the bank and line terminals;
- b) The capacitor stacking frame;
- c) The damping/filter reactor/resistor assembly; and
- d) Unbalance and REF current transformer and terminal layout.

8.1.4.2 Construction/Installation Drawings

They shall include:

- a) The capacitor rack holding down bolt detail, bending schedule and specifications;
- b) The damping/filter reactor and damping resistor unit holding down bolt detail and loading details; and
- c) The unbalance and REF current transformer holding down bolt detail and loading details.

8.1.5 Field Assembly Drawings

They shall include:

- a) The bank general assembly;
- b) The capacitor stacking frame assembly;
- c) The bus assembly;
- d) The bus assembly Aux. View (front, side and rear);
- e) The filter (tuning) reactor general assembly (when applicable);
- f) Current transformers.

8.1.5.1 Wiring and Connection Drawings

The following wiring and connection drawings shall be supplied:

- a) The unbalance and REF current transformer wiring diagram.

8.1.6 Accepted Programme

The Accepted Programme shall be updated and issued monthly by the *Contractor*. The Accepted Programme shall be used for contract management purposes and updated prior to the project review meetings and as per the conditions of contract.

8.1.7 Plan and Procedures

The *Contractor* shall submit a Master Test Plan and Procedures indicating the order in which the manufacturing process and tests will be conducted and the test method being used along with required instrumentation. Within 30 days after Notification of Acceptance, the *Contractor* shall submit a preliminary Master Test Plan and Procedures for the *Project Manager's* review.

8.1.8 Quality Assurance Manual

Within 30 days after Notification of Acceptance, the QA Manuals shall be provided.

8.1.9 Study Reports

The *Contractor* shall submit all design study, including RAM and simulation and field test reports to the *Project Manager* in a timely manner in accordance with this specification and the documentation requirements. These reports shall contain assumptions, study methods, results, significant findings and conclusions.

8.1.10 Maintenance Schedule

The *Contractor* shall prepare a comprehensive maintenance schedule listing required maintenance for all equipment based on specific maintenance triggers. This schedule shall cover the thirty year design life and make direct reference to maintenance and spares requirements listed in the manufacturer's Instruction Books.

8.1.11 Test Reports

The *Contractor* shall prepare test reports. Formal test reports are required for all tests listed in the Master Test Plan and Procedures. The test reports will include the subject test plan, required data and discrepancy reports or failure reports resulting from performance of the test. The *Contractor* shall submit test reports for all factory and commissioning tests that are performed.

8.1.12 Training Manuals

30 Days prior to the start of training the *Contractor* shall provide draft training manuals and course outlines for review. The training manuals shall include relevant portions of the Operation and Maintenance Manuals and shall be retained by the students.

8.1.13 Operation and Maintenance Manuals

8.1.13.1 General

The *Contractor* shall supply a set of instruction books (operation and maintenance manuals) for all the plant and material as applicable. Clarity and readability shall be equal to the highest commercial standards. The books shall be orientated toward modification, re-engineering, operation and maintenance of the plant and material without the services or intervention of a manufacturer's representative. The portions devoted to descriptive matter and theory shall be limited to those that are essential to a proper understanding of the plant and material for satisfactory operation and maintenance.

The *Contractor* shall provide all instruction books/manuals also to be available in a CD ROM format for a PC system with a menu driven indexing system and using MS Windows as the operating system, as the majority of the typing packages are in a PC format using Windows. This shall be supplied together with all the relevant software. The documentation shall be supplied in the Microsoft version (see list below) or as agreed with the *Employer*.

- a) MS Word 2010 for Windows or latest version;
- b) MS PowerPoint 2010 for Windows or latest version;
- c) MS Excel 2010 for Windows or latest version.

8.1.13.2 Format

Standard format matter, listed in the normal sequence of appearance, shall consist of:

- a) File Spine

The contents of the file shall be clearly stated, as well as the file number and total number of files in the set.

- b) Title Page

The title page containing the title, contract number, Item number and issue date.

- c) Revision Record

A revision record page containing tabulation columns for the revision code, date, and revision description.

- d) Table of Contents

- A table of contents listing all primary divisions (i.e. chapters, sections, and paragraphs) with their corresponding page, volume numbers and indices.
- A list of drawings containing all figures and drawings, their titles, and page numbers.
- A list containing all tables, their titles, and page numbers.
- Supplier Brochures

- e) Binding

The instruction books shall be a hard cover, 4 ring file construction and they shall open flat at any page. Folders, which do not comply with these requirements, are not acceptable. Different sections of the handbooks shall be separated by means of thumb tab separators. The binders shall adequately protect the contents. The thickness of the binders shall not exceed 75 mm. No more than 50% of the binder capacity shall be used by the *Contractor*. The binders shall be a high commercial grade.

- f) Inserts

- All handbook drawings and descriptions shall conform to the international A4 series (295mm x 210 mm). Larger drawings, which cannot be accommodated, of this size shall be folded in a single plane, along the 210 mm axis of the standard A4 series. Handbook drawings, which must be unfolded in two directions, are not acceptable. Reduced size drawings shall have lower case printing at least 1,6 mm (1/16 inch) high.
- Narrative Descriptions
- Narratives or instructions shall be written for the specific type, class, rating and manufacturer of plant and material and components provided.

- g) Manufacturer's Terminology

Any terminology that is unique to the *Contractor's* plant and material shall be clearly explained by the *Contractor* in a supplementary section bearing the heading "DEFINITIONS".

8.1.14 Contents

The operation and maintenance manuals shall include, but not be limited to, the information specified below:

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- a) Manufacturer's Definitions: All terminology peculiar to the *Contractor's* equipment shall be clearly explained by the *Contractor* in a supplementary section bearing the heading "Definitions".
 - b) Factory Specification of the Equipment.
 - c) Shipping Instructions, Warehouse Storage and Handling Instructions: List of major components for warehouse inspection and site receiving and storage instructions.
 - d) Parts and Factory Service Instructions: Factory repair policy shall be provided. Describe in detail the procedure to obtain spare parts or factory service: (1) under normal conditions, (2) under emergency conditions. Specify the mailing address and telephone number(s) of the service department.
 - e) Installation Instructions: Installation instructions and information to supplement the installation drawings shall be provided. This information shall include power requirements, assembly procedures, safety precautions, grounding instructions, alignment instructions, installation test requirements and details associated with equipment testing to verify proper performance.
 - f) Preventative Maintenance Instructions: Preventative maintenance instructions shall be supplied for all subsystems indicating manufacturers' recommended maintenance intervals based on specific maintenance triggers. These instructions shall include required test procedures, alignment instructions, cleaning requirements and instruction for visual examinations.
 - g) Test Results
 - h) Test failure reports
 - i) Maintenance Schedule: The maintenance schedule shall include maintenance trigger points for each type of equipment. Such trigger points shall identify monitored parameters that can be used to perform preventative maintenance and spares when needed based on operating conditions rather than time based maintenance.
 - j) Troubleshooting Instructions: Troubleshooting instructions shall be to the spare parts level with adequate details for quick and efficient location of cause for equipment malfunction. Include adjustment limits, timing diagrams, troubleshooting and recommended corrective action steps and resetting requirements before return to service.
 - k) Parts Information: This section shall contain a complete parts list and subsections which include a breakdown to the smallest assembly or component considered a replacement part, showing name and description, catalogue number, quantity used and reference by item number on the applicable drawing. The description shall include electrical and mechanical ratings, settings, nameplate drawings, additional instructions or instruction books, testing requirements, wire list, curves, drawings and inspection and installation instructions.
 - l) Spare Parts: Spare parts as recommended by the manufacturer, including the descriptive information listed in the preceding paragraph.
 - m) Tools Information: A list of all tools needed to install or maintain the equipment shall be provided in this section. Tools shall be identified by either the *Contractor's* part number or manufacturer's part number and cross-referenced where applicable. All special tools supplied with the equipment shall be identified as such on the tool list.
 - n) Theory of Operation: Include a system overview and detailed information pertaining to the individual systems and subsystems which make up the Shunt/Filter Capacitor Bank system, as shown on *Contractor* supplied outline, logic, schematic and one-line diagrams. Portions devoted to describing fundamental theory shall be limited to those which are essential to a proper understanding of the equipment operation.
 - o) Installation Procedure: This section shall include a detailed step by step instruction of the test procedure and calibration. Additional information shall include power requirements, assembly procedures, safety precautions and installation test requirements.
 - p) The equipment instruction book shall contain the following information:

8.1.14.1 Description of the Shunt/Filter Capacitor Bank

The shunt/filter capacitor bank description will include:

- a) A general description of the shunt/filter capacitor bank;
- b) A description of the frame-mounted equipment;
- c) The rating details for the frame-mounted equipment;
- d) Photographs of typical shunt/filter capacitor equipment used in that application.

8.1.14.2 Installation Procedures and Instructions on supporting rack equipment:

- a) The capacitor supporting racks;
- b) The capacitor interconnections,
- c) The bus assembly.

8.1.14.3 Operation Instructions:

These instructions shall cover:

- a) Personnel safety;
- b) Capacitor unit failure;
- c) Handling and disposal of capacitor insulating fluid.
- d) Handling of capacitor lifting device
- e) Operating Instructions

8.1.15 Drawing Review

Unless specifically waived by the *Project Manager*, drawing review will be required before commencement of fabrication. The *Project Manager* will examine each drawing submitted and will return, within 14 calendar days, one complete set marked.

After receipt of approved documents, the *Contractor* shall resubmit within 20 calendar days one full-size and two A3 size white print of documents marked "Certified for Construction" and a digital/electronic version on CD rom.

8.1.16 Documentation Requirements:

Documentation submitted shall be accompanied by a letter of transmittal which shall provide the following:

- a) The *Employer* purchase order number.
- b) This Specification number.
- c) Substation name.
- d) The document identification number, title, revision, date.
- e) *Contractor's* description and quantities of items sent.

8.1.17 Delivery/Shipment Documentation

The *Contractor* shall furnish to the *Project Manager* the following documents in the quantities listed below, 30 days prior to shipment of the equipment, unless otherwise specified:

- a) One full-size, reproducible tracing and one full-size, white print of a complete bill of material.
- b) Two copies of certified test reports. Test reports based on the completely assembled equipment shall be sent at the same time the equipment is shipped.

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- c) One A3 size white print of each drawing necessary for installation, testing and maintenance, including complete assembly drawings and schematic diagrams, instruction books, renewal parts list, testing procedures, outline drawings, maintenance schedules and procedures. (Only if not legible in A3 size prints, are original size prints to be provided).
- d) One copy of its instruction and renewal parts book. The instruction books shall be clearly indexed and completely assembled in suitable ring-type binders. Each instruction book, in addition to the minimum information required in this specification and in IEEE Std. 824, shall contain a complete list of materials provided, installing, testing, operating and maintenance instructions, and necessary logic, elementary and schematic diagrams for these purposes. The list of materials shall include a parts list for use in ordering spares or replacements. Complete descriptive and technical pamphlets of all individual components or equipment shall be included in the instruction book. Drawings and instructions necessary to place the equipment into operation, including calibration procedures for the equipment, shall also be included in the instruction books.
- e) Transportation procedure to be approved by the Project Manager before any transport of any plant takes place.

8.2 Quality Programme

- a) The Employer's requirements in terms of quality are specified in NST 39-60 [48].
- b) The Contractor must have at all times a QA Programme, which clearly establishes the authority and responsibility of those responsible for the QA Programme. Persons performing quality functions shall have sufficient and well-defined responsibility and authority to enforce quality solutions to quality problems, and to verify the effectiveness of the solutions. This QA Programme shall be submitted to Eskom with the tender document.
- c) Contractor's Responsibilities for sub contractors: The Contractor shall identify, in purchase documents to its sub contractors all applicable quality and QA requirements imposed by the specification on the Contractor and shall ensure compliance thereto. The Contractor has the responsibility for co-ordinating all the quality activities specified in the work contract.
- d) Contractor's Quality Assurance Interface: The Contractor shall be subject to audits, inspections, and witnessing by the Project Manager to ensure compliance with the requirements of the specification, codes, drawings and submittals. The Project Manager's exercise of, or failure to exercise, his right to inspect, witness or audit shall not relieve the Contractor of his obligation to comply with the terms and conditions of the Contract.
- e) Manufacturing, Test and Inspection Plan: After notification of Acceptance, but prior to the commencement of manufacturing and procurement of material, the Contractor shall submit copies of his Manufacturing and Inspection Plan to the Project Manager. As a minimum, the Manufacturing Test and Inspection Plan shall outline the basic manufacturing/production/testing sequence and specific pre-planned Contractor inspections that are to be performed. Employers witness and hold points to be incorporated.
- f) The Contractor will set up a design reviews.
- g) Deviations and Non-conformances: No deviations will be accepted until approved in writing by the Project Manager. Deviations are considered departures from any requirement of this specification.
- h) All equipment supplied on this contract to be attended to by the Employers representative not later than 1 month after each order placement.
- i) The quality programme shall include the following activities:
- Planning and execution of inspections and tests – hold and witness points for Testing;
 - Establishing quality level and requirement for sub-contractor work;
 - Assessing supplier's quality programmes and documentation;
 - Verification and auditing of supplier's product quality and the manufacturing capability and process;

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- Establishing and maintaining quality records; and
- Ensuring that all contractual quality requirements with the Employer are met.
- Quality control plan shall include:
 - Engineering specifications;
 - Sub-contractor purchase order;
 - Supplier quality programme manuals and verification documents;
 - Quality Inspection and test plans;
 - Plant and Equipment check-lists;
 - Test reports and inspection records;
 - Materials certificates
 - Test and monitoring equipment calibration certificates
 - Supplier quality assurance audits;
 - Corrective/preventative action records and
 - NCR monitoring system and reports.

8.3 Testing and Reliability Evaluation

8.3.1 General

The *Contractor* shall establish a programme directed toward evaluating equipment system reliability throughout the design and development process. This shall be accomplished by an integrated test programme conducted in parallel with a reliability assessment programme that will incorporate the results of the tests.

8.3.2 Testing

The *Contractor* integrated Test Programme shall be designed to evaluate all aspects of performance capability of the equipment system and its elements and shall include evaluation of reliability throughout the tests at various equipment levels. Qualification tests and environmental testing using overstress, testing to failure, and life testing are an essential part of the test programme. These and other tests shall be planned using statistical design of experiment techniques insofar as practicable and shall be conducted under levels of environmental stress and for periods of time appropriate to the purpose of the test. Tests shall be based on a concept of failure pattern and directed toward:

- a) Evaluating susceptibility to known or identified failure modes.
- b) Identifying unknown interactions among components.
- c) Identifying failure modes that reflect deficiencies in material, workmanship and Quality Control.
- d) Verify design performance including reliability and life expectancy.

Test Specifications, Procedures and Reports

- a) Environmental and performance conditions.
- b) Monitoring variables affecting significant failure modes.
- c) Testing time or cycles.
- d) Allowable maintenance.
- e) Logging requirements.
- f) Analysis method.

- g) Reliability goal.
- h) Allowable failure for each test.
- i) Definition of failure.
- j) Ageing

Failure Reporting and Correction Action

The *Contractor* shall employ a strictly controlled system for reporting, analysis, corrections and data feedback of all failures and malfunctions that occur throughout the fabrication, handling, test, checkout, and operation of the equipment. This system shall emphasise reporting and analysis of all failures and malfunctions that occur regardless of their apparent magnitude. The system shall assure timely and appropriate evaluation, corrective and recurrence control action and follow-through are accomplished by responsible design, fabrication, quality and field personnel (This system need only be referenced in the Reliability Programme if already covered in the Quality Programme).

8.4 Inspection and Tests

Inspection and test requirements consist of design reviews, factory evaluation, testing at works (type and routine tests), factory acceptance tests (FAT), shipping/transportation inspection and monitoring plan, preservation/storage plan, installation evaluation, site acceptance tests (SAT) for main components and sub-systems, commissioning tests, performance verification and acceptance tests, as well as extended performance acceptance tests and RAM requirements. General procedures consist of the development and submission of Inspection, monitoring and Test Plans to the *Project Manager* for review and comments, successful completion of the tests by the *Contractor* (witnessed by the *Project Manager*), and the submission of test reports by performing each test, in accordance with the requirements of this specification and the General Conditions of Contract.

The *Employer* reserves the right to witness and hold the manufacturing/testing stages of the equipment as required and identified on ITP.

General procedures involve the provision as per IEC 60871:

- a) A Master Test Plan,
- b) Design Review,
- c) Manufacturing Inspection and Test Plans
- d) Specific Test Plans (type, routine),
- e) Shipping/Transportation Inspection and Monitoring Plan
- f) Preservation/Storage Inspection Plan
- g) Site Inspection during installation
- h) Site Acceptance Test Plan,
- i) Pre Commissioning Test Plan ,
- j) Commissioning Test plan
- k) Performance Acceptance Test Plan,
- l) Extended Performance Acceptance Test Plan (RAM).

The scope and details of items a) to g) above shall be submitted to the *Project Manager* four weeks after *Notification of Acceptance*, where after the final scope and details of all testing shall be agreed with the *Project Manager* within seven weeks after the *Notification of Acceptance*.

In addition to the tests called for, the *Contractor* shall submit proposals for tests to demonstrate the capability of the complete shunt/filter capacitor bank device to meet the required duty.

The *Contractor* shall supply all necessary labour and test equipment to perform all tests and inspections that are the *Contractor's* responsibility.

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The cost of all routine, type, shipping/transportation, preservation/storage, site and commissioning inspections, monitoring and tests shall be included in the tender price for the plant and material.

8.4.1 Testing Responsibilities

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

All tests that require connection of the shunt/filter capacitor bank to the *Employer's* main distribution system (shunt/filter capacitor bank HV bus) shall be done under the supervision of the *Project Manager* and in accordance with the *Employer's* safety requirements and operating regulations. (Refer to E 32/846 [52]). Energised system testing shall be kept to a minimum.

The *Contractor* shall provide recorders and energization procedures as part of the Commissioning Test Plan based on *Employers* commissioning standards.

The tests shall be performed in a fashion to minimise unanticipated disturbances on the power system. These tests may have to be performed during the low load periods. Low load periods are defined as nights, weekends, vacation and summer seasons as may be deemed appropriate by the *Employer*.

8.4.2 Inspection and Test Plan (ITP)

The Inspection and Test Plan shall be in accordance with this specification and shall cover all aspects of testing and inspection. The preliminary and detailed ITP shall be submitted to the *Project Manager*.

As a minimum, the following plant and material shall be included in the Master Test plan:

- a) Capacitors;
- b) Filter circuit ,
- c) Unbalance current transformers.
- d) Restricted earth fault transformer
- e) Damping circuits (damping reactors and damping resistors)

8.4.3 Inspection and Testing

All inspecting and testing requirements as stated herein shall be adhered to and such information as is required under this specification shall be made available to the *Project Manager*. The *Project Manager* reserves the right to visit and inspect the *Contractor's*, or any of his subcontractor's, works during the course of this contract. Notification period is 8 weeks.

The *Contractor* shall be responsible for all the provisions of these visits to the *Contractor's* or subcontractor's works. All material, equipment, personnel for all tests shall be supplied by the *Contractor* at no extra cost unless specified differently in this specification.

8.4.3.1 Inspection (General)

Plant and material manufactured in South Africa and overseas for the installation portion of the contract, the *Project Manager* will carry out the inspections or may employ a representative for inspections.

The *Contractor* shall give the *Project Manager* at least eight (8) weeks' notice of the time at which the *Contractor* expects to:

- a) Perform design review
- b) Commence manufacture of major components
- c) Commence manufacture of accessories

Carry out the specified tests. This requirement is necessary to ensure that the *Employer*

This requirement is necessary to ensure that the employers can make arrangements to attend these activities.

The *Project Manager* will not be responsible for any delays in delivery due to the failure of the *Contractor* to observe the requirements of this clause.

Before preparing plant for despatch to stores or site, the plant shall be inspected and released in writing by the *Employer* to ensure compliance with the contract and shall be marked to that effect before being submitted to final works inspection, by the *Project Manager*.

8.4.3.2 Testing (General)

Unless otherwise stated or approved the tests to be carried out shall be those set down in the relevant *Employer* Standards and other international Standards and in particular IEC 60871-1,-2,-3. Where a Standard provides for agreement on testing between the "Manufacturer" and the "Purchaser" the *Contractor* shall ascertain the *Project Manager's* requirements and carry out the tests in accordance with them.

If standards for testing a particular plant and material do not exist, the *Contractor* shall develop detailed test procedures, which will be subject for review, comments, acceptance modification, rejection and additions by the *Project Manager*.

All type and routine tests required to prove that the plant and material meets the requirements of this specification shall be carried out by an approved testing authority at the *Contractor's* expense with the involvement of the *Employer*. These tests shall include any reasonable mechanical, electrical, thermal or hydraulic test, which may be called for by the *Project Manager* to ensure compliance with the requirements of this specification.

The *Contractor* shall submit details of any tests additional to those included herein which he believes are necessary to prove the performance and reliability of the plant and material.

Prior to any test, the calibration of all measuring/control/monitoring equipment shall be demonstrated by the *Contractor* to comply with the relevant Standard or shall be approved by the *Project Manager*. Details of the test equipment and instruments used shall be noted in the test sheets where the instrument or plant and material characteristics can have a bearing on the test results.

In addition to particular tests required by the Specification, for which the cost shall be included in the contract, the *Project Manager* may carry out such other tests as the *Project Manager* may deem necessary to ensure that all work (design, manufacturing, testing, installation, testing and commissioning) complies in all respects with the requirements of the contract.

The passing of any inspection or test in the manufacturer's works, shipping/transportation, preservation/storage, erection and commissioning at site shall not prejudice the right of the *Project Manager* to reject the whole or part of the plant, if it does not comply with the requirements of the contract when placed in service at site.

If parts fail or are replaced during testing, a full written description and explanation shall be provided to the *Project Manager* within 48 hours and shall be included in the final test report. The Non Conformance Report (NCR) and Corrective Action Report (CAR) shall also be recorded by the contractor.

If any piece of equipment provided as part of the system does not pass a test or is damaged, the *Contractor* shall immediately replace or repair the failed or damaged equipment and modify the equipment design, if applicable, so as to minimize the possibility of further failure.

The *Contractor* shall perform the test previously performed on any equipment or assembly, which is to be replaced, repaired or modified. All expenses for the material, removal, re-installation and re-testing shall be the responsibility of the *Contractor*.

No tests as agreed under the programme of tests shall be waived except upon the instruction or agreement of the *Project Manager* in writing.

The *Contractor* shall record all the procedures and results of the tests clearly, in an approved form and with clear reference to the plant and material and items to which they refer, so that the record can be used as the basis for maintenance tests during the working life of the plant and material. The required quantity of site test results records shall be provided by the *Contractor* to the *Project Manager* within 2 weeks of the completion of the test. Test records and certificates shall form part of the documentation of the shunt/filter capacitor bank.

In addition to the requirements specified in NST 39-60 [48], the *Contractor* shall establish a Test Programme designed to evaluate all aspects of performance capability and reliability of the equipment supplied throughout tests conducted under environmental stress and for period of time approximate to the purpose of the tests.

8.4.3.3 Type Tests

Type tests establishing the performance detailed in the Schedules and elsewhere in this specification shall be carried out in accordance with the requirements of the relevant IEC specifications. Type tests shall demonstrate the adequacy of a particular type, style, or model of plant and material to meet assigned ratings and to operate satisfactorily under specified operating conditions.

Copies of the test certificate of type tests that have been carried out previously on plant with similar and material shall be submitted as part of the tender. All required type tests shall be carried out according to the relevant IEC standards.

A complete list and cost of all type tests required by this specification shall be included in the Activity Schedule. Type test certificates for tests carried out after the date of an order or letter of acceptance will not be accepted unless the *Project Manager* or representative has witnessed the tests. The results of all such tests shall be subject to review, comments and approval or rejection by the *Project Manager*.

In order to assist the *Project Manager* in making provision for inspection and witnessing of testing, the name of the manufacturer and place of manufacture where the plant and material can be inspected and the place where plant and material will be tested, shall be given in the Accepted Programme. Should the *Contractor* wish to change to another manufacturer or manufacturing facility, he shall submit to the *Project Manager* in writing and in due time, before commencing manufacturing, all the new details as listed above.

The *Contractor* shall advise all sub-Contractors at the time of placing orders or sub-orders that all plant and material may be subject to inspection and witnessing of tests by the *Project Manager*.

8.4.3.4 Routine Tests

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

8.4.3.5 Capacitor Units Tests

The type and routine tests shall be performed in accordance with IEC 60871 and 240-76429758 on one capacitor unit of each type and rating.

8.4.3.6 Filter (Tuning) Reactors Tests

The type and routine tests shall be performed in accordance with 240-42587021 and IEC 60076 on one reactor unit of each type and rating.

8.4.3.7 Unbalance and Restricted Earth Fault Current Transformers Tests

One unbalance current transformer and restricted earth fault current transformer of each type and rating shall be type tested in accordance with IEC 61869 -1 & 2. All current transformers shall be routine tested in accordance with IEC 61869 -1 & 2.

8.4.3.8 Post Insulators

The type and routine tests shall be performed in accordance with 240-56030435 on one capacitor unit of each type and rating [10].

8.4.3.9 Surge Arrestors

The type and routine tests shall be performed in accordance with 240-75540566 on one surge arrestor unit of each type and rating [8].

8.4.3.10 Damping Resistors (Where applicable)

a) Type Tests

The following type tests shall be performed on one damping resistor of each type and rating used:

- Measurement of resistance referred to a temperature of 20 °C;
- Heat run test to confirm the continuous kJ rating;
- Short time current test to prove the specified short time kJ rating; and
- Impulse test applied across the resistor.

b) Routine Test

Each damping resistor shall be subjected to the following routine test:

- Measurement of resistance referred to a temperature of 20 °C.

8.4.3.11 Test Certificates

The *Contractor* shall provide three copies of test certificates (certified by the manufacturer) summarising all tests conducted on the plant and material. Where appropriate, latest logs and graphs for all tests and three copies of all such certificates, failure reports, NCR's, CAR's, test logs and graphs shall be supplied for approval as specified.

Information shall be given on each test certificate, test logs and graphs sufficient to identify the material or plant to which the certificate, test logs and graphs refer, and the certificate, test logs and graphs shall be endorsed with the following wording:

Employer Specification No (number to be provided by the Employer).

The relevant manufacturer's serial number, Eskom contract or order number and the item number shall be stated on each test certificate. Applicable site name to be reflected.

Inspection reports submitted to the Project Manager, notwithstanding that these may contain full details of all readings taken, will not be accepted in lieu of test certificates or type test results. In addition, one copy of all instrument readings recorded, all graphs drawn and all calculations made during any tests conducted to prove compliance with this specification shall be supplied to the Project Manager on completion of the tests.

Original readings and calculations will be accepted provided that the results can be derived from the information given. The Contractor shall retain a complete set of routine test certificates for a period of five (5) years after the tests were done and these shall be stored under the conditions specified in NST 39-60.

8.4.3.12 Tests after Delivery

After delivery of the plant and material and before it is put into commercial use (end of trial operation) the *Project Manager* will carry out such tests as may be considered expedient and necessary to prove that the plant and material fulfils the requirements of this specification.

The *Contractor* will provide all labour, material and equipment necessary for the tests, any expense incurred by the *Contractor* in having representatives present shall be borne by the Contractor.

8.4.3.13 Rejection of Plant

If the plant and material, or any part thereof, fails to give satisfactory results under these tests, then all costs incurred in making good the plant and material and of carrying out further tests shall be borne by the *Contractor and reports to be submitted within 48 hours*.

8.4.4 Capacitor Bank Tests

8.4.4.1 Capacitance Measurement

The following capacitance shall be measured and recorded after erection of the bank to confirm that the bank is properly balanced:

- a) Individual units capacitance measurements
- b) Resulting total capacitance of each parallel group or series string of units, of each module and of each phase.
- c) Resulting total capacitance of each phase
- d) Insulation Test.

8.4.4.2 Unbalance Current Transformer Measurement

- a) The supplier must provide the test certificate that indicates the ratios of all current transformer cores
- b) The supplier must provide the test certificate that indicates magnetisation curve tests results that were done on all the secondary cores of each current transformer.
- c) Insulation test to be done by the supplier after the installation.

8.4.5 Site Acceptance Tests (SAT)

Tests on completion of erection (after all the plant and material has been installed and set up on site), shall be carried out by the *Contractor* in accordance with the relevant *Employer* Standards and for the requirements listed below. The site acceptance test plan shall be reviewed by the Engineer before any plant and material is installed at the site.

The purposes of these tests are to:

- a) Provide the Employer with comparative plant and material data for a benchmark;
- b) To verify that no shipping/transportation, preservation/storage damage has occurred;
- c) To verify that the plant and material or system was assembled correctly;
- d) To ascertain the plant and material is ready for energised testing.

The *Contractor's* test engineer shall advise the *Project Manager's* site representatives at the end of each week which tests he will be performing during the next week.

The *Contractor* shall advise the *Project Manager* in writing at the time of site access of the site supplies (AC and DC) which will be required for the operation of the test equipment, to enable the Employer to provide these supplies or to agree to alternative arrangements should this be necessary.

All tests shall receive verification by the *Project Manager* that the tests have been performed and the results were acceptable. These tests shall include all tests that require joint testing between the *Project Manager* and the Contractor.

8.4.5.1 SAT Requirements

All tests that require interfacing to the *Employers* plant and material shall be conducted jointly with the *Project Manager's* staff.

These tests shall include, but not be limited to the following:

- a) Identification and Nameplates: Verification of accuracy of nameplate information and application;
- b) Connectors tightness torque;
- c) Insulation resistance,

- d) Clamps/joints contact resistance
- e) Capacitor inspection
- f) Filter/Damping reactor inspection;
- g) Unbalance and restricted earth fault current transformers inspections
- h) Earthing Tests

8.4.5.2 Pre Commissioning Tests

The pre commissioning tests are those tests to be performed at the site on the fully assembled Project facility with the circuit breaker and the isolator switch open and the capacitor bank not connected to the Employer's power system.

These tests shall include, but not limited to the following

8.4.5.3 Checkout Tests:

- a) Visual inspection of capacitor units;
- b) The *Contractor* shall measure and verify that the capacitance of each unit within acceptable limits and shall record the measured capacitance;
- c) The Contractor shall advise on protection coordination requirements and levels;
- d) Capacitance checks of the three phases of shunt/filter capacitor bank: The *Contractor* shall measure and verify that the capacitance of each phase is within acceptable limits; and
- e) In addition to the tests listed above, the *Contractor* shall specify any additional checkout tests, which will be performed.
- f) Earthing suitability

8.4.5.4 Performance Acceptance Tests: (System Commissioning Tests)

Upon satisfactory completion of the Project pre commissioning tests, system commissioning tests shall be performed. System commissioning tests are those tests performed at the site on the fully assembled facility and the shunt/filter capacitor operating and connected to the *Employer's* power system. Initial energising records of the voltage, current and unbalance currents to be recorded by the *Contractor*. Point on wave functionality under energised conditions with the recordings of the voltage and current conditions. The *Employer* will arrange these tests. The *Contractor* will be notified 14 working days in advance of such tests and will be allowed to witness them. These tests may be conducted during low load period, such as nights, weekends, vacation or summer seasons. All test results and recordings must be handed to Eskom within one week of completion.

8.4.5.5 Extended Performance Acceptance Tests

If it is not possible due to system constraints to test all facets of the system function as part of the system commissioning tests specified above, actual operating experience will be documented through sequence of events recorders, digital fault recorders and other system monitoring equipment capable of identifying system disturbances and associated system performance.

Documented failure or malfunction of any system component during the Guarantee Period shall be deemed as a failure of the system commissioning or performance acceptance tests and the *Contractor* shall, at no expense to the *Employer*, make the necessary repairs, replacements, modifications or adjustment to prevent the same failure or malfunction from occurring again.

The replacement of certain system components, in response to a system failure, may necessitate, at the discretion of the *Employer*, the duplication of certain system commissioning tests which shall be performed at the *Contractor's* expense.

If system conditions prevent completion of the performance acceptance tests following the commissioning and functional tests, the *Project Manager* may choose to perform additional performance acceptance tests during commissioning or at any time during the 12 month period following completion. The *Employer* will provide all labour, material and equipment necessary for the tests but any expense incurred by the *Contractor* in having representatives present shall be borne by the Contractor.

Time needed to conduct these tests will not delay acceptance. These tests could include, but not be limited to performance tests.

8.4.5.6 Completion of Works

The Completion of the Works is inclusive of the following items:

- a) Successful completion of all Site Acceptance, Commissioning and Performance Acceptance tests as specified;
- b) Complete operational and functional shunt/filter capacitor installations as defined in this specification;
- c) Shunt/filter capacitor installation available for continuous operation as defined in this specification;
- d) All deliverables delivered (as defined in this specification but not limited to that noted below):
 - Documentation (Manuals and Drawings);
 - Training;
 - RAM programme, studies and guarantees; and
 - Spares.

All deliverables received, safely delivered and accepted by the Project Manager.

9. Maintenance, Training and Spares

9.1 Maintenance Guarantee Period (Defects Liability Period)

- a) The Contractor shall be responsible for all maintenance and repair work on equipment supplied by him, during the guarantee period (defects liability period 24 months from commissioning).
- b) At least one (1) month before the shunt/filter capacitor is commissioned, the Contractor shall submit for approval, the name, qualification, experience and factory training of the engineer or technician who will be available locally for any repair or maintenance work during the guarantee period and during commissioning and during the RAM period.
- c) Alternatively, the Contractor shall guarantee to provide an experienced engineer or technician in South Africa from the factory or manufacturer's works to undertake any emergency repair or maintenance work within 12 hours of notice from Eskom.
- d) The Contractor shall supply at his own expense maintenance personnel, all tools, equipment, material and replacement units, that will be required to complete any maintenance or repair work during the guarantee and RAM period.

9.2 Maintenance after Guarantee Period

The Contractor shall provide Maintenance Schedules for the shunt/filter capacitor equipment. The Maintenance Schedules and manuals explaining the requirements shall contain information on:

- a) The periodic replacement or refurbishment of individual components in order to maintain the bank's availability and reliability at the required level.
- b) The outage periods required for the routine maintenance of each apparatus to comply with RAM requirements.
- c) The manpower required to carry out the maintenance of each equipment or part of it.

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d) The design service life of each device.

e) Spares required

The Contractor shall compile a report specifying calculated design values for availability and reliability of the equipment used.

The Contractor shall specify for all equipment supplied the number of spare units (or spare parts) which are required to operate the filter capacitor installation for 25 years without facing maintainability problems.

9.3 Training of Employer Personnel

9.3.1 General

The *Contractor* shall provide training of Eskom's personnel or its representatives in the manufacturer's works and at the *Employer's* relevant site, in order that they gain the necessary instructions for repairing and maintaining the filter capacitor bank after the guarantee period has expired. This training shall be provided before the bank goes into service and be repeated at the end of the guarantee period.

The *Project Manager* shall determine the actual training location.

The *Contractor* shall provide training and training material including as part of this contract for the shunt/filter capacitors as specified below. The *Contractor* shall determine the content and duration of each training session. The suggested class duration in this specification is meant to illustrate the level of all trainees (i.e. a written test) is required for all classes.

9.4 Maintenance and Safety Training

The Contractor, with the assistance of his equipment suppliers shall conduct a training class of the Employer's maintenance/technical personnel at site. The duration of the training class is anticipated to be 1 to 2 days with 10 Employer participants. The training class shall be aimed at properly familiarising the personnel with the shunt/filter capacitor bank and the designer's theory.

Should the Project Manager determine the training to be inadequate, additional training shall be provided to the Employer by the Contractor at no additional charge to the Employer to guarantee adequate knowledge of the system for the Employer's personnel.

The maintenance training shall include, but not be limited to:

- a) Normal maintenance methods;
- b) Condition monitoring;
- c) Repairs and replacement
- d) Diagnostic procedures;
- e) Equipment calibration;
- f) Re-energisation;
- g) Safety Practises:
- h) Demonstration of using the capacitor lifting device:
- i) Special tests.
- j) Compilation of cold commissioning procedure

9.5 Spares

9.5.1 General

- a) The price schedules shall include costs for the manufacture, testing, long term packing and delivering to site of the spare parts. The prices stated shall be valid for a period of one (1) year after the placing of the order and shall not be subject to any change at the time of ordering or the number of each part that the Employer may eventually decide to purchase.
- b) Spares shall be packed for long term storage (24 months) in separate crates, clearly labelled and dispatched to the relevant filter capacitor site, unless instructions to the contrary are received.
- c) Any special safety requirements that need to be adhered to regarding the spares shall be indicated on the cases, i.e. individual capacitor units that need to be short-circuited to prevent spontaneous charge build-up.
- d) Each item of the spares in a crate shall be suitably identified by means of a metal label and lists complete with diagrams showing the application of all parts supplied. The Employer's order or contract number shall appear on the cases containing spares.
- e) All spares shall be delivered to site, correctly calibrated, tested and configured at site before the start of the trial operation.

9.5.2 Spare Parts

Spare parts for the shunt/filter capacitor installation shall be provided as follows:

9.5.2.1 Capacitors

A minimum of 5% spares per capacitor installation

9.5.2.2 Current Transformers and Insulators

A minimum of one of each type and rating used.

9.5.2.3 Filter (Tuning)/ Damping Reactor

In accordance with 240-42587021 [2].

9.5.2.4 Damping Resistors

A minimum of one of each type and rating used.

9.5.2.5 Post Insulators

In accordance with 240-56030435 [10].

9.5.2.6 Surge Arrestors

In accordance with 240-75540566 [8].

9.5.3 General Spares List

Spare parts of items not covered above but which will be required during the RAM guarantee period shall be supplied in sufficient quantities to cover the three-year period.

9.5.4 Spares List

A detailed spares list with the description, price and lead time of every different part that will be required as spares for possible replacement during the operating life of the shunt/filter capacitor installation, shall be submitted to the Project Manager with the tender.

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9.5.5 RAM Spares

The number of spare parts required to satisfy the equipment availability shall be determined by failure rate data used in the RAM calculations (see section RAM), the number of similar parts installed, and the mean time to repair or replace.

In the event that spare part utilisation exceeds the calculated levels, the Contractor shall increase the number of spare parts so that the quantity supplied is sufficient for 5 years of operation taking into consideration the replacement lead time.

The original spares level to be re-instated by the Contractor after the RAM period following the use of any spares during the RAM period.

A complete list together with a price option shall be included with Annexure A. The Employer will determine whether this option will be included in an order.

9.6 Maintenance Instruments

9.6.1 General

A device for lifting, removing and replacing the capacitor units shall be supplied by the *Contractor*. The design of the lifting device shall be such that it can be safely operated in the shunt/filter capacitor area by one person with associated bays in the high voltage yard still in service.

9.6.2 Capacitance Meters

One set of portable instruments for testing capacitor units shall be supplied to be used on both installations.

A set of instruments shall consist of (2) two capacitance meters. One meter to be of the hand held type and the second shall be a bridge injection type for each substation.

Both meters may be of the digital type with the following features:

- a) The meters shall be built into a small, robust, portable panel with a lid and carrying handle.
- b) The meters shall be accurate to two decimal points and of accuracy of $\pm 1\%$.
- c) The meters shall be designed so that the capacitance of individual capacitor units belonging to a parallel group or a series string in the bank may be tested without opening any connection in the bank. The current rating and the testing range of the instrument shall permit the capacitance of the largest group of parallel or series string of capacitor units to be measured without the instrument being overloaded.
- d) The sensitivity of the meters shall allow the detection of one element that has failed in a fuseless unit.
- e) The meters shall be provided with the means to isolate the capacitor units in a discharged condition prior to the commencing of any capacitance measurement.
- f) Details of the testing instruments shall be submitted for the Project Manager's approval at the time of tendering.

9.7 Defects Liability Period

The defects liability period will be 24 months from hot commissioning of the plant.

9.8 Interchangeability

All capacitor units, damping resistors, filter/damping reactors and CT's of a particular type shall be identical and completely interchangeable (electrically and mechanically) with one another at any time. This includes equipment in different phase positions.

10. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Neels van Staden	Senior Consultant
Preshnee Chetty	Design Manager
Aroon Sukhnandan	Senior Engineer
Michael Govender	Plant Sector Manager
Nerandra Krishnaswamy	Senior Engineer
Tyne Muller	Senior Engineer
Mohamed Khan	Senior Engineer
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Nomkhosi Gumede	Network Planning Middle Manager
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Arushen Govender	Engineer
Siyabonga Madlala	Engineer
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Sibusiso Mpanza	Technician Electrical
Caldon Smith	Snr Supervisor Tech Plant
Nivashin Naidoo	Engineer
Dayahalen Chetty	Network Optimisation Manager
Akheel Ambaram	Engineer
Devan Nardhamuni	Zone Manager
Martin Pietersen	Specialised Maintenance Manager
Moeketsi Mathosa	Plant Middle Manager
Dave Oerder	Project Manager
Agrippa Mpontshane	Sector Manager
Siyabonga Mbokazi	Engineer

11. Revisions

Date	Rev	Compiler	Remarks
March 2022	Draft 0	J. K. Raghubir	First Issue – Based on Apollo Substation Capacitor Bank Specification

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12. Development team

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

- Vuyani Masuku
- Neels Van Staden

13. Acknowledgements

Not applicable.

Annex A – Schedules A and B

SCHEDULE A: PARTICULARS OF ESKOM'S REQUIREMENTS AND

SCHEDULE B: SUPPLIER'S GUARANTEES OF TECHNICAL PARTICULARS OF EQUIPMENT OFFERED.

IN CASE OF CONFLICT THIS SCHEDULE SHALL TAKE PRECEDENCE, AND ALSO SHALL COMPLY WITH THE LATEST REVISION OF ALL RELEVANT IEC STANDARDS.

WHERE XXXXX IS INDICATED, THE SUPPLIER MUST COMPLETE IN SCHEDULE B.

Item	Description	Units	Schedule A	Schedule B
1	GENERAL			
1.1	Summary of Requirements			
1.1.1	Number of new 3-phase banks required		2	
1.1.2	Substation		Makhathini	
1.1.3	Nominal distribution system voltage (UN)	kV (rms)	22	
1.1.4	3-phase output at nominal system voltage	MVA _r	3	
1.1.5	Erection and commissioning required		Yes	
1.2	Access and completion dates			
1.2.1	Delivery not before		As per project schedule	
1.2.2	Erection and commissioning completed not later than		As per project schedule	
1.3	Site Details			
1.3.1	Site location		Makhathini Substation, Kwa-Zulu Natal	
1.3.2	IEC pollution classification	mm/kV	Extra Heavy Pollution classification as per the latest version of IEC 60815	
1.3.3	Within 20 km of the coast		Yes	
1.3.4	Transport to site		Road	
1.3.5	Contractor responsible for off-loading from transport vehicle		Yes	
1.3.6	Crane facilities available on site		No	
1.3.7	400/230 V, 3-phase, 4-wire, 50 Hz construction supply: Available on site		Yes	
1.3.8	Maximum space available for shunt capacitor banks including safety fence for a three phase	m	5m x 5m	

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Item	Description	Units	Schedule A	Schedule B
	installation			
1.4	Service Conditions			
1.4.1	Ambient temperature	°C	30	
1.4.2	Maximum		40	
1.4.3	Minimum		-10	
1.4.4	Daily average		30	
1.4.5	Yearly average		20	
1.4.6	Average daily temperature variation		25	
1.4.7	Altitude above sea level	m	95	
1.4.8	Maximum solar radiation	watts/mXm	2,5 x 10 3	
1.4.9	Wind loading	kPA	1.2	
1.4.10	Environmental conditions		High humidity	
1.4.11	Seismic	g	0.3	
1.5	Distribution System Details			
1.5.1	Nominal voltage (UN)	kV	22	
1.5.2	Maximum continuous voltage (UM)	kV	24.2	
1.5.3	Frequency (fN)	Hz	50	
1.5.4	Maximum steady state variation	Hz	+/- 0.15	
1.5.5	Minimum steady state variation	Hz	+/- 0.15	
1.5.6	Minimum system frequency	Hz	47.5	
1.5.7	Duration for minimum system frequency	s	60	
1.5.8	Maximum system frequency	Hz	51	
1.5.9	Duration for maximum system frequency	s	15	
1.5.10	Maximum guaranteed performance	Hz	50.5	
1.5.11	Minimum guaranteed performance	Hz	49.5	
1.5.12	Number of phases		3	
1.5.13	System effectively earthed		Yes	
1.5.14	Maximum short-circuit current level at 22kV: Symmetrical	kA	10	
1.6	Routine and Type Test Certificates to be supplied		Yes	
1.7	Spares to be delivered to		To be confirmed	

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Item	Description	Units	Schedule A	Schedule B
1.8	Special Requirements		Check all capacitors in last month of guarantee and replace faulty units	
2	SHUNT/FILTER CAPACITOR BANK			
2.1	Rating and Connections			
2.1.1	Nominal distribution system voltage, UN	kV rms	22	
2.1.2	Over voltage ratings, UM	kV rms	24.2	
2.1.3	Output of the 3 phase per bank at nominal distribution system voltage and frequency	MVA _r	3	
2.1.4	Total capacitance per phase per bank (Main Capacitors)	μF	19.73	
2.1.5	Voltage rating per phase (Main Capacitors)	kV rms (Line to ground)	13.97	
2.1.6	Total capacitance per phase per bank (Decoupling Capacitors)	μF	140.522	
2.1.7	Voltage rating per phase (Decoupling Capacitors)	kV rms	Specify	
2.1.8	Tuned frequency per phase	Hz	50	
2.2	Tolerances			
2.2.1	Single units or bank with one unit per phase		0 to +5%	
2.2.2	Above 30 MVA _r total rating		0 to +5%	
2.2.3	Ratio between min and max capacitances between any two line terminals		<1.08%	
2.3	Connections			
2.3.1	Bank Configuration		Specify (Double Star / Single Star / H)	
2.3.2	Neutral		Earthed	
2.3.3	Inrush current - Peak value	kA	100 x I_N rms	
2.3.4	Number of inrushes per year over 25 years life of the bank		1500 per year	
2.4	Losses			

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Item	Description	Units	Schedule A	Schedule B
2.4.1	Maximum total losses of bank at rated voltage and frequency and at an ambient temperature of 20 °C	kW	≤ 0.1 kW per kVAr	
2.4.2	Number of drawing illustrating the layout of the bank		XXXXX	
2.4.3	Drawing copies per bank		3	
3	CAPACITOR UNITS			
3.1	General			
3.1.1	Rated voltage Un	kV rms	6.986	
3.1.2	Minimum over voltage ratings(per unit of rated capacitor voltage)			
3.1.2.1	Continuous average:	p.u	1	
3.1.2.2	12 h in every 24 h:		1.1	
3.1.2.3	30min in every 24 h:		1.15	
3.1.2.4	5 min, 200 times		1.2	
3.1.2.5	1 min, 200 times		1.3	
3.1.2.6	5 seconds		1.5	
3.1.2.7	1 second		1.75	
3.1.3	Rated output at rated voltage and frequency (QN)	kVAr	Specify (Typically 302.5)	
3.1.4	Rated nominal capacitance Cn	μF	Specify (Typically 19.73)	
3.2	Arrangement of Capacitor Units in a Bank			
3.2.1	Configuration		Specify (Double Star / Single Star / H)	
3.2.2	Fuse technology		Specify (Internal Fused /Fuseless)	
3.2.3	Number of units in series		Specify	
3.2.4	Number of strings		Specify	
3.2.5	Total number of capacitors per bank		Specify	
3.2.6	Spares per bank		Specify	
3.3	Loss Tangent Delta			
3.3.1	At ambient temperature of 25°C		XXXXX	
3.3.2	At elevated temperature for type test in		XXXXX	

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Item	Description	Units	Schedule A	Schedule B
	accordance with IEC 60871-1			
3.4	Bushings			
3.4.1	Number on each capacitor unit		2	
3.4.2	Impulse withstand voltage at sea level (1.2x50µs)	kV peak	150	
3.4.3	60s power frequency wet withstand voltage at sea level	kV rms	See Table 1	
3.4.4	Total creepage distance	mm/kV	To comply with Extra Heavy Pollution classification as per the latest version of IEC 60815	
3.5	Capacitor Elements			
3.5.1	Number of capacitor element groups in series in each capacitor unit		XXXXX	
3.5.2	Number of capacitor elements in each parallel group		XXXXX	
3.5.3	Rated voltage of elements (Un)	kV rms	XXXXX	
3.6	Capacitor Internal Insulation			
3.6.1	Type of insulation (film, etc.)		XXXXX	
3.6.2	Rated field strengths in film kV/mm		XXXXX	
3.6.3	Rated field strengths in fluid kV/mm		XXXXX	
3.6.4	Insulation to container in one or two bushing units			
3.6.4.1	Impulse withstand voltage	kV peak	XXXXX	
3.6.4.1	60s power frequency withstand Voltage	kV rms	XXXXX	
3.6.5	Insulating fluid, if Mineral oil is used it must comply to ES32-406		No PCB	
3.7	Discharge Device			
3.7.1	Type		XXXXX	
3.7.2	Time to discharge to 50 V	minutes	5	
3.7.3	Resistance	ohms	XXXXX	

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Item	Description	Units	Schedule A	Schedule B
3.8	Details of The Container			
3.8.1	Material details		Stainless steel	
3.8.2	Thickness details		XXXXX	
3.8.3	Finish		XXXXX	
3.8.4	Overall length		XXXXX	
3.8.5	Overall width		XXXXX	
3.8.6	Overall height including bushings		XXXXX	
3.8.7	Mass	kg	≤ 65	
3.8.8	Paint colour and specification		XXXXX	
3.9	Rack Details			
3.9.1	Materials		XXXXX	
3.9.2	Finish		XXXXX	
3.9.3	Number of capacitor units on each rack		XXXXX	
3.9.4	Number of series groups on each rack		XXXXX	
3.9.5	Maximum voltage between racks at rated bank voltage		XXXXX	
3.10	Inter Rack Insulation			
3.10.1	Rated voltage	kV rms	XXXXX	
3.10.2	Type reference	kV rms	XXXXX	
3.10.3	Impulse withstand voltage at sea level	kV line-line	XXXXX	
3.10.4	60s power-frequency wet withstand voltage at sea level	kV peak	XXXXX	
3.10.5	Total creepage distance	mm/kV	To comply with Extra Heavy Pollution classification as per the latest version of IEC 60815"	
4	MAIN CAPACITOR UNBALANCE CURRENT TRANSFORMERS			
4.1	General			
4.1.1	Type		Post	

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Item	Description	Units	Schedule A	Schedule B
4.1.2	Location and connection		Star Point	
4.1.3	Number of post current transformers on the bank		1	
4.1.4	Number of spares		1	
4.2	Core Details			
4.2.1	Number of secondary cores		3	
4.2.2	Core 1		5/1	
4.2.3	Core 2		5/1	
4.2.4	Core 3		20/1	
4.2.5	Rated Burden	VA	10	
4.2.6	Accuracy Class limit factor		10P10	
4.2.7	Drawing number of magnetisation curve		XXXXX	
4.3	Current Ratings			
4.3.1	Continuous rating	A rms	XXXXX	
4.3.2	Fuseless application	A rms	XXXXX	
4.3.3	1s rating	A rms	XXXXX	
4.3.4	Peak asymmetrical current rating	kA	1.5	
4.4	Total primary and secondary leakage inductance referred to the primary	μH	XXXXX	
4.5	Surge arrester or gap for CT primary winding protection			
4.5.1	Type designation		XXXXX	
4.5.2	Continuous operating voltage		XXXXX	
4.5.3	Discharge current withstand strength		XXXXX	
4.6	Insulation levels to earth			
4.6.1	Rated voltage	kV rms L-L	22	
4.6.2	Lightning impulse withstand voltage at sea level	kV peak	As per Table 3	
4.6.3	60s power-frequency wet withstand voltage at sea level	kV rms	As per Table 3	

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Item	Description	Units	Schedule A	Schedule B
4.6.4	Total creepage distance	mm/kV	To comply with Extra Heavy Pollution classification as per the latest version of IEC 60815"	
4.7	Type Tests and Certificates (IEC 61869-2)			
4.7.1	Impulse test		YES/NO	
4.7.2	Mechanical strength and sealing test		YES/NO	
4.7.3	Dielectric dissipation factor test		YES/NO	
4.7.4	Long duration voltage test		YES/NO	
4.7.5	Chopped impulse tests		YES/NO	
4.7.6	Internal arc withstand capability test		YES/NO	
5	EARTHING CAPACITOR UNITS			
5.1	Power frequency ratings			
5.1.1	Rated voltage (Un)	kV	825	
5.1.2	Rated nominal capacitance Cn	µF	781	
5.1.3	Continuous average:	p.u	1	
5.1.4	12 h in every 24 h:	p.u	1.1	
5.1.5	30min in every 24 h:	p.u	1.15	
5.1.6	5 min, 200 times	p.u	1.2	
5.1.7	1 min, 200 times	p.u	1.3	
5.1.8	5 seconds	p.u	1.5	
5.1.9	1 second	p.u	1.75	
5.1.10	Rated output at rated voltage and frequency (Qn)	kVAr	167	
5.2	Loss tangent delta (as per IEC)			
5.2.1	At an ambient temperature of 20 °C		XXXXX	
5.2.2	At elevated temperature for type test in accordance with IEC 60871-1		XXXXX	
5.3	Bushings			
5.3.1	Number on each capacitor unit		2	

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Item	Description	Units	Schedule A	Schedule B
5.3.2	Impulse withstand voltage at sea level (1,2 x 50 micro second)	kV peak	XXXXXX	
5.3.3	60s power frequency wet withstand voltage at sea level	kV rms	XXXXXX	
5.3.4	Total creepage distance	mm/kV	to comply with Extra Heavy Pollution classification as per the latest version of IEC 60815"	
5.4	Capacitor elements			
5.4.1	Number of capacitor element groups in series in each capacitor unit		XXXXXX	
5.4.2	Number of capacitor elements in each parallel group		XXXXXX	
5.4.3	Rated voltage of elements (Un)		XXXXXX	
5.5	Capacitor Internal Insulation			
5.5.1	Type of insulation (film, etc.)		XXXXXX	
5.5.2	Rated field strengths in film kV/mm		XXXXXX	
5.5.3	Rated field strengths in fluid kV/mm		XXXXXX	
5.5.4	Insulation to container in one or two bushing units			
5.5.4.1	Impulse withstand voltage	kV	XXXXXX	
5.5.4.1	60s power- frequency withstand voltage	kV	XXXXXX	
5.5.5	Insulating fluid		No PCB	
5.6	Arrangement of capacitor units in a bank			
5.6.1	Configuration		Neutral Point	
5.6.2	Fuseless configuration per H leg		XXXXXX	
5.6.3	Number of units in series		1	
5.6.4	Number of strings		XXXXXX	
5.6.5	Total number of capacitors per bank		1	
5.6.6	Total units		1	
5.6.7	Spares per bank		1	
5.6.8	Total no of Spares		1	
	One capacitor shall be used for every 100 A of rated current (78.4A)			

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Item	Description	Units	Schedule A	Schedule B
5.7	Bushings			
5.7.1	Number on each capacitor unit		2	
5.7.2	Impulse withstand voltage at sea level (1.2x50µs)	kV peak	See table 2	
5.7.3	60s power frequency wet withstand voltage at sea level	kV rms	See table 2	
5.7.4	Total creepage distance	mm/kV	Comply with Extra Heavy Pollution classification as per the latest version of IEC 60815"	
5.8	Discharge Device			
5.8.1	Type		XXXXX	
5.8.2	Time to discharge to 50 V	minutes	5	
5.8.3	Resistance		XXXXX	
5.9	Details of the container			
5.9.1	Material details		Stainless steel	
5.9.2	Thickness details		XXXXX	
5.9.3	Finish		XXXXX	
5.9.4	Overall length		XXXXX	
5.9.5	Overall width		XXXXX	
5.9.6	Overall height including bushings		XXXXX	
5.9.7	Mass	kg	≤ 65	
5.9.8	Paint colour and specification		XXXXX	
6	RESTRICTED EARTH FAULT CURRENT TRANSFORMERS			
6.1	Core details			
6.1.1	Type		Ring	
6.1.2	Location connection		Between Star and neutral common rail	
6.1.3	Number of current transformers per bank		1	
6.1.4	Number of spares		1	
6.1.5	Number of secondary cores		1	

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Item	Description	Units	Schedule A	Schedule B
6.1.6	Ratio Core 1		Specify	
6.1.7	Rated Burden	VA	XXXXXX	
6.1.8	Accuracy class and limit factor		TPS	
6.1.9	Drawing number of magnetisation curve		N/A	
6.2	Current ratings			
6.2.1	Continuous rating	A	XXXXXX	
6.2.2	Fuseless	Arms primary	400	
6.2.3	1s rating		600	
6.2.4	Peak asymmetrical current rating	kA	1.5	
6.3	Total primary and secondary leakage inductance referred to the primary	μH	XXXXXX	
4.7	Type Tests and Certificates (IEC 61869-2)			
4.7.1	Impulse test		YES/NO	
4.7.2	Mechanical strength and sealing test		YES/NO	
4.7.3	Dielectric dissipation factor test		YES/NO	
4.7.4	Long duration voltage test		YES/NO	
4.7.5	Chopped impulse tests		YES/NO	
4.7.6	Internal arc withstand capability test		YES/NO	
7	GENERAL INFORMATION			
7.1	Manufacture of:			
7.1.1	Capacitor units		XXXXXX	
7.1.2	Supporting insulators		XXXXXX	
7.1.3	Capacitor racks		XXXXXX	
7.1.4	Unbalance current transformers		XXXXXX	
7.1.5	Restricted earth fault transformer		XXXXXX	
7.1.6	Measurement instruments		XXXXXX	
7.1.7	Lifting device		XXXXXX	
7.1.8	Insulated neutral cable		XXXXXX	
7.1.9	Filter (Tuning) reactors		XXXXXX	
7.1.10	Damping resistors		XXXXXX	

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Item	Description	Units	Schedule A	Schedule B
8	FILTER (TUNING) REACTORS	See Reactor AB Schedules separately attached		
9	DAMPING RESISTORS			
9.1	General			
9.1.1	Number to be supplied on each three-phase filter bank including spare		4	
9.1.2	Mounted separately or on top		Specify – dependent on space required	
9.2	Total Resistance per Phase			
9.2.1	Resistance at 20°C	Ω	300	
9.2.2	Tolerance	%	+/- 2.5	
9.2.3	Continuous current rating	A rms	Specify	
9.3	Total Resistance per phase			
9.3.1	Minimum continuous rating	kW	Specify	
9.3.2	Short time rating for one second	kW	XXXXX	
9.4	Temperature rise at rated power		XXXXX	
9.5	Insulation Level	kV peak	150	
10	COUPLING CAPACITOR UNBALANCE CURRENT TRANSFORMERS			
10.1	General			
10.1.1	Type		Post Type	
10.1.2	Location and connection		Between H Halves / Star Point	
10.1.3	Number of post current transformers on the bank		3	
10.1.4	Number of spares		1	
10.2	Core Details			
10.2.1	Number of secondary cores		2	

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Item	Description	Units	Schedule A	Schedule B
10.2.2	Core 1		XXXXX	
10.2.3	Core 2		XXXXX	
10.2.4	Core 3		XXXXX	
10.2.5	Rated Burden	VA	10	
10.2.6	Accuracy Class limit factor		10P10	
10.2.7	Drawing number of magnetisation curve		XXXXX	
10.3	Current Ratings			
10.3.1	Continuous rating		XXXXX	
10.3.2	Fuseless application		XXXXX	
10.3.3	1s rating		XXXXX	
10.3.4	Peak asymmetrical current rating		XXXXX	
10.4	Total primary and secondary leakage inductance referred to the primary		XXXXX	
10.5	Surge arrester or gap for CT primary winding protection			
10.5.1	Type designation		XXXXX	
10.5.2	Continuous operating voltage		XXXXX	
10.5.3	Discharge current withstand strength		XXXXX	
10.6	Insulation levels to earth			
10.6.1	Rated voltage	kV rms	22kV	
10.6.2	Lightning impulse withstand voltage at sea level	kV peak	See table 2	
10.6.3	60s power-frequency wet withstand voltage at sea level	kV peak	See table 2	
10.6.4	Total creepage distance	mm/kV	31	
10.7	Type Tests and Certificates (IEC 61869-2)			
10.7.1	Impulse test		YES/NO	
10.7.2	Mechanical strength and sealing test		YES/NO	
10.7.3	Dielectric dissipation factor test		YES/NO	
10.7.4	Long duration voltage test		YES/NO	
10.7.5	Chopped impulse tests		YES/NO	
10.7.6	Internal arc withstand capability test		YES/NO	

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Item	Description	Units	Schedule A	Schedule B
11	DAMPING RESISTOR CURRENT TRANSFORMERS			
11.1	General			
11.1.1	Type		Post Type	
11.1.2	Location and connection		Specify	
11.1.3	Number of post current transformers on the bank		3	
11.1.4	Number of spares		1	
11.2	Core details			
11.2.1	Number of secondary cores		2	
11.2.2	Core 1		XXXXX	
11.2.3	Core 2		XXXXX	
11.2.4	Core 3		XXXXX	
11.2.5	Rated Burden	VA	10	
11.2.6	Accuracy Class limit factor		10P10	
11.2.7	Drawing number of magnetisation curve		XXXXX	
11.3	Current ratings			
11.3.1	Continuous rating	A rms	Specify	
11.3.2	Fuseless application	A rms	XXXXX	
11.3.3	1s rating	A rms	XXXXX	
11.3.4	Peak asymmetrical current rating	kA	XXXXX	
11.4	Total primary and secondary leakage inductance referred to the primary	µH	XXXXX	
11.5	Surge arrester or gap for CT primary winding protection			
11.5.1	Type designation		XXXXX	
11.5.2	Continuous operating voltage	kV	XXXXX	
11.5.3	Discharge current withstand strength		XXXXX	
11.6	Insulation levels to earth			
11.6.1	Rated voltage	kV rms L-L	22kV	
11.6.2	Lightning impulse withstand voltage at sea level	kV peak	See table 2	
11.6.3	60s power-frequency wet withstand voltage at	kV peak	See table 2	

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Item	Description	Units	Schedule A	Schedule B
	sea level			
11.6.4	Total creepage distance	mm/kV	31	
11.7	Type Tests and Certificates (IEC 61869-2)			
11.7.1	Impulse test		YES/NO	
11.7.2	Mechanical strength and sealing test		YES/NO	
11.7.3	Dielectric dissipation factor test		YES/NO	
10.7.4	Long duration voltage test		YES/NO	
10.7.5	Chopped impulse tests		YES/NO	
10.7.6	Internal arc withstand capability test		YES/NO	

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Annex B – Deviation Schedule
(Normative)

DEVIATION SCHEDULE		
<p>1) Any deviations/modifications/alternatives offered to standard specification shall be listed below with reasons for the departures.</p> <p>2) No deviations/modifications/alternatives offered to the specification will be recognized unless listed on this schedule.</p> <p>3) If no deviations/modifications/alternatives are offered, this schedule must be marked - "Not applicable".</p>		
SPECIFICATION/ SCHEDULE PAGE NUMBER	SPECIFICATIO N/ SCHEDULE CLAUSE NUMBER	PROPOSED DEVIATION/MODIFICATION/ ALTERNATIVE

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