Eskom	Standard	Technology

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Content

1. Introduction

Air core reactors are utilised in a number of applications, including shunt, static var compensators, filters, capacitor banks, HVDC schemes, current limiting, neutral grounding, etc. These reactors are single phase reactors connected phase-to-earth, phase-to-neutral or between phases in a power system, in series with capacitor banks, in-line for current limiting, etc. These reactors are used for limiting current during fault conditions, reducing inrush or discharge current in capacitor banks and reducing harmonics, voltage control when used as a shunt, among other things. This document outlines the general requirements for air core reactors as well as the specific requirements for different reactor applications.

2. Supporting clauses

2.1 Scope

This specification outlines general requirements for design, manufacture, testing, supply and installation of air core reactors, applying to various reactor applications.

2.1.1 Purpose

The purpose of this document is to outline Eskom's requirements for air core reactors.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

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

2.2.1 Normative

[1] IEC 60060-1, High Voltage test techniques – Part 1: General definitions and test requirements.

[2] IEC 60076-1, Power transformers – Part 1: General.

[3] IEC 60076-2, Power transformers – Part 2: Temperature rise for liquid-immersed transformers

[4] IEC 60076-3, Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air

[5] IEC 60076-5, Power transformers – Part 5: Ability to withstand short circuit

[6] IEC 60076-6, Power Transformers – Reactors

[7] IEC 60076-10, Power transformers – Part 10: Determination of sound levels

[8] IEC 60076-11, Power transformers – Part 11: Dry-type transformers

[9] IEC61378-2, Converter transformers – Part 2: Transformers for HVDC applications

[10] IEC 60518, Dimensional standardization of terminals for high-voltage switchgear and controlgear

[11] IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V

[12] IEC 60273, Characteristic of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V

[13] IEC 60551, Audible sound

[14] IEC 60721-2-6, Classification of environmental conditions. Part 2: Environmental conditions appearing in nature. Earthquake vibration and shock

[15] IEC 60943, Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals

[16] IEEE P57.16/D7-2010, Standard requirements, terminology and test code for dry-type air-core series-connected reactors

[17] IEEE 57.21, Standard requirements, terminology and test code for shunt reactors over 500 kVA

[18] IEEE 1277-2010 Standard general requirements and test code for dry-type and oil-immersed smoothing reactors for DC power transmission

[19] IEEE 32-1972, Standard requirements, terminology and test procedure for neutral grounding devices

[20] SANS 10103, The measurement and rating of environmental noise with respect to annoyance and to speech communication

[21] 240-56030435, outdoor ceramic station post insulators for systems with nominal voltages up to 765kV specification

[22] 240-79707491, technical evaluation standard for outdoor ceramic station post insulators for systems with nominal voltages up to 765kV

[23] 240-89963721, Technical evaluation standard for air core reactors

[24] ISO 9001, Quality Management Systems

2.2.2 Informative

[25] 32-9, Definition of Eskom documents.

[26] 32-644, Eskom documentation management standard

[27] 474-65, Operating manual of the Steering Committee of Technologies (SCOT)

[28] QM58, Supplier contract quality requirements specification

[29] TPC41-246, Management of Manufacturers/Supplier Equipment Drawings

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

Public domain: published in any public forum without constraints (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
HVDC	High Voltage Direct Current
NER	Neutral Earthing Reactor
SVC	Static VAr Compensator
TCR	Thyristor Controlled Reactor

2.5 Roles and responsibilities

The Air Core Reactor Care Group Coordinator must ensure that this document is updated, renewed and current at all times.

2.6 Process for monitoring

Eskom will provide and update this document as required.

2.7 Related/supporting documents

Not applicable.

3. General requirements

The technical requirements for all air core reactors are outlined below.

3.1 Ratings

Detailed information on the rating of the reactor including all the necessary electrical requirements can be found in Schedule A. Some additional requirements are listed below:

- A minimum life expectancy of 40 years is required.
- The reactors shall be suitable for a continuous operation at the maximum operating voltage, U_m as specified in Schedule A, without exceeding 80 K winding temperature rise.
- The reactors shall be designed for continuous operation at maximum system voltage (U_m); they shall be capable of withstanding mechanical, electrical and thermal stress that may arise due to abnormal conditions in the system or during fault conditions.
- The reactors shall be capable of handling short circuit forces based on a pre-fault voltage of 1.1 pu and maximum design short circuit level with an infinite busbar configuration.
- Audible noise levels from the reactors shall be coordinated to meet the requirements in Section 3.4 and Schedule A of this specification as well as the applicable IEC standards.
- The number of switching operations per day is specified in Schedule A of this specification.

3.2 Tolerances

3.2.1 Impedance

The reactor impedance tolerance shall comply with the requirements listed in Schedule A of the enquiry document according to the reactor application.

3.2.2 Losses

The total power losses measured and corrected shall not exceed the declared values.

Eskom shall apply penalties on any losses that exceed the guarantee according to a capitalised loss evaluation with the coefficient of evaluated cost of load loss as indicated in Schedule A of the enquiry document.

For the purpose of tender evaluation, Eskom will consider the losses as part of the capital cost over the lifespan of the unit when using the capitalised loss coefficient.

If the measured losses exceed the guaranteed value, Eskom reserves the right to reject the reactor.

No credit or payment of premium will be made should the actual values be better than the guaranteed values.

3.3 Reactor construction

The complete winding assembly shall be encapsulated to provide full protection against extreme weather, direct sunlight and temperature variations.

The reactor shall be finished with a uniform RTV coating on its exposed surfaces. This coating shall be tested in accordance with IEC 62217 section 9.3.2 accelerated weathering.

The contractor shall submit evidence that the material can withstand prolonged exposure to sunlight and ambient conditions as specified in Schedule A of this specification.

The reactor spiders/clamping structures shall be prepared according to the relevant corrosion standards.

The equipment shall be constructed such that:

- It is not affected by normal handling during transport;
- Maintenance can be carried out conveniently and safely;
- The finish of all components is free from surface blemishes and sharp edges.

The reactor assembly mounted on its pedestal insulators shall provide a minimum clearance as specified in Schedule A, between the live metal/insulator base and earth. Each reactor shall be mounted on outdoor type insulators with mechanical and electrical characteristics suitable for continuous operation under the specified conditions.

The reactor shall be supplied complete with all the necessary support structures and hardware and shall be designed for mounting outdoors with its longitudinal axis vertical.

Connections between the winding and the line terminals, as well as connections between concentric cylinders of the winding shall be welded. No joints will be permitted internal to the winding.

Line terminals shall consist of terminal pads complying with IEC 60518. The number of bolted connections will be specified in Schedule A. The terminals shall be made of corrosion-resistant, high-conductivity Aluminium. Terminals other than Aluminium terminals may beused only with prior approval from Eskom.

Steel support structures shall be galvanised, complying with SANS 1461.

Each reactor shall be supplied complete with stainless steel mounting bolts. All nuts and bolts shall be fitted with approved anti-vibration locking devices. All fasteners shall be stainless steel – Grade 316 bolts with Grade 304 nuts and washers. Thread lubrications shall be applied to all bolts and nuts. Any good quality, high temperature grease is acceptable, but silicon-based grease is preferred.

The holding-down bolts on supports or concrete foundations shall be suitable for a 15mm thick supporting structure top plate in the case of steel and for grouting in the case of concrete.

The following fittings shall be provided:

- rating and diagram plates
- structural earthing terminals for 50 x 3 mm copper strap
- lifting lugs
- pedestal insulator

All structural and fence metalwork, including foundations, should be designed to avoid, as far as possible, metallic loops and parallel circuits in which induced currents can run.

Each reactor must be designed and constructed such that maintenance can be carried out safely and conveniently.

3.4 Reactor crating

The reactor shall be placed in a non-returnable crate, suitable for handling by overhead crane and forklift truck. The crate shall bear permanent markings for: “correct side up”, “centre of gravity”, “sling connections” and “total weight” (crate and reactor).

The crate shall be constructed of a material that is suitable for long-term (> 10 years), outdoor storage. Any special storage and maintenance requirements shall be specified.

The reactor crate shall be equipped with an inspection window, situated to allow convenient inspection of transportation impact indicators.

The reactor details (make, type and rating) shall be marked on the crate, where they can be conveniently read.

3.5 Audible sound level

The sound level emanating from the reactors shall be less than that specified in Schedule A of this enquiry at a distance as specified in Schedule A from the surface of the reactors; no octave band measurement being above the specified sound pressure level.

If the tendered equipment does not meet the specified sound levels, the manufacturer shall include an offer to provide and put in place sound abatement measures to reduce the sound levels to the specified level.

Installation of these measures shall not compromise the maintainability of the reactor or the circuit in which it operates. Fire retardant materials shall be used for any necessary sound abatement measures.

Any sound abatement measures required shall be stipulated in Schedule B of this enquiry and be included in the tender price.

3.6 Vibration

The reactor shall be designed to minimise all vibration and to minimise transmission of vibration to other equipment.

The maximum vibration level shall be less than 100 µm.

The reactor shall be designed such that the reactor's mechanical resonant frequency does not coincide with the system frequency or its lower order harmonics.

3.7 Seismic requirements

The complete reactor installation, including post insulators and pedestals, is to withstand a minimum of 0.3g seismic activity without damage to the reactor installation.

The reactor's capability to operate with the specified seismic requirements must be demonstrated by calculation in accordance with IEC 60721-2-6.

3.8 Pollution mitigation

Pollution levels are specified in Schedule A. Should mitigation measures such as top hats, special coatings, etc. be required for the specified pollution levels, the manufacturer is to inform Eskom of these measures and any additional maintenance requirements and include this in the reactor design.

Any pollution mitigation measures required shall be stipulated in Schedule B of this enquiry and be included in the tender price.

Demonstration of the reactor's ability to withstand the specified pollution level must be made during the design review and testing.

Measures shall be taken to provide vermin-proofing.

The reactor's post insulators shall comply with the [21] and will be evaluated as per [22].

The insulators shall be hydrophobic and be open-aerodynamic (no under-ribs). The insulators shall be capped.

For insulators rated 132 kV and below, the insulators shall be KIPTS tested. For insulators rated > 132 kV, an equivalent profile, lower voltage rated insulator shall be provided for KIPTS testing.

3.9 Temperature rise

Full details of how hot spot temperature is calculated and measured shall be provided by the manufacturer as part of the tender response.

The reference temperature shall be the calculated/tested temperature rise of the reactor plus 20 °C.

The temperature rise shall not be exceeded when the reactor is operated at or below the specified overload rating and shall be limited as per the values stipulated in Table 2 of [8].

During the temperature rise test, the ultimate temperature rise is considered to be reached when the temperature rise does not vary more than 1 K during the last hour and the testing time is at least five times the thermal time constant of the reactor. If the thermal time constant is incorrectly estimated and the duration of the temperature-rise test is not sufficient (based on 5 times the thermal time constant), then the temperature-rise test is to be repeated.

3.10 Tests

The required tests are specified in Schedule A of this specification. If required, the following tests shall be performed in accordance with the latest IEC specification at the specified test levels:

3.10.1 Routine Factory tests (mandatory)

- Measurement of winding resistance
- Measurement of impedance at rated continuous current
- Measurement of incremental inductance
- Measurement of losses at ambient temperature: Specification of the method of test is to be provided and documentation qualifying the accuracy of the proposed method is to be provided. All metal parts forming part of the support structure of the reactor shall be in place during this measurement.
- Measurement of harmonic current loss
- Turn-to-turn overvoltage test
- Lightning impulse test
- Switching impulse test
- Overvoltage / Overload (as defined)

3.10.2 Type tests (optional, as specified)

- Temperature rise test at rated continuous current: The Temperature rise test shall be carried out on each reactor with maximum continuous rating and during this test the following shall be measured; Total losses, current and reactance.
- Measurement of acoustic sound levels
- Measurement of loss and quality factor

3.10.3 Special tests (optional, as specified)

- Short-circuit test
- Measurement of harmonics of the current
- Double-ended lightning impulse test
- Measurement of coupling factor
- Wet lightning impulse test

- Measurement of acoustic sound level at service temperature.
- Inrush current withstand test
- Modified short-circuit / discharge test
- Mechanical resonance test

Should a short-circuit test not be specified, the supplier is to submit calculations demonstrating the reactor's ability to withstand thermal and mechanical short-circuit stresses and highlight the design considerations.

Special tests shall be quoted for separately in the tender and shall be accompanied by test certificates for units of identical or similar design.

Suppliers are invited to submit details (including costs) of any special tests they recommend, particularly tests designed to detect conditions which might lead to premature failure of reactor elements and units.

Should any difficulties arise with the performance of these tests, alternative arrangements shall be made by Eskom and the manufacturer.

Any limitations in test levels for any of the specified tests shall be highlighted by the manufacturer at the tender stage and shall be included in the list of deviations included in the Schedule B.

Should the reactor fail any of the specified tests, the manufacturer shall bear all costs incurred by Eskom as a result of retesting and re-inspection.

3.11 Drawings and instruction manuals

3.11.1 Contract drawings

The following drawings shall be supplied in both soft and hard copy in English:

- Reactor outline
- Nameplate
- Magnetic clearance requirements for external structures as well as between phases
- Details of winding construction and all clamping and support hardware

All drawings shall be supplied to Eskom within one month of the design review. These drawings shall be managed according to [29].

3.11.2 Instruction manuals

The manufacturer shall provide instruction manuals (printed in English), in both hard and soft copy, outlining packaging and storage requirements, installation and maintenance. Specifications and test results shall also be included in the manuals.

Six hard and soft copies of these documents are required.

These manuals shall be subject to review prior to any work being completed.

3.12 Interchange ability

All reactors of a particular type shall be identical and completely interchangeable (electrically and mechanically) with one another at any time. This includes reactors in different phase positions.

3.13 Condition monitoring

The manufacturer shall inform Eskom of any condition monitoring techniques that are available, both on and off-line. Any condition monitoring equipment supplied shall not reduce/limit the life expectancy of the reactor and shall also have a minimum life expectancy equal to or exceeding that of the reactor. All required tools and test equipment shall be provided to Eskom. All condition monitoring shall be costed separately.

3.14 Name / Rating plate

A nameplate of etched or engraved (printing is not acceptable) stainless steel (Grade 316) at least 1.2 mm thick shall be supplied and attached at a height that can be safely and conveniently read while the reactor is in service.

In addition to the information specified in IEC 60076-6 the following information shall be included on the nameplates:

- Service voltage
- Reactance and resistance
- Employer's name and specification
- Eskom order number
- Measured losses
- Seismic rating

3.15 Transport

It shall be the supplier's responsibility to make all arrangements for transport with the appropriate authorities. Eskom will only accept delivery of the reactors from the supplier on site. It shall be the supplier's responsibility to co-ordinate the arrangements for all stages of the transport and off-loading of the reactor from the manufacturer's works to site. The dimensions of the reactor shall be such that when packed for transport, it will comply with the requirements of the loading and clearance restrictions for the approved route.

The manufacturer of the reactor shall specify the maximum gravitational forces that the reactor is designed to withstand in all directions during the design review meeting. Impact indicators with the required forces shall be attached to the reactors, in all directions, at the factory and shall remain on the reactor until it is in its final position. These indicators shall be clearly observable without disturbing transport crating. The indicators shall be inspected as part of the quality process at each point of the transportation process. Should the acceleration limit be exceeded, Eskom shall be notified immediately.

3.16 Overload capability

The required overload capability of the reactor is specified in Schedule A of this specification. The manufacturer is to provide detail on the overload capability of their design.

3.17 Design review

Eskom reserves the right to do a complete review of the design of any reactor tendered for, as part of the technical evaluation, before or after the placing of orders for that particular reactor. The design review shall be concluded no later than one month after the order is placed with the contractor.

A design review meeting is required before procurement of any materials. The purpose of the design review is to allow Eskom to understand the basic design, manufacturing and installation of the reactor. Eskom may appoint a consultant to attend the design review.

Eskom reserves the right to reject a reactor design if the manufacturer fails to demonstrate that the design is capable of meeting the specified and/or internationally accepted criteria for the required reactor. Eskom's acceptance of the design does not absolve the manufacturer of any responsibility/liability regarding the performance of the design.

The manufacturer is required to provide information on the design of the mechanical, dielectric and thermal strengths of the reactor, including overload capabilities and all manufacturing processes, as a minimum. A minimum safety margin of 20% shall be demonstrated on all design parameters.

Should a design review be required, the manufacturer shall inform Eskom a minimum of 8 weeks prior to the design review. Minutes shall be taken recording all discussions and final decisions taken during the design review and shall be submitted to Eskom.

The manufacturer shall not make any changes to the design, materials to be used, or any other change to the reactor once the order has been placed, without prior approval from Eskom.

3.18 Tender adjudication

Tender adjudication shall be done in line with the scoring matrix included in Appendix B.

3.19 Deviations from specification

The supplier shall notify Eskom of any deviations from the specification and these deviations must be highlighted in the appropriate section in the submitted schedules.

Final written approval shall be provided by Eskom, once a technical evaluation has been completed and equipment has been found in compliance with this specification and Eskom requirements.

3.20 Inspections

Prior to placement of any orders, Eskom shall perform an assessment of the factory and only factories complying with the audit requirements shall be considered.

Eskom reserves the right to inspect the reactor/s at any point during manufacturing and to witness all tests that are performed. An inspection and test plan (ITP) shall be provided to ensure that all hold and witness points are identified by Eskom. The ITP must be agreed to and signed off by Eskom technical and quality responsible persons, prior to the commencement of any work.

The manufacturer shall inform Eskom at least 8 weeks prior to the identified hold/witness points.

Should a reactor fail under test, the supplier shall notify Eskom, officially, in writing within 24 hours of the failure. The supplier will set up a meeting with Eskom to discuss and agree on the way forward. The supplier shall inform Eskom of the date of investigation of the failure. The supplier will supply Eskom with a written report on the failure and actions to be taken within 30 days of the failure.

The manufacturer is to demonstrate their capability to design and supply reactors by supplying Eskom with a comprehensive reference list for all reactors of identical or similar design. This list shall outline the size and ratings of supplied equipment as well as the customer and country to which the reactors were supplied.

3.21 Spares

The price schedules shall include costs for the manufacture, testing, long term packing and delivering to site of any spares specified. The prices stated shall be valid for a period of one year after the placing of the order, and shall not be subject to any conditions as to the time of ordering or the number of units that may eventually be purchased.

Spares shall be packed for long term storage in separate crates, clearly labelled and dispatched to the relevant site, unless instructions to the contrary are received. The procedure outlining long term storage requirements shall be supplied by the manufacturer.

Each reactor shall be supplied with a set of 2 (two) spare insulators complete with all required fittings and bolts.

3.22 Training

Training shall be supplied to five Eskom employees for a period of one month with a three yearly frequency as part of the contract. This training will cover the following as a minimum:

- Design
- Manufacturing

- Testing
- Installation and commissioning
- Maintenance

4. Shunt reactors

This section covers the specific requirements for shunt reactors. Shunt reactors are reactors which are connected phase-to-earth, phase-to-neutral or between phases in a power system to compensate for capacitive current. This includes Thyristor Controlled Reactors (TCR) for application in Static Var Compensators (SVC).

4.1 Thermal requirements

The maximum inrush current level shall be calculated with rated voltage, frequency and the most onerous (in the range 90-120°) switching angle. The inrush current level shall be provided by the manufacturer in Schedule B of this enquiry.

4.2 Electrical requirements

The total losses for a shunt reactor shall be determined at rated voltage and rated frequency.

The rated voltage is as per Schedule A of this enquiry. The rated voltage across the reactor surface and interturn voltage shall be below the partial discharge inception level.

The thyristor controlled reactors shall be designed to allow for the trapped decaying component of current caused by a three phase zero impedance fault on the primary side of the SVC transformer which is cleared in 5 cycles and followed by temporary overvoltage specified in Schedule A.

These reactors shall be capable of withstanding a minimum of 5 daily switching duty cycles.

4.3 Mechanical requirements

These reactors shall be designed to withstand short circuit and fault conditions without any mechanical damage for the switching and fault frequency and duration as specified in Schedule A of this enquiry.

5. Current limiting / neutral grounding reactors

Current limiting reactors are reactors which are connected in series with the phase conductors for the purpose of limiting the current that can flow in a circuit under short-circuit conditions or under various operating conditions, such as capacitor switching, motor starting, synchronizing, arc stabilization, etc.

Neutral grounding reactors are reactors which are used for the purpose of controlling the ground current or the potentials to ground of an alternating current system during ground fault conditions.

5.1 Thermal requirements

The rated current shall be defined as the thermal current rating of the reactor, i.e. the current through the reactor during ground fault conditions.

Current limiting reactors shall be capable of withstanding multiple successive short circuits, without cooling to normal operating temperatures, provided the cumulative duration of the short circuits does not exceed the short time duration as specified in Schedule A of this enquiry.

5.2 Electrical requirements

The rated voltage across the reactor surface and interturn voltage shall be below the partial discharge inception level.

The reactor shall meet the overload conditions specified in Schedule A of this specification. In the case of a current limiting reactor this shall correspond to the transformer overload capability to which it is connected.

The neutral grounding reactors shall be capable of withstanding a minimum of 5 daily switching duty cycles.

5.3 Mechanical requirements

These reactors shall be capable of withstanding all forces associated with the crest of the offset current wave from subtransient reactance fault conditions, without mechanical failure.

The mechanical short circuit rating shall be designed for the worst-case fault and the resulting offset peak current.

6. Filter and damping reactors

Air core reactors are utilised in connection with capacitor banks for the following reasons:

- To limit inrush current from capacitor bank switching
- Reduce outrush currents during close-in faults
- Detune the capacitor bank to avoid resonances with the electrical network
- Filtering to reduce harmonics

These reactors are therefore subject to frequent switching operations, with a number of operations daily. The expected switching frequency is defined in Schedule A of this specification.

6.1 Thermal requirements

Thermal design of the reactor is to be completed using the current spectrum provided in Schedule A of this enquiry.

The reactor may be overloaded according to the overload capability of the capacitor bank. The reactor shall be designed to operate without damage with the specified overload conditions.

6.2 Electrical requirements

The harmonic currents as stipulated in Schedule A of this specification shall be used in the design of these reactors.

Damping reactors shall have a fixed inductance rating suitable for connection to the HV side of the shunt capacitor bank.

The insulation system of the reactor shall be designed to withstand the voltage drop due to the power frequency as well as harmonic currents and transient overvoltages. The manufacturer is to demonstrate that this requirement is achieved for the filter reactors supplied during the design stage and verified by factory acceptance testing.

Filter tuning reactors shall be designed for the specific harmonic frequency ring-down stress created when the circuits are discharged during AC busbar short circuits. Assume that the filter capacitors are charged to peak NETWORK voltage at the incipience of the busbar fault and that the busbar fault is cleared in 100ms. The design must accommodate at least 20 such faults in the life of the filter reactor.

The supplier shall provide proof that the design is adequate for this stress. Appropriate test method shall be recommended.

6.3 Mechanical requirements

The reactor shall be designed to ensure that the reactor does not have any mechanical resonances close to twice the inrush frequency to ensure no mechanical damage to the reactor due to frequent switching operations.

The damping reactor windings shall be braced and clamped to prevent damage due to electromagnetic forces resulting from the peak asymmetrical 50Hz short-circuit current, or from high-frequency inrush currents occurring during the life of the shunt capacitor bank or standing harmonics, the design must be reviewed by the Employer.

7. Smoothing reactors

Smoothing reactors are applied in HVDC power transmission schemes. These reactors are series connected to the DC system to provide high impedance to the flow of harmonic currents which are superimposed on the DC and to reduce the surge current amplitude during fault conditions in the DC system.

7.1 Thermal requirements

Thermal design of the reactor is to be completed using the current spectrum provided in Schedule A of this enquiry.

The reactor may be subjected to various overload conditions (DC plus harmonics). The reactor shall be designed to operate without damage within the specified overload conditions.

7.2 Electrical requirements

Smoothing reactors shall be designed for operation with rated DC current plus harmonics. The DC overload current is specified in Schedule A of this enquiry.

The DC current and harmonic current spectra specified in Schedule A of this enquiry shall be considered in the design for audible noise for smoothing reactors.

7.3 Mechanical requirements

These reactors shall be capable of withstanding repetitive high current stress, as seen during commutation failure, without mechanical damage and aging (fatigue).

The mechanical stress withstand capability of the reactor is to be demonstrated by the manufacturer.

The frequencies of the harmonics specified in Schedule A of this enquiry should be considered in the mechanical design in order to avoid resonances for those frequencies..

8. Authorization

This document has been seen and accepted by:

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Bheki Ntshangase	Senior Manager (HV Plant Engineering)
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Kooben Munsamy	HV Plant Manager (North East Grid)
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Name and surname	Designation
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9. Revisions

Date	Rev.	Compiled By	Clause	Remarks
March 2015	2	Keri Pickster	Document	Template updated
			Reference	Updated to include evaluation standards for post insulators and for air core reactors. Post insulator reference updated.
			Annex A	Evaluation criteria removed
March 2014	1	Keri Pickster	3.1.1	References updated to include drawings management procedure
			3.2	References updated to include additional post insulator specifications
			4.3	Reactor construction updated to include further requirements.
			4.4	New clause included on reactor crating
			4.8	Pollution mitigation requirements updated
			4.11	Drawing requirements updated
			4.13	Condition monitoring requirements updated.
			4.15	Transport requirements updated
			4.19	Specification deviations updated
			5.2	Electrical requirements for shunt reactors revised to include switching duty cycle.
			6.2	CLR and NER electrical requirements revised to include overload capability and switching duty cycle.
			10	List of authorisations updated
			Appendix A	Schedules updated to include relevant changes in the specification. New header included.

10. Development team

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

- Keri Pickster
- Roger Cormack
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- Sidwell Mtetwa
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- Marilize le Rouz
- Wayne Kinsella
- Willie Liebenberg
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11. Acknowledgements

Not applicable.

Annex A – Schedules A and B

THIS SCHEDULE FORMS PART OF SPECIFICATION 240-42587021 "SPECIFICATION FOR AIR CORE REACTORS" DATED 16/03/2015, REVISION 2.

SCHEDULES A AND B FOR 132 kV 9.982 mH SERIES FAULT CURRENT LIMITING REACTORS FOR SOL MTS STATION (SOUTH) REV 1 DATED 30/11/2017.

SCHEDULE A: PARTICULARS OF ESKOM'S REQUIREMENTS AND

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

THIS SCHEDULE SHALL BE USED IN CONJUNCTION WITH ESKOM SPECIFICATION FOR AIR CORE REACTORS REF 240-42587021. IN CASE OF CONFLICT, THE TENDERER SHALL REQUEST CLARITY IN A FORM OF AN EMAIL OR LETTER TO ESKOM, AND SHALL COMPLY WITH THE LATEST REVISION OF ALL RELEVANT IEC STANDARDS.

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

Technical specifications				
Item	**Description**	**Units**	**Schedule A**	**Schedule B**
1	**Delivery and off-loading**			
1.1	Delivery to:			
1.1.1	Reactors	Address	Sol MTS Substation (South)	
1.1.2	Spares	Address	Sol MTS Substation (South)	
1.2	Delivery effected not before	Date	TBA	
1.3	Off-loaded from transport vehicle by supplier	Yes/No	Yes	
1.4	Transferred to intended operation position	Yes/No	Yes	
1.5	Installation	Indoor/ Outdoor	Outdoor	
2	**Quantity**			
2.1	Reactors		6	
2.2	Spares		2	
3	**Erection**			
3.1	Erected ready for service	Yes/No	Yes	
3.2	Erection complete not later than	Date	TBA	
3.3	Erected for storage	Yes/No	No	
4	**Environmental information**			
4.1	Altitude above sea level	m	1800	
4.2	Ambient temperature			
4.2.1	• Maximum	° C	45	
4.2.2	• Minimum	° C	-10	
4.2.3	• Daily average	° C	35	
4.2.4	• Yearly average	° C	25	

4.2.5	• Maximum average daily temperature variation	° C	20	
4.3	Relative humidity			
4.3.1	• Minimum	%	50	
4.3.2	• Maximum	%	96	
4.3.3	• Average	%	68-83	
4.4	Solar radiation (maximum)	W/m^2	2.6×10^3	
4.5	Wind loading	Pascals/ ms^{-1}	1200/40	
4.6	Pollution			
4.6.1	• Type		Industrial	
4.6.2	• Classification (IEC 60815)	mm/kV	31 (Very Heavy)	
4.6.3	• Climatic conditions		Rain/dry/ hail/high UV radiation	
4.7	Seismic level	g	0.3	
5	**System Details**			
5.1	Maximum system voltage (U_m)	kV	145	
5.2	Temporary overvoltages			
5.2.1	• For 10 min	kV	1.05 U_m	
5.2.2	• For 1 min	kV	1.25 U_m	
5.2.3	• For 5 s	kV	1.5 U_m	
5.2.4	• For 1 s	kV	1.75 U_m	
5.3	Nominal system frequency	Hz	50	
5.4	Number of phases		3	
5.5	Three-phase system fault levels at the substation	kA	53.33	
5.6	Single-phase system fault levels at the substation	kA	55.52	
5.7	Interval between fault conditions	hr	6	
5.8	Frequency of short circuit application / year		5	
5.9	Number of switching operations / day		5	
6	**Type**			
6.1	Application		Current Limiting	
6.2	Phases	1Ø/3Ø	1Ø	
6.3	Model		xxxxxx	
6.4	Physical layout for single-phase dry-type	Δ/in-line	in-line	
7	**Reactor Rating**			
7.1	Rated frequency (tuning / inrush / discharge)	Hz	50	

7.2	Rated power	MVAr	xxxxxx	
7.3	Rated voltage	kV	132	
7.4	Rated continuous / power frequency current (I_N)	A	3000	
7.5	Current density of windings at rated current	A/mm^2	xxxxxx	
7.6	Root sum square current (I_{rss})	A	N/A	
7.7	Current spectrum	A	N/A	
7.8	Rated inrush current (Damping and filters)	kA	N/A	
7.9	Rated thermal short-time / circuit current (I_{KN}) - provide calculations	kA	xxxxxx	
7.10	Rated short-time / circuit current duration	s	2	
7.11	Rated mechanical short-time / circuit current - provide calculations	kA_{peak}	150	
7.12	Rated mechanical short-time duration	s	2	
7.13	Rated linear impedance	Ω	3.136	
7.14	Rated inductance	mH	9.982	
7.15	Tolerance on inductance	%	+2.5, -0	
7.16	Rated incremental inductance	mH	N/A	
7.17	Rated resistance	Ω	xxxxxx	
7.18	Rated short-time overload DC	A	N/A	
7.19	Rated short-time overload current spectrum	A	xxxxxx	
7.20	Short-time overload duration	s	xxxxxx	
7.21	Overload capability (130% I_{MAX})	kA	N/A	N/A
7.22	Magnetic clearance required			
7.22.1	MC1	mm	xxxxxx	
7.22.2	MC2	mm	xxxxxx	
7.22.3	Centre-to-centre	mm	xxxxxx	
7.23	Coupling factor	%	xxxxxx	
7.24	Quality factor (Q)		xxxxxx	
7.25	Tolerance of Quality factor (Q)	%	xxxxxx	
7.26	Total losses at rated current	kW	xxxxxx	
7.27	Coefficient of loss evaluation	R / kW	N/A	
8	**Temperature rise at site altitude at maximum continuous current**			
8.1	Hot spot temperature	°C	xxxxxx	
8.2	Maximum hot spot temperature rise of windings	K	xxxxxx	
8.3	Thermal time constant	min	xxxxxx	
8.4	Insulation class (IEC 60076-11)		xxxxxx	
8.5	Coating material required – see clause 3.3 and 3.8	Yes/ No	Yes	
9	**Reactor details**			

9.1	Type of cooling	AN	AN	
9.2	Line terminals		xxxxxx	
9.3	Mounting		xxxxxx	
9.4	Minimum clearance between base of insulators and ground level	mm	2500	
9.5	Single-phase switching	Yes/No	No	
9.6	Number of coils per phase		1	
9.7	Winding material		xxxxxx	
9.8	Insulation material		xxxxxx	
9.9	Mass of one coil	kg	xxxxxx	
9.10	Coil dimensions			
9.10.1	• Diameter	mm	xxxxxx	
9.10.2	• Height	mm	xxxxxx	
9.11	Dimensions of unit including pedestals			
9.11.1	• Diameter	mm	xxxxxx	
9.11.2	• Height	mm	xxxxxx	
9.12	Capacitance of one coil			
9.12.1	Series capacitance	pF	xxxxxx	
9.12.2	Ground capacitance	pF	xxxxxx	
9.13	Number of concentric coils		xxxxxx	
9.14	Number of turns in each coil		xxxxxx	
9.15	Arrangement of coils			
9.15.1	• Spacing between coils of same phase	mm	xxxxxx	
9.15.2	• Spacing between coils of different phases	mm	xxxxxx	
9.16	Maximum amplitude of vibration peak to peak at operating temperature and I_N	Absolute maximum Average maximum	100µm 30µm	
9.17	Maximum audible noise level of individual reactor	dB	≤75	
9.18	Distance at which noise level is to be measured	mm	2000	
9.18	Reactor corona shielding	Yes/No	xxxxxx	
9.19	Pollution mitigation	Yes	RTV coating minimum	
9.20	Sound abatement		xxxxxx	
9.21	Life expectancy	yrs	40	
9.22	Manufacturer		xxxxxx	
9.23	Country of manufacture		xxxxxx	

10	**Reactor insulation**			
10.1	Insulation level (BIL)	kV peak	550	
10.2	60s power frequency withstand voltage	kV rms	230	
10.3	Interturn voltage withstand	kV	xxxxxx	
10.4	External voltage grading	mm/kV	31	
10.5	Reference temperature	°C	80	
10.6	Temperature rise test voltage	kV	U_{max}	
10.7	Temperature rise test duration	hr	xxxxxx	
10.8	Short circuit test current	A	N/A	
10.9	Short circuit shot duration	s	N/A	
10.10	Number of short circuit shots		N/A	
10.11	Q factor test frequencies	Hz	xxxxxx	
11	**Pedestal insulator** SANS/IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000V. Single copies of all certificates and full reports of type tests performed by an accredited test authority shall be submitted with a tender offer	Yes/ No	Yes	
11.1	Material	Porc/Si	Porc	
11.2	Type		xxxxxx	
11.3	Minimum creepage distance	mm	4496	
11.4	60s power frequency withstand voltage	kV rms	230	
11.5	Insulation level (BIL)	kV peak	550	
11.6	Steady mechanical load factor		xxxxxx	
12	**Tests**			
12.1	Measurement of impedance	Yes/No	Yes	
12.2	Measurement of losses	Yes/No	Yes	
12.3	Lightning impulse	Yes/No	Yes	
12.4	Temperature rise	Yes/No	Yes	
12.5	Acoustic level	Yes/No	Yes	
12.6	130% Overload for one hour	Yes/ No	N/A	
13.	**Special requirements:**			
13.1	To be supplied together with Surge Capacitors 240-131747620	Yes/ No	Yes	
13.2	Pedestal adaptor plates to be provided	Yes/No	Yes	
13.3	Storage and maintenance procedure	supplied	Yes	
13.4	Must be fully interchangeable with the installation on site.	Yes/No	Yes	
13.5	Minimum design safety margin factor		1.2	

13.6	For acoustic compliance a frequency sweep should be conducted across the frequency spectrum up to 5 kHz (audible noise test system dependant from the manufacturer). IEC 60076-6 specifies this special test (section 9.10.11), and should be used as reference, with the results shown as calculated (IEC 60076-10) together with measured values. The requirement must be satisfied without an acoustic shield. Calculations of audible noise levels for the reactors showing compliance to the specification is required. Test report for audible noise reactors showing the third octave spectrum levels from measurements is required. In meeting the audible noise criteria, the third octave spectrum levels from calculation and measurements should be given in the test reports.	Yes/No	Yes	
13.7	**Note:** All pertinent design parameters including mounting requirements will be assessed/confirmed as part of the design review program. The successful bidder will be required to demonstrate acceptability of the design offered and compliance to safety margins.			
14.	**Deviations**			

Clause	**Description of deviation**	**Proposed alternative**	**Accept/Reject**