Eskom	Standard	Technology

Title: **SPECIFICATION FOR COMBINED THREE-PHASE NEUTRAL ELECTRO-MAGNETIC COUPLERS WITH NEUTRAL EARTHING RESISTORS AND AUXILIARY TRANSFORMERS (NECRT'S)**

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1. Introduction

This standard stipulates Eskom's requirements for the designing, manufacturing, testing before dispatch, supply, and delivery of 6,6 kV, 11 kV, 22 kV, 33 kV and 44 kV combined neutral electromagnetic couplers with neutral earthing resistors and auxiliary transformers (NECRT's). The NECRT is designed for two conditions; namely, when the system is normal (steady state) and when a fault occurs (abnormal). The NECRT is designed to limit the earth fault current to 300 A, 800 A or any other current adequate for the secondary plant circuits as shall be stipulated in the relevant schedule A &B.

The requirements stipulated in this document are based on international practices combined with Eskom's field experience. The requirements are specified in order to ensure integrity of the product thereby minimising the risk of failure of this equipment and the major loads transformers.

Each unit must be designed and/or manufactured in line with the Eskom drive of low loss units, minimum to maintenance free, safe, and environmentally friendly technologies.

2. Supporting clauses

2.1 Scope

This standard covers the specification for combined oil-immersed, three-phase NECRT's which are comprised of an auxiliary transformer with an additional neutral earthing compensator winding to provide a neutral point in a delta connected system and a resistor connected to the neutral point to limit earth fault current in the event of a fault. The auxiliary transformer serves to supply the local auxiliary loads for example, the 400V equipment within the substation.

Note that the specification also caters for neutral electromagnetic couplers (NEC) and neutral-earthing resistors (NER) in the range of 6.6kV to 44kV. The schedules for the NECRT will still apply to the NEC, NER with the unwanted portion marked "Not Applicable (N/A)" e.g. if a 33kV NER is required the A schedule for the 33kV NECRT can be used but the requirements for the NEC and auxiliary transformer shall be voided by marking them N/A.

This specification excludes Single Wire Earth Return (SWER) NECs.

2.1.1 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] ISO 9001 Quality Management Systems.

[2] IEC 60071-1/2, Insulation co-ordination.

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

[4] IEC 60076-2, Power transformers – Temperature Rise.

[5] IEC 60076-3: Power transformers – Part 3: Insulation levels and dielectric tests.

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

[7] IEC 60076-6: Power transformers – Part 6: Reactors.

[8] IEC 60085: Thermal evaluation and classification of electrical insulation.

[9] IEC 60137: Insulated bushings for alternating voltages above 1000 V.

[10] IEC 60156: Insulating liquids – Determination of the breakdown voltage at power frequency.

[11] IEC 60185: Current transformers.

[12] IEC 60216-2: Guide for the determination of thermal endurance properties of electrical insulating materials.

[13] IEC 60233: Tests on hollow insulators for use in electrical equipment.

[14] IEC 60270: Partial discharge measurements.

[15] IEC 60505: Guide for the evaluation of insulation systems of electrical equipment.

[16] IEC 60507: Artificial pollution tests on high voltage insulators to be used on ac. systems.

[17] IEC 60815: Guide for the selection of insulators in respect of polluted condition.

[18] IEC 61109: Composite insulators for a.c. overhead lines with a nominal voltage greater than 1000 V – Definitions, test methods, and acceptance criteria.

[19] BS 1872: Electroplated coatings of tin.

[20] SABS 97: Electric cables – Impregnated paper-insulated metal-sheathed cables for rated voltages, 3.3/3.3 kV to 19/33 kV (excluding pressure assisted cables).

[21] SABS 156: Moulded-case circuit-breakers.

[22] SABS 780: Distribution transformers.

[23] SABS 833: Standard Transformer Bushings (Metric Units).

[24] SABS 1091: National colour standards for paint.

[25] NRS 079-1: Mineral insulating oils (uninhibited) Part 1: Purchase, management, maintenance and testing.

[26] 32-9: Definition of Eskom documents.

[27] 240-57648800: Specification for New Oil Filled Auxiliary Transformers Rated 1MVA and Below and 33kV and Below,

[28] 240-56063886: Dehydrating Breather specification

[29] 240-56063908: Buchholz relay specification

[30] 240-56063871: Transformer and Reactor Pressure Relief Devices

[31] QM 58: Eskom Quality Procedure

[32] 32-644: Eskom documentation management standard.

[33] 474-65: Operating Manual of the Steering Committee of Wires Technologies (SCOWT)

[34] 240-68973110: Specification for Power Transformers rated for 1.25MVA and above with the highest voltage of 2.2kV and above

[35] 240-75655504: Corrosion Protection Specification for New Indoor and Outdoor Distribution Equipment Manufactured From Steel.

[36] DST_34-304: Generic Substation Design

[37] 240-75661431: Mineral Insulating Oils (Uninhibited and Inhibited) Part 1: Purchase, Management, Maintenance and Testing

[38] DPC-34-224: KIPTS natural ageing and pollution performance test procedure for outdoor insulation products Section 0- General requirements

[39] DPC-34-213: KIPTS natural ageing and pollution performance test procedure for outdoor insulation products - Section 1- Particular requirements for Post, Long rod and Stand-off insulators.

[40] DPC-34-214: KIPTS natural ageing and pollution performance test procedure for outdoor insulation products - Section 2- Particular Requirements for through Wall Bushings.

[41] TRMSCAAH5: Specification for HV electrical equipment main terminals.

[42] 32-644: Eskom documentation management standard.

[43] 474-65: Operating Manual of the Steering Committee of Technologies (SCOT).

[44] 240-56063843: Winding and oil temperature specification.

[45] 240-56356191: Transformer and reactor oil level.

[46] 240-56030674: Corrosion Protection of new and in-service power & station auxiliary transformers.

[47] 240-56062726: Standard for Intrusive work and Oil filling, under vacuum of transformers and reactors on site.

[48] QM 58: Eskom Quality Procedure

[49] D-DT-3202: Eskom Drawing MV and LV cable box

[50] 32-136: Eskom construction regulations

[51] 10TB-018: Load and no-load loss factors for large power transformers (1.25MVA to 160MVA).

[52] TPC 41-246: Management of manufacturers and suppliers equipment drawings

[53] 240-56062799: Technical Specification for Capacitive Bushings for application in Power Transformers and Shunt Reactors in all Eskom Divisions standard.

[54] D-DT-5207: NECRT/AUX TRFR Lattice Support Foundation Details (Soil Type 1 & 2)

[55] 240-70413291: Specification for Electrical Terminal Blocks

The following schedules are attached to, and form part of this specification as guides to purchasers.

Schedule 'A': Particulars of Eskom's requirements.

Schedule 'B': Guarantees and technical particulars.

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

All definitions and abbreviations as stated in NRS000 are applicable to this document.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
Aux	Auxiliary transformer
IEC	International Engineering Council
ISO	International Standards Organization
MV	Medium Voltage
NEC	Neutral electromagnetic coupler

Abbreviation	Description
NECRT	Combined three-phase neutral electromagnetic coupler with neutral earthing resistor and auxiliary transformer
NER	Neutral earthing resistor
PRV	Pressure release valve

2.5 Roles and responsibilities

All the Eskom employees and/or appointed bodies involved in the procurement of transformers and/or the associated accessories shall ensure that the product meets the requirements of this specification. Any deviation from these requirements shall constitute a non-conformance, unless it was agreed to in advance by a delegated Eskom transformer specialist in writing and is based on sound engineering judgement.
All the Contractors supplying transformers to Eskom must be conversant with the requirements of this specification, and shall comply with the requirements. All the deviations shall be clearly listed in the deviation schedule as part of the tender deliverables. No deviations will be accepted unless approved by Eskom in writing. The Contractor shall ensure that he gets clarity where required and that he has all the supporting information or documents necessary for the contractor to comply with this document. The Eskom Transformer Corporate Specialist shall be responsible for ensuring the validity of this document.

2.6 Process for monitoring

This document and its relevance will be annually evaluated by the relevant SCOT Care Group.

2.7 Related/supporting documents

The schedule A of the relevant AB schedules shall form part of this specification and they shall take precedence over this specification in case the two documents are conflicting.

3. Requirements

3.1 General

The combined oil-immersed three-phase neutral electromagnetic couplers with neutral-earthing resistors and auxiliary transformers (NECRT's) shall comply with this specification, unless otherwise specified in schedule A of an enquiry document, which supersedes all other documents.

The NECRT shall comply with all the requirements of IEC 60076 Parts 1 – 5, plus any other part that is relevant to this equipment. Notwithstanding the fact that a unit has been type tested, Eskom reserves the right to re-test any produced unit supplied to Eskom (before it has been in service) in accordance in line with IEC 60076. The same compliance criteria will apply as in the case of a type test for these units, and failure of the unit in such a test will constitute non-compliance with the Eskom purchasing specification.

The manufacturer shall have the factory accredited by Eskom before orders can be placed. Factory evaluation, when required, can be part of the enquiry qualification process.

3.1.1 Design reviews and design changes

All designs must be reviewed for approval by Eskom and only when a design has been approved in writing will the ordering of components and manufacturing start. The approval of the design by Eskom does not take away the responsibility from the OEM to provide a unit that is fit for purpose and is safe to use.

Approval shall be obtained from Eskom before any design and/or material changes can be implemented on designs approved by Eskom. Eskom will evaluate the proposed changes and if deemed necessary the manufacturer will be instructed to redo (at the manufacturer's cost) the relevant type tests.

3.1.2 Designing for short circuit withstand requirements

All designs must comply with IEC 60076-5 to prove their ability to withstand short circuits.

NOTE: Eskom requires that the ability to withstand short circuits be demonstrated by both, calculation and by short circuit testing. Only one manufactured NECRT per design needs to be tested as a demonstration of the capability to withstand short circuits. Notwithstanding the fact that a unit has been tested to withstand the dynamic effect of short circuits, Eskom reserves the right to test any unit produced for Eskom (before it has been in service) in accordance with IEC 60076-5 as amended here. Failure of the unit in such a test will constitute non-compliance with the Eskom purchasing specification.

3.1.3 Dimensional requirements

The height of any unit will be a maximum of 3m (from the base of the NECRT to the highest point) due to transport and rigging requirements. This is an essential transport requirement in order to meet the bridge clearances without the use of low bed trailers.

All units shall be designed for both overhead and cable connection. In order to achieve the minimum working clearances from the ground to the base of the bushing, the dimensional limits specified in Table 1 shall be adhered to.

The support stands used to achieve the height as per Table 1 must be supplied with the NECRT. The support stands for all NECRT's must be bolted to the tank and not welded, and must be compatible with the standard interface (D-DT-5207) for NECRT plinths used in Eskom. A prototype of the support stand must be inspected and accepted by Eskom.

Table 1: Mandatory height requirements

1	2	3
U_n r.m.s. (kV)	**Vertical working clearance (m)**	**Minimum Height from ground level to base of HV bushings (m)**
6,6	2,6	2,5
11	2,7	2,5
22	2,8	2,5
33	2,9	2,5

NOTE: A vertical arrangement of the units will be preferred in order to achieve a maximum practical height to the base of the bushings with a minimum practical base area.

3.1.4 General Service Conditions

The units shall have a life expectancy of 40 years and shall be suitable for use under the following conditions:

a) outdoor applications;

b) at any altitude up to 1 800 m above sea level;

c) at the following ambient temperatures:

1) maximum: 45 °C,

2) maximum diurnal variation: 35 °C, and

3) minimum: -10 °C;

4) yearly daily average 25 °C

d) relative humidity: up to 100 %;

e) a sinusoidal voltage waveform with a 50 Hz frequency;

f) be capable of withstanding seismic shocks of 0.3g without any problems,

g) symmetrical three-phase supply voltages, with negative and zero phase sequence voltages less than 2 %; and

NOTE: Due to higher prevailing ambient temperature, winding temperature rises/top oil temperature rises shall not exceed 65 °C /60 °C respectively. In this respect the above temperature limits differ from those specified in IEC 60076.

3.1.5 General Requirements

The units shall be:

a) Naturally cooled

b) Free-breathing / sealed unit

c) Outdoor type

d) Oil-immersed

e) Fully-insulated

f) Zig-zag connected three-phase 50Hz neutral electromagnetic couplers (NECs)

g) Combined with a neutral earthing resistor and three-phase 400/240 V auxiliary power transformer

h) All contained in the same tank

i) With only one common set of HV terminals

j) The inner winding shall be designed to withstand the free buckling criteria. However, the specific stress ($\sigma_{average}$) of the inner winding shall not exceed 50% of the copper conductor yield strength.

k) Any paper insulation shall be thermally upgraded paper

l) Class 3 enamel insulation to be used.

3.1.6 Auxiliary Transformer

The auxiliary transformer shall in all aspects be designed and constructed in accordance with 240-57448800 – Specification for New Oil Filled Auxiliary Transformers Rated 1MVA and Below and 33kV and Below, and:

a) The core and winding assembly shall be adequately braced in the two horizontal directions and fixed at the level of the upper yoke clamps.

b) Not have core and winding assemblies suspended from the tank cover.

c) Have access hand holes in the tank sides to facilitate the connection of leads to the lower ends of the bushings.

d) Windings shall be manufactured from copper or aluminium. The suitability of the conductor must be proven at the design review.

e) The inner winding shall be designed to withstand the free buckling criteria. However, the specific stress ($\sigma_{average}$) of the inner winding shall not exceed 50% of the conductor yield strength.

f) Any paper insulation shall be kraft paper.

g) Class 3 enamel insulation to be used.

NOTE: The unit must be able to withstand a gravitational force of 3G in all directions.

3.1.7 Current limiting resistor

The current limiting resistor shall:

a) Be suitably insulated.

b) Be mounted in the tank and securely located in each plane. It shall be mounted in such a fashion in the tank that any possible gas production from overheating resistors will not compromise the insulation levels of the NEC nor aux transformer, oil damaged by overheating of the NER will not contaminate the other components.

c) Be laser cut.

3.1.8 Neutral earthing compensator

The NEC shall:

a) Have a three-limb stacked core.

b) Have adequate bracing for axial forces.

c) Consist of copper conductors.

d) Have adequate cooling ducts distributed throughout winding.

3.1.9 Oil

Each unit shall leave the factory:

a) Filled to the normal level.

b) A formal test certificate shall be provided in the NECRT manual indicating the electric strength, moisture and acidity of the oil in addition to the Dissolved Gas Analysis. The sampling and testing must be done prior to dispatch from the factory. The quality of the oil must be in accordance with 240-75661431, with appropriate action being taken to maintain the oil dryness during transportation and storage, and to avoid oil pollution of the dehydrating breather prior to delivery at site.

c) The breather must be fitted (without the oil in the oil bath to avoid contamination of the silica gel) and secured, prior to dispatch from the factory. Upon delivery, the oil must be filled in the oil bath, to the appropriate level.

d) Oil sampling point to be labelled as follows: Main tank sampling point, Buchholz sampling point etc.

e) Buchholz must be in accordance with Eskom specification 240-56063908-Buchholz Relay specification

f) Transformer oil supplied in the NECRT's shall be compliant with the 240-75661431 specification.

g) All oils used in the NECRT's shall be free of Polychlorinated biphenyl (PCB's - zero ppm). A formal test certificate to this effect shall be included in the NECRT manual and the NECRT shall be fitted with a label indicating that the oil is PCB free.

3.1.10 Auxiliary power output

The auxiliary transformer LV connections shall be brought out through two, moulded-case, air-insulated circuit-breakers (MCCBs) rated as specified in table 2.

Table 2: Moulded-case circuit-breaker ratings

1	2	3
Description	**MCCB feeding relay house**	**MCCB feeding MIB for cooling fan motors**
Current rating	100 A	50 A
Breaking capacity	10 kA	10 kA
Voltage	440 V	440 V

The Moulded–case circuit breaker shall:

a) Be the type that provides for bolted connections on the transformer side.

b) Be suitable for bolting to crimped lugs on the tails of 35 mm² and 120 mm² solid aluminium cables respectively on the load side. (Pinch screws will not be acceptable)

c) Have a load capability inherently independent of ambient temperature or shall be fully ambient temperature compensated up to 80 °C.

d) Have all MCCB terminals and LV bushing terminals suitably shrouded to prevent inadvertent human contact.

e) In all other respects comply with SABS 156.

f) Together with a bolted neutral-link, be mounted in a dust-, vermin- and weather-proof, lockable enclosure (using a standard Eskom padlock) with a vertically-hinged access door with IP 55 rating.

g) The mounting arrangement of the MCCB in the enclosure shall be accessible from ground level at all times and:

h) Also allow for the installation of additional MCCB alongside the main MCCB. (A mounting back plate shall be provided)

i) Provide an opening for cable entry (not less than 300 mm × 150 mm) which shall be covered by an un-drilled, removable, gland-plate at an adequate distance (i.e. not less than 450 mm in the case of 100 kVA auxiliary transformers) below the outgoing terminals of the MCCB.

3.1.11 HV terminals

All units shall be suitable for both overhead and cable connection. In order to cater for both conditions:

a) M12 threaded HV terminals, with three nuts and two washers shall be provided.

b) Cylindrical stems that are 26 mm in diameter and 125 mm long shall also be supplied with each unit.

The bushings' terminals and the cylindrical stems shall:

a) Be aluminium, electro-tinned, solid copper or copper alloy.

b) Be electroplated in accordance with BS 1872 Cu/Zn/Sn/10/b without subsequent heat treatment or machining.

3.1.12 Power cable connections

Provision shall be made for a minimum of two HV cable supports.

3.1.13 Bushings

a) All units shall be provided with outdoor bushings that comply with IEC 60137. 33kV Solid bushings must be fitted to the primary side of NECRT's of 33kV voltage rating and below. For voltages above 33kV the bushings must conform to 240-56062799.

b) The profile characteristics of the bushings shall comply with the requirements of IEC 60815 for voltages of 33kV and below, and 240-56062799.for voltages 33kV and above.

c) Bushings never used in Eskom before shall be subjected to the KIPTS natural ageing and pollution performance tests in accordance with DPC 34-224.

d) HV bushings shall be vertically mounted on the tank.

e) Bushings shall be spaced in order to accommodate a standard EX-type cross-clamp (bolted-bolted) and still meet the requirements of SABS 780. (It can be assumed that the clamps will extend a maximum of 120mm to each side of the bushing centre)

f) The phase-to-phase clearances between the centre lines of the neighbouring bushings shall be 700mm.

NOTE: All NECRT's below 33kV shall be fitted with bushings to be 33/36kV, 70kV 60 second RMS withstand voltage and 200kV peak. NECRT's rated 33kV and above will be fitted with a 52kV Capacitor bushing as per 240-56062799.

g) The earth terminal of the NER shall be brought out via a bushing labelled ZN.

h) An additional neutral bushing, labelled P2, shall be provided.

i) The internal neutral current transformers shall be located between P2 and ZN (see figure 2).

j) The P2 bushing will be used on site as a current injection point when testing the current transformers. The current carrying capacity of the conductor connecting P2 and ZN shall therefore be equal to the rated short-time current of the NECRT.

k) The label shown in Figure 1 shall be located on the tank directly below the P2 bushing. The value of the maximum injection current shall be equal to the rated short-time current of the NECRT

Current injection terminal for site testing of neutral CTs
Maximum injection current ____ for ____ seconds

Figure 1: Label located below neutral bushing, P2

3.1.14 Earth terminals

a) The main earth terminal shall comprise of two stainless steel (grades 304 and 316) plates welded to opposite long sides of tank.

b) The plate shall be a minimum of 40mm deep and shall be fitted with a stainless steel bolt, washer and spring washer.

c) The bolt shall be a M16 x 35mm bolt, threaded through.

d) The main earth terminal shall be located directly below the ZN bushing, not more than 100mm from the base.

e) A suitably rated connector (not copper) shall be provided between ZN and the tank and from tank to support if applicable. (The tank and support structure if applicable shall act as continuity between the ZN and the holding down bolt).

f) A secondary earth terminal shall be provided inside the terminal box and shall comprise a M12 threaded earth stud with nut and washer, welded to the terminal box or tank.

g) The manufacturer shall ensure that a good electrical connection is achieved between the main and secondary earth terminals.

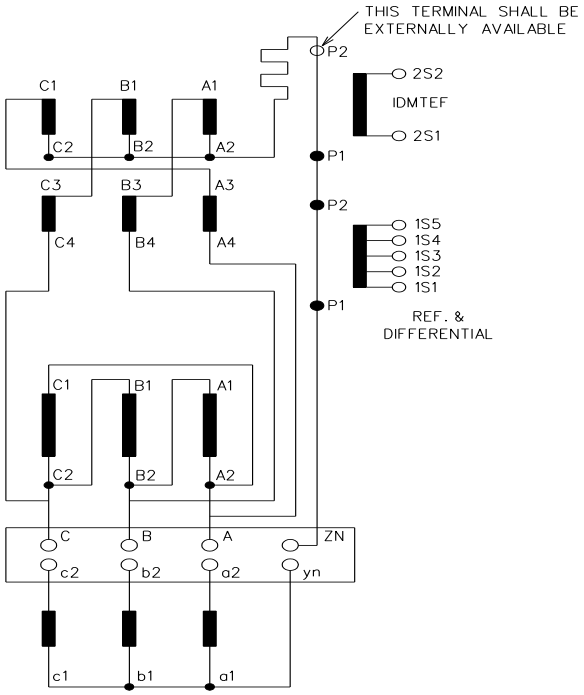

Figure 2: Schematic diagram of the NEC, NER and the Auxiliary transformer

3.1.15 Fittings

The following fittings shall be provided:

a) oil-filling pipe, drain plug and drain valve, earthing terminal, flat under base, lifting lugs and a breather pipe;

b) oil conservator with direct-reading oil level indicator which should be interchangeable with a magnetically connected dial-type oil level indicator upon request. The type of oil level indicator will be specified in schedules. The oil gauge diameter should be 80 to 100mm. The oil conservator shall be mounted perpendicular to an imaginary line drawn through all three bushing centres;

c) gas- and oil-actuated relay as specified in 240-56063908, cabled to the terminal box;

d) dehydrating breather; in accordance with 240-56063886 Dehydrating Breather specification

e) top-oil thermometer with alarm and tripping contacts, selected, mounted, connected and arranged in accordance with the requirements of 240-56063843 Analogue Oil and Winding Temperature Gauges for Transformers and Reactors;

f) thermometer pocket;

g) the dehydrating breather, thermometer and gas and oil actuated relay (buchholz) gas release cock shall be mounted 1500 mm above ground level;

h) For the current-limiting resistor the following data shall be inscribed on the rating plate:

Current-limiting resistor in accordance with 240-57648848 specification:

Resistor nominal voltage (U_n/1, 73).....kV

Resistance at 100°C, in ohms.....

Rated current for seconds, in amperes .....….

Maximum continuous current, in amperes.....

Rated frequency, in hertz.....

Insulation levels ……...

Impulse/50 Hz power frequency, in kilovolts...../.....

Eskom Order Number.....

SAP Material Number.

Serial number.....…….

Diagram gives terminal markings (as in figure 2).

i) Terminal (cable marshalling) box. To prevent entry of water into the terminal box the secondary wiring from the gas-and oil-actuated relay, current transformers, oil level indicators and dial-type thermometer shall be arranged for side or bottom entry into the box. All terminal boxes shall be provided with a 25 mm diameter gauze-covered drain hole at the lowest part of the box with IP 55 rating.

j) An unobstructed, brass or aluminium, removable gland plate shall be provided on the bottom of this box. The gland plate shall have a minimum dimension of 70 mm x 130 mm.

3.1.15.1 Pressure relief device

The NECRT shall be provided with a pressure relief device of sufficient capacity to limit internal pressure, under internal low current arcing fault conditions, so that the tank rupture does not occur. The device shall be in accordance with 240-56063871 Transformer and Reactor Pressure Relief Devices and:

a) be set to open at a pressure to be determined at the design review.

b) attain its full opening in not more than 2,5 ms when subjected to internal pressure impulse equal to the static operating head of oil plus 50 kPa.

c) be capable of withstanding full internal vacuum at sea level.

NECRT's shall be equipped with pressure relief devices to relieve excessive pressure in the tank due to internal arcing. The device shall be fitted directly to the side wall of the tank at a level as near as possible to the top of the windings.

It is good practice, to prevent harm to persons or property from violent jets of hot oil exiting from the valve, by enclosed ducting that shall direct the oil to the ground level in the event of the operation of the pressure relief valve. The manufacturer shall provide data pertaining to the flow capacity of the pressure relief device.

The pressure relief device shall not be influenced to generate invalid trip signals by tank vibrations and the magnetic field generated during normal operation and fault conditions.

3.1.15.2 Pipe Work Connections

Pipework connections shall be the correct size for their duty and shall be as short and direct as possible. Only radiused elbows shall be used.

The feed pipe to the transformer tank shall enter the transformer cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer side of the Buchholz relay, and straight for not less than three times its internal diameter on the conservator side of the relay. This pipe shall rise toward the oil conservator, through the relay and at an angle in the range specified by the manufacturer of the buchholz relay.

3.1.16 Nameplate

The nameplate shall;

1. Be made of stainless steel and shall have the various ratings and data engraved, embossed or stamped on it, as specified in IEC 60076-6 and SABS 780.
2. Contain details of the current transformer, but the standard number shall be the number as specified (i.e. N33, N22 etc.).
3. Contain details of the type of oil supplied in the transformer.
4. Contain details of the bushings and their ratings.

Note : The manufacturer must specify the absolute internal pressure at sea level at which the NECRT tank may be filled with oil, otherwise it shall be stated that the NEC/auxiliary transformer is suitable for the application of an absolute internal pressure of 1,5 kPa at sea level.

3.1.17 Secondary wiring and terminals

3.1.17.1 Secondary wiring

Current transformer secondary circuits and other auxiliary circuits, shall

a) be wired with either 2,5 mm^2 wire or 4 mm^2 wire;

   1) for secondary circuits the 2,5 mm^2 conductors shall have not less than 44 strands,

   2) for secondary circuits the 4,0 mm^2 wire shall have not less than 48 strands, and

   3) for auxiliary circuits the 2,5 mm^2 wire and the 4,0 mm^2 wire shall have not less than 7 strands,

b) have oil and moisture-proof insulation and, where the temperature exceeds that of ambient air, thermal characteristic insulation at least equal to class A of IEC 60085;

c) be, in the case of external wiring, protected, either in the form of armoured cable, which shall be supported on rails clear of the tank surfaces, or by a conduit consisting of a metal protective channel (mineral insulated copper sheathed cables will not be acceptable);

d) be, suitably braced, clipped and/or laced to prevent vibration;

e) be, unless otherwise specified fitted with crimped terminations, compatible with the terminals with which they are associated (only the required minimum of wiring insulation shall be removed, for making wiring terminations, leaving the conductor strands clean and undamaged);

f) be, if situated inside the tank (internal wiring), connected to the terminals of the terminal box; and have, at each end of each lead, an interlocking type ferrule with permanent black characters, impressed, on a white background, which display the same designation marked on the apparatus terminal to which each end (of a lead) is connected.

Terminations without lugs will not be acceptable; the types of lugs to be used with different types of terminals are listed in 240-70413291. The wiring designation, marked on the ferrules, shall be read from terminal to insulation, independently of direction of entry into any devices (vertical or horizontal terminal strips, relay apparatus and instruments). All terminals and wiring identification devices shall be easily accessible after wiring and cabling have been completed.

3.1.17.2 Secondary terminals

The secondary terminals shall comply with 240-70413291, and shall be type "B" only (i.e. rail-mounted, screw clamp, spring-loaded insertion type) as specified in 240-70413291. Other types will not be acceptable.

In addition, since not more than two conductors shall be connected to any side of a terminal, the size of all terminals, to be used by Eskom's contractor for external cables, shall be suitable for the termination of at least two multi-stranded copper leads of 4 mm^2 each.

3.1.18 Corrosion proofing and finishing

Corrosion proofing shall be C5 in accordance with 240-75655504, Corrosion Protection Specification for New Indoor and Outdoor Distribution Equipment Manufactured from Steel. The final colour, including the conservator, shall be Cloud Grey SABS F48 as per 240-75655504. Coating of interior surfaces shall be as per 240-75655504.

Lifting points must be clearly marked by being sprayed onto the tank using a stencil.

3.1.19 Tank Construction

The tank, complete with fittings and conservator tank shall be capable of withstanding the effects of full vacuum at sea level. The tank under-base shall be at least 10 mm thick. The tank cover shall be bolted.

The oil conservator shall be mounted off one end of the unit, transversely to its major axis. A 15 mm brass drain valve shall be provided at the base of the conservator tank. The valve opening shall be sealed by means of a threaded plug. The electrical clearance from any part of the conservator to the line of approach of a horizontal conductor, supported on a line bushing terminal and approaching in a direction normal to the transformer major axis, shall be not less than 430 mm.

A drain valve shall be provided at the lowest point on the main tank. The valve shall be of the gate valve type, double flanged, with a nominal bore of 25mm and manufactured of brass. The valve shall be fitted with a blanking plate and gasket on the outlet. Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete unit when filled with oil without structural damage to any part of the unit. The factor of safety at any one point shall not be less than 2.

The lifting lugs shall be so arranged and located as to be accessible for use when the transformer is loaded on the transport vehicle, and so as not to cause fouling of any of the transformer fittings and accessories.

All brass fittings must be painted in the same coating as the tank.

3.1.19.1 Shape

The shape of the transformer tank and fittings, including the under-base shall be such that no water can be retained at any point on their external surfaces. Furthermore the lid on the inside shall be shaped to ensure that all free gas generated inside the transformer escapes to the conservator by way of the gas and oil actuated relay.

3.1.19.2 Cooling corrugations

Corrugated tanks will not be accepted unless approved in writing.

3.1.19.3 Guides for core and winding assembly

Guides shall be provided inside the transformer tank to correctly locate the core and winding assembly in the tank.

3.1.20 Tank strength and oil tightness

3.1.20.1 Rigidity

NECRT tanks and their associated components shall have adequate mechanical strength and rigidity to permit the complete transformer, filled with oil, to be lifted, jacked and hauled in any direction, and to be transported without structural damage or impairment of the oil tightness of the transformer, and without the necessity for the special positioning of sliding rails in relation to the tank. Tank stiffeners shall not cover welded seams, to enable the repair of possible oil leaks. The tank and transformer as a whole shall be suitable for transport by low-bed or beam wagon.

3.1.20.2 Internal pressure and vacuum

NECRT tanks, complete with all fittings and attachments normally in contact with the transformer oil, and filled with oil of the specified viscosity, shall withstand the pressure and the leakage tests prescribed in 240-68973110: Specification for Power Transformers rated for 1.25MVA and above with the highest voltage of 2.2kV and above. In the case of type tests for strength and oil tightness the fittings (e.g. pressure relief valves and bushing stems) may be tested separately. The ability of the tank to withstand overpressure shall be co-ordinated with the pressure relief valves as per 240-56063871, Transformer and Reactor Pressure Relief Devices

3.1.21 Radiators

The radiators on the NECRT shall be welded onto the main tank, bolted radiators are not acceptable. The radiators shall have the same coating application as the main tank and shall be coated by a system as specified in 240-75655504, where radiator tubes of 1.6mm thick walls are used, and the minimum coating thickness of hot dip galvanising is at least 100 microns as per SANS ISO 146.

3.2 Design details

Both the NEC and auxiliary transformer components of the NECRT should be of a three limbed – core form design.

3.2.1 Ratings

It is required that the NEC/NER combination shall limit earth fault currents on the relevant systems to the order of:

a) 300 A to 360 A at nominal system voltage U_m (i.e. 396 A at 1, 1 U_n), or

b) 800 A to 960 A at nominal system voltage U_m (i.e. 1056 A at 1, 1 U_n).

Tables 1 and 2 of annex B give values for the following variables for systems with a fault current that is limited to 360 A and 960 A respectively.

- the system nominal voltage (U_n);
- the zero sequence impedance limits for the combined NEC and NER;
- the apparent power from auxiliary transformer; and
- the NEC neutral current transformer ratings.

3.2.2 Over fluxing

The voltages on the main transformer terminals to which the NEC and auxiliary power transformer are connected shall not exceed 1,1 times the relevant system nominal voltage, the maximum permissible over flux is 1.1 per unit.

3.2.3 Insulation levels

Notwithstanding the requirements of IEC 60076-6, the windings and terminals, including the neutral connections of the NEC and the associated auxiliary power transformer shall be fully insulated as specified in SABS 780. The NER shall be insulated to withstand the applied voltage test prescribed in the same specification.

Table 3 specifies the acceptable insulation levels for the different voltages.

Table 3: Standard voltages and insulation levels

System nominal voltage (U_n) r.m.s. (kV)	System maximum voltage (U_m) r.m.s. (kV	System fault level (kA)	Rated lightning impulse withstand voltage, peak (kV)	Rated short duration power-frequency withstand voltage r.m.s. (kV)
6,6	7,2	25	75	22
11	12	25	95	28
22	24	20	150	50
33	36	20	200	70
44	48	20	250	95

NOTE: Excludes the bushings

3.2.4 Ability to withstand short-circuits

The NEC and auxiliary transformer must both be independently tested for short circuit capability.

3.2.4.1 The auxiliary power transformer

a) The auxiliary power transformer shall meet the short circuit capability requirements stipulated in section 11.6 of 240-57648800 – Specification for New Oil Filled Auxiliary Transformers Rated 1MVA and below and 33kV and below.

3.2.4.2 The NEC and combined NEC/NER

a) Short-time currents

The combined nec/ner shall be capable of withstanding the rated short-time current, specified in Tables 1 and 2 in Annex B.

b) Dynamic requirements

The combined NEC/NER shall be capable of withstanding the dynamic mechanical forces resulting from the application of the rated short-time current, specified in Tables 1and 2 in Annex B.

c) The NEC shall meet the short circuit capability requirements stipulated in IEC 60067-5.

3.2.4.3 Buchholz relay

The Buchholz relay shall have the characteristics specified in 240-56063908.

3.2.5 Temperature rise limits

At the end of the temperature rise test the tank thermal image shall be determined with an IR camera.

DGA samples shall be taken before any test is conducted and after the conclusion of the temperature rise test. At 15min intervals the tank shall be observed with an IR camera to detect for the development of hot spots.

3.2.5.1 Acceptance criteria

The temperature rises shall not exceed the following:

a) Top-oil temperature rise resulting from the losses due to the passage of maximum continuous neutral current together with full load on the auxiliary transformer at rated voltage, shall not exceed 55 °C.

b) Temperature rise of the metallic resistor under the conditions of (a) above shall not exceed 60 °C.

c) Temperature rise of the metallic resistor after passing the rated short-time current for 10 s and from an initial temperature of 100 °C (i.e. 45 °C ambient + 60 °C rise from (b)), shall not exceed 350 °C.

d) No exorbitant gas development.

NOTE: The above will be demonstrated by the manufacturer by measurement in the case of a) and b) and by calculation (at least) in the case of c). It is to be assumed that no dissipation of heat into the oil takes place during the period of 10s.

Manufacturers have to show that the construction of the resistor is such that, it is not degraded by the temperature rise as a result of passage of short circuit current i.e., that all materials used on the resistor construction is capable of handling the temperature rise. Manufacturers shall supply curves of the current versus time diagrams for the resistor.

3.2.6 Tolerances

After completion of the unit, the value of the combined zero sequence reactance, i.e. of the NEC winding and the NER and expressed as Xo = Xc + 3 Xr Ω/phase, and the value of the combined zero sequence resistance, expressed as Ro = Rc +3 Rr Ω/phase, shall be such that the ratio Ro/Xo shall not be less than 2 (a value as close as possible to 2 is the preferred one), and the combined zero sequence impedance Zo = √(Xo2 + Ro2) shall be within the limits specified in Table 1and 2 in Annex B.

The minimum and maximum values of Zo refer to the minimum and maximum values of Xo and Ro. The minimum values of Ro refer to the values at 100 °C of Rc (see 4.2.6(c)). The maximum values of Ro refer to the sum of the minimum values at 100 °C (see 4.2.6(c)) and the increase of Rc and Rr due to the combined effects of manufacturing tolerances and temperature rise above the permitted 100 °C. Namely 150 °C for copper windings and 350 °C for the resistor material, resulting from the passage of the 10 s short time current at its maximum level. The maximum values of Xo refer to the sum of the minimum value of Xo and the increase of Xo (by not more than 20 % above the minimum values) due to the manufacturing tolerances only.

NOTE: Rc and Xc are the resistance and reactance of one phase of the NEC winding, while Rr and Xr are the resistance and the reactance of the resistor

3.3 Current transformers

3.3.1 300A/800 A current transformers

Two current transformers shall be fitted in the neutral connection of the earthed end of the NER as follows:

Nearer to the earthed terminal, a current transformer, used for restricted earth fault and differential protection, with a turns ratio of 1/2400 and tapings at 1/1600, 1/600 and 1/400 to give turns ratios of 1/2400/2000/1800/1600/1200/1000/800/600/400/200. This current transformer shall be tested on the 1/600 turns ratio to demonstrate that it meets all the requirements of Class TPS and will produce, in the secondary, not more than 100 mA exciting current at 300 V, with an internal resistance of not more than 2,4 Ω. The requirements of IEC 60185 (ratio error) will not apply to all other turns ratios, but

1) the voltage produced on any tapping shall be equivalent to the product of its value on the 1/600 turns ratio and the nominal turns on the particular tapping divided by 600, for example:

2400 tap: (300 V) × (2400/600) = 1200 V

2000 tap: (300 V) × (2000/600) = 1000 V

1800 tap: (300 V) × (1800/600) = 900 V

1600 tap: (300 V) × (1600/600) = 800 V

1200 tap: (300 V) × (1200/600) = 600 V

800 tap: (300 V) × (800/600) = 400 V

200 tap: (300 V) ×(200/600) = 100 V

i.e. a current transformer with 0, 5 V/turn.

2) the value of the internal resistance on any tapping shall be equivalent to the product of its value on the 1/600 turns ratio and the nominal turns on the particular tapping divided by 600, for example:

2400 tap: (2, 4Ω) × (2400/600) = 9, 6 Ω

2000 tap: (2, 4Ω) × (2000/600) = 8 Ω

1800 tap: (2, 4Ω) × (1800/600) = 7, 2 Ω

1600 tap: (2, 4Ω) × (1600/600) = 6, 4 Ω

1200 tap: (2, 4Ω) × (1200/600) = 4, 8 Ω

800 tap: (2, 4Ω) × (800/600) = 3, 2 Ω

200 tap: (2, 4Ω) × (200/600) = 0, 8 Ω

i.e. a current transformer with 4 mΩ/turn.

3) the magnetizing current drawn on any tapping shall be equivalent to the product of 100 mA and 600 divided by the nominal turn's ratio at the particular tapping, for example:

2400 tap: (100 mA × 600)/ (2400) = 25 mA

2000 tap: (100 mA × 600)/ (2000) = 30 mA

1800 tap: (100 mA × 600)/ (1800) = 33, 3 mA

1600 tap: (100 mA × 600)/ (1600) = 37, 5 mA

1200 tap: (100 mA × 600)/ (1200) = 50 mA

800 tap: (100 mA × 600)/ (800) = 75 mA

200 tap: (100 mA × 600)/ (200) = 300 mA

NOTE: For the 300A single ratio CT

A single ratio 10 VA 10P10 current transformer used for inverse definite minimum time earth fault (IDMTEF) protection with a turn's ratio of 100/1.

NOTE: For the 800A single ratio CT

A single ratio 10 VA 10P10 current transformer used for inverse definite minimum time earth fault (IDMTEF) protection with a turn's ratio of 800/1.

3.4 Technical data

3.4.1 Current transformer magnetization curve

A magnetisation curve shall be provided for each protection current transformer, on the specified reference tapping for the multi-ratio type.

3.4.2 Drawings

A hard copy and an electronic copy of the required drawings shall be submitted. The drawings shall be to scale. Electronic copies of drawings shall be in DWG or DXF or DGN format. The following drawings shall be submitted for approval with the tender:

a) outline and general arrangement;

b) rating and diagram plate;

c) physical dimensions and transport weight;

d) auxiliary wiring diagram;

e) internal general assembly diagram;

f) Bushings to be used.

3.4.3 Design calculations

Within 30 days of the contract award, the supplier must provide Eskom with the design for the NECRT

a) A calculation proving that the Buchholz relay will not operate under short time rated current conditions for 10s shall be provided.

b) It must be shown that the clamping forces of the NECRT are greater than the calculated short circuit forces.

c) It must be shown that the temperature rise of the metallic resistor after passing the rated short-time current for 10s and from an initial temperature of 100 °C (i.e. 45 °C ambient + 60 °C rise from (b)), shall not exceed 350 °C.

d) It must be shown that the value of the combined zero sequence resistance, expressed as Ro = Rc +3 Rr Ω/phase, shall be such that the ratio Ro/Xo shall not be less than 2, and the combined zero sequence impedance Zo = √(Xo2 + Ro2) shall be within the limits specified in Table 1and 2 in Annex B.

3.5 Component approval

The components and fittings associated with the NEC/NER /auxiliary transformer units will be subject to Eskom's approval. Samples, technical literature, drawings, test reports and lists of the names of principal users, with experience gained shall be supplied on request.

3.5.1 Oil Temperature Indicator

Oil temperature indicator shall comply with 240-56063843, but without remote temperature monitoring facility.

3.5.2 Oil Level Indicator

Oil level indicators must comply with 240-56356191.

3.5.3 Oil Sample Points

A single oil sample point shall be provided for oil sampling. The sample pipe shall be connected to the top of the Buchholz relay and routed to ground level. The sample point must be clearly labelled "Routine Oil Sampling Point" in accordance with section **Error! Reference source not found.**.

The sample point shall be easily accessible from ground level, approximately 200 mm from the base of the NECRT.

10 mm (outer diameter, 7mm inner diameter) copper tubing, sufficiently long to allow the sample point to be approximately 200mm from the base of the NECRT from the Buchholz, with SAE 45 flared connections shall be used as sample pipes. Only corrosion resistant needle valves shall be used as sample valves. The open end of the valve shall be sealed by means of a threaded plug. Alternatives shall be considered with prior evaluation and approval by Eskom.

3.5.4 Alarm and Trip Termination

All transformers shall be provided with the following alarm contacts:

3.5.4.1 Alarm Signalling:

High Oil Temperature (Top Oil)

Low Oil Level: (Main Conservator Tank)

Gas actuated relay (Buchholz) alarm

LV Circuit breaker trip alarm

3.5.4.2 Trip Signalling:

High Oil Temperature (Top Oil)

Gas actuated relay (Buchholz) trip - gas and surge

4. Tests

The combined NEC/NER auxiliary transformer units shall be tested as prescribed in the relevant standards listed in the normative references, except where otherwise stated here or in schedule A of an enquiry document. Failure of a unit to pass any test listed in this section will constitute non-compliance with this specification. In addition to the combined test certificate, separate test certificates must be provided for each of the NECRT components i.e. the auxiliary transformer, compensator winding (zigzag configuration) and resistor for type and special tests. Type tests must be completed and passed for the first of each design for both the auxiliary transformer and NEC for each NECRT type.

4.1 Type and special tests

Unless certified records of previous tests performed on identical units are available test reports for the following type and special tests will be required:

4.1.1 Temperature rise test.

The stable top-oil temperature shall be measured for the following conditions:

a) Auxiliary power transformer loaded at the full load current and the NEC/NER loaded to the rated continuous nominal current (10 A).

b) NEC/NER loaded at the rated short-time neutral current for 10 seconds, directly after completion of condition (a): The top-oil temperature rise shall not exceed 65 °C.

4.1.2 Demonstration of ability to withstand the dynamic effects of short-circuit and short-time current

a) Short-circuit withstand test performed on the auxiliary transformer, NER and NEC must be done so in accordance with IEC 60076-5.

4.1.2.1 Short circuit withstand testing requirements over and above the requirements of IEC60076-5

Value of the symmetrical short-circuit current (IEC 60076-5 paragraph 4.1.2)

The resistance value at 20 degree Celsius shall be used to calculate the short circuit currents to be applied to the NECRT.

A voltage of 115% of V nominal tap voltage, (i.e. 5% above V max and 15% above Vrated, shall be used to calculate the short circuit currents to be applied to the NECRT).

Notwithstanding the over current limits tabulated in IEC 60076-5, the transformer with the standard minimum percentage impedances given in of this specification, shall be capable of withstanding the thermal, mechanical and other effects using the following criteria for calculating the short circuit withstand condition:

a) Pre-fault voltage of 1.1Un;

b) Source impedance shall be assumed to be infinite;

c) Fault duration of 10s

d) The inner winding shall be designed to withstand the free buckling criteria. However, the specific stress ($\sigma_{average}$) of the inner winding shall not exceed 50% of the copper conductor yield strength.

e) The yield strength that shall apply to the conductor of the outer winding shall be 80% of the conductor yield strength.

f) All material used for winding cylinders shall be pre-dried and pre-impregnated with oil prior to use.

g) The blocks which are used to apply the axial compression shall be pinned to the clamping system.

h) Any paper insulation shall be thermally upgraded paper.

4.1.2.2 Number of short circuits

NECRT's are subject to many short circuits in their lives and manufacturers needs to note this. (This is their prime function in the network.)

The NECRT's are required to withstand at least 9 short circuits (three tests per phase) in a pre-set short circuit test configuration.

The initiation of the short circuit shall be so timed that the inrush current adds to the peak short circuit current on at least one phase.

4.1.2.3 Compliance criteria:

Measurement of the inductance of a NECRT is done by measuring the parallel value of the (Zero sequence inductance) three phases to ground. This has the effect that a 4.0% change in inductance on one arm of the NEC will only reflect as a 1.30% change in the zero sequence inductance of the NECRT. (A 7.5% change in one arm will reflect as 2.38% change in the zero sequence inductance and 2.0% change in inductance in one winding reflects as 0.65% change etc).

4.1.2.4 Circular concentric windings

Total change in the inductance per phase (first to last test) is not allowed to exceed 2% (0.66% of NEC measurement).

The supplier has to demonstrate that a change greater than 1.0% (0.33% of NEC measurement) is of a non-detrimental self-limiting nature. Testing has to be repeated until the change after each successive test stabilise to less than 0.25% (0.082% of NEC measurement) of the inductance of the winding.

4.1.2.5 Non-circular concentric winding

Radial dimension changes in non-circular concentric winding transformers are recognised as potentially acceptable, but it has to be demonstrated by the supplier that these changes are of a non-detrimental self-limiting nature. Total change in the inductance per phase (first to last test) is not allowed to exceed 4.0% (1.30% of NEC measurement).

The supplier has to demonstrate that a change greater than 2% (0.66% of NEC measurement) is of a non-detrimental self-limiting nature. Testing has to be repeated until the change after each successive test stabilise to less than 0.5% (0.161% of NEC measurement) of the inductance of the winding.

4.1.3 Vacuum test

Vacuum test to be conducted at full vacuum at sea level.

4.1.4 Accelerated ageing test for composite bushings

The preferred test is the KIPTS natural ageing test. An artificial ageing test in accordance with Annex C of IEC 61109 is also acceptable.

NOTE: The rated short-time tests cannot be enforced due to limitations of testing facilities in South Africa. Eskom do however reserve the right to perform these tests on the network.

4.2 Routine tests

Routine tests must be carried out in compliance with all parts of the latest version of IEC 60076. All NECRT's must be issued with routine test certificates prior to dispatch from the factory. Separate test certificates must be provided for each component of the NECRT i.e. the auxiliary transformer, compensator and resistor. The manufacture is obliged to provide a test procedure that Eskom staff may follow in site testing for the NECRT such that the performance of each component of the NECRT i.e. the auxiliary transformer, compensator and resistor, can be verified.

4.2.1 Zero sequence impedance test

This test consists of:

4.2.1.1 The measurement, at a voltage that produces rated continuous neutral current, of the combined zero sequence reactance of each NEC and NER (Un being the nominal phase to phase voltage of the NEC) to meet the requirements of 4.2.6(a);

4.2.1.2 The measurement of the overall resistance between the three HV terminals (with the auxiliary transformer disconnected) and the earthed terminal of the resistor.

The resistance shall be measured as follows:

a) each phase separately between line and earthed terminal, (which gives the value of $R_c + R_r$); and

b) the three line terminals, connected together, to the earthed terminal, (which gives the reading of $R_c/3 + R_r$).

The measured value of $R_c/3 + R_r$ shall be multiplied by 3 and corrected to a reference temperature of 100 °C; this corrected value and its increase, due to the temperature rise above 100 °C allowed in accordance with 4.2.6(b), shall respectively meet the requirements of 4.2.6(a).

4.2.2 Applied voltage test

4.2.2.1 Secondary wiring

Each secondary wiring insulation circuit shall withstand a test voltage as per IEC, or the higher voltage as specified in 240-68973110 in the case of current transformer circuits, to earth and to all other circuits.

4.2.2.2 HV winding

The resistor shall be included with the NEC and auxiliary transformer for the test.

4.2.2.3 Separate source voltage withstand test

The test shall be conducted as specified in IEC 60076-3,

4.2.2.4 Induced over voltage withstand test

The test shall be conducted as specified in IEC 60076-3,

4.2.3 Tests to be conducted on the auxiliary transformer

4.2.3.1 Measurement of no load loss and no load current

The test shall be conducted as specified in IEC 60076-1,

4.2.3.2 Measurement of impedance voltage and, short-circuit impedance and load loss

The test shall be conducted as specified in IEC 60076-1.

4.2.3.3 Measurement of voltage ratio and check of voltage vector relationship

The test shall be conducted as specified in IEC 60076-1.

4.2.4 Partial Discharge Testing

Test to be conducted as per IEC 60076-3.

4.2.5 Dielectric tests in accordance with IEC 60076-3

a) Short duration (60 s) power-frequency withstand voltage test, performed on the combined unit.

b) Full- and chopped-wave impulse test, performed on the combined unit.

c) Separate source voltage withstand test, performed on the combined unit.

d) Induced over voltage withstand test, performed on the combined unit.

4.2.6 Measurement of zero sequence impedance

It shall be shown that the zero sequence impedance of the NEC/NER combination is within the specified tolerances, up to rated short-time current.

the zero-sequence impedance shall be measured by connecting the three-phase terminals together and applying a single-phase voltage (V) between them and the earthed terminal, of the NER then:

$$Z_o = 3V/I\ \Omega/\text{phase}$$, where I is the single-phase current,

a) measurements shall be made at I equal to 5 A, 10 A and 15 A and it shall be shown by extrapolation that the zero sequence impedance is within the specified tolerances, up to rated short-time current.

b) alternatively, a measurement can be made at I equal to rated short-time current in the NEC/NER.

4.2.7 Sweep Frequency Response Analysis SFRA

SFRA is used to test the mechanical integrity of windings by examining the frequency response of the Resistive, Inductive and Capacitive circuits of the NECRT.

4.3 Inspection and witnessing of tests

Factory and quality inspections will be conducted for evaluations, including the inspection of the active part.

Eskom reserves the right to inspect the units at any stage during their manufacture and to be present at any of the tests specified.

Eskom must be notified to carry out an active part inspection. This is a hold-point. The manufacturer shall inform Eskom of the firm date on which tests are to be carried out, not less than 14 days prior to the date and shall ascertain whether Eskom requires witnessing of the type and routine tests. No unit shall be dispatched from the manufacturer's works without Eskom's approval.

4.3.1 Test certificates

Copies of all test certificates or reports shall be supplied to Eskom. All NECRT's must be issued with routine test certificates prior to dispatch from the factory. Separate test certificates must be provided for each component of the NECRT i.e. the auxiliary transformer, compensator and resistor. The manufacturer is obliged to provide a test procedure that Eskom staff may follow in site testing for the NECRT such that the performance of each component of the NECRT i.e. the auxiliary transformer, compensator and resistor, can be verified.

5. Transport

Each unit shall be crated and/or fitted with lashing lugs in compliance with the requirements of the road transport authorities for safe transport, and shall bear appropriate transport warning notices.

A non-resettable impact recorder/detector shall be provided and located in such a position so as to record/detect the acceleration of the NECRT tank and not the packaging.

6. Authorization

This document has been seen and accepted by:

Name and surname	Designation
S Mtetwa	Corporate Specialist Transformers and Reactors
B Ntshangase	Senior Manager - HV Plant, and SCOT/SC Chairperson
K Dioka	Chief Engineer for Transformers and Reactors
C Wolmarans	Engineer for Transformers and Reactors
V Kula	HV Plant Manager – South Grid
Dr H Geldenhuys	Corporate Specialist – Power Delivery Engineering

7. Revisions

Date	Rev	Compiler	Remarks
March 2014	Draft 0.1	A Singh	Document number changed to 240-57648848 Compiled By: A. Singh for the NECRT Specification Work Group New document format. Incorporation of the findings of the failure investigations into specification and design.
			Removed Distribution Group and included "Eskom's" as this document is applicable to all Eskom Divisions. Edited content. Scope: Added text regarding SWER NECs. Edited content. Normative references: Updated Clause 4.1 Included reference to IEC 60073 – 3, design reviews, height Clause 4.1.1 Increased maximum ambient temperature, added note. Clause 4.1.2 Added points k to n Clause 4.1.3 Increased MV Voltage %, added points g to j and note. Clause 4.1.5 Added points b and g and added text to c, d, e and f Clause 4.1.6 Edited column 3 heading in table 2 Clause 4.1.9 Text added to points a, and b. Text modified in points f and g. Table 3 removed. Text modified in Note. Clause 4.1.10 Edited text in point a

Date	Rev	Compiler	Remarks
			Clause 4.1.11 Removed "dial-type" from point e. Edited text in point g. Changed econds to 20 seconds. Clause 4.1.11.1 Edited text in point a. Removed points d and e. Added Note. Clause 4.1.11.2 Added section on Pipe Work Connection Clause 4.1.12 Added clause Clause 4.1.14 Edited document reference and added text Clause 4.1.15 Added section on Tank Construction Clause 4.1.16 Added radiator requirements Clause 4.2.1 Updated table references Clause 4.2.4.1 Updated point a Clause 4.2.4.2 Updated table reference and updated to 20 s Clause 4.2.5 Updated text Clause 4.4.2 Added point c Clause 4.4.3 Changed to 20 s Clause 5.1.2 Added text
			Clause 5.2 Added clause for partial discharge testing and moved type tests to routine tests Clause 5.2.7 Added requirements for SFRA Clause 5.3. Added new text Clause 6 Added point b Annex A Updated Annex B Updated Annex C removed. Will be issued as separate document.
Feb 2009	0		Document published
Nov 2008	6	I Sebeko	Document reference number changed from DISSCAAD1 to DSP 34-1690 Document text modified and rearranged Introduction text added and the scope updated Clause 2: Dates and revision numbers removed from normative references. Schedules for 33 kV/ 800 A NECRT added. Transformer oil supplied shall be compliant with NRS 079 Clause 4.1.2 b) Option of a sealed unit added

Date	Rev	Compiler	Remarks
			Clause 4.1.5 Clause on oil modified 4.1.6 f) Text modified 4.1.9 f) All bushings are clamp type 4.1.11.1 Text on pressure relief valve modified 4.1.12.1-2 Secondary winding revised and DSP 34-253 referenced 4.2.5 Current / Time curves for the resistor shall be supplied
Oct 2004	5	I Sibeko	Document approved
Sept 2004	4	I Sibeko	General Page 4, 4.1 Ability to withstand short circuit Page 16, 5.1.4, 5.1.4.1 to 5.1.4.5 Addition to general requirements on short circuits etc; the Removal of the tap changer, item 4.1.2 (f) and the addition of the 44kV technical schedules.
Dec 2002	3	C B Clark	Document approved. Comments addressed.
			Page 4, Table 1, 2.4 changed to 2.5 Page 6, 4.1.6 Power cable connection added Page 6, note under table 3 modified to allow for the BIL to be added. Page 7, 4.1.7 point e modified. Page 17, table 6 CT for REF and DIFF changed from 1600/1 to 2400/.
Oct 2001	2	R Theron and D Padayachy	Comments addressed – Multi ratio CT requirements for 300A applications changed to match multi ratio CT requirements used for 800A applications. Both to be 2400/1 multi ratio (This is to cater for a 40MVA 11kV application). All bushings changed to 33kV with 700mm spacing between centres. Complete format revised. Technical Schedules A and B complimented with new compliance schedule. Clearances between bushings changed to cater for double conductor connections. Cu conductor between ZN and earth terminal removed and compensated for by using the tank as conductor. Label inserted under terminal P2 to specify maximum time and current permissible during current injection test. Calculations requested to prove the correct operation of the Buchholz relay
Aug 2000	1		Cable hoods requirements removed. Clarified type test requirements.

Date	Rev	Compiler	Remarks
			Document updated and revised
Sept 1996	0		Document updated and revised

8. Development team

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

- Hendri Geldenhuys
- Adesh Singh
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- Carl Wolmarans
- Sidwell Mtetwa
- Abre Le Roux

9. Acknowledgements

Not applicable

Annex A – Impact assessment

(Normative)

Impact assessment form to be completed for all documents.

1) Guidelines

- All comments must be completed.
- Motivate why items are N/A (not applicable)
- Indicate actions to be taken, persons or organisations responsible for actions and deadline for action.
- Change control committees to discuss the impact assessment, and if necessary give feedback to the compiler of any omissions or errors.

2) Critical points

2.1 Importance of this document. E.g. is implementation required due to safety deficiencies, statutory requirements, technology changes, document revisions, improved service quality, improved service performance, optimised costs.

Comment: The document provides specific requirements for the NECRT's which are in line to improve the safety and service performance of the product.

2.2 If the document to be released impacts on statutory or legal compliance - this need to be very clearly stated and so highlighted.

Comment: The document specifies products which are compliant with the requirements of the earthing code.

2.3 Impact on stock holding and depletion of existing stock prior to switch over.

Comment: There is no impact on stock holding as the process is managed on a national contract.

2.4 When will new stock be available?

Comment: As soon as the new contract is established as the products are supposed to be manufactured according to the specification.

2.5 Has the interchange ability of the product or item been verified - i.e. when it fails is a straight swop possible with a competitor's product?

Comment: The product is as far as possible interchangeable as this forms part of the requirements.

2.6 Identify and provide details of other critical (items required for the successful implementation of this document) points to be considered in the implementation of this document.

Comment: None.

2.7 Provide details of any comments made by the Regions regarding the implementation of this document.

Comment: (N/A during commenting phase)

3) Implementation timeframe

3.1 Time period for implementation of requirements.

Comment: The requirement shall be implemented during the tender phase.

3.2 Deadline for changeover to new item and personnel to be informed of DX wide change-over.

Comment: There is no deadline for change over.

4) Buyers Guide and Power Office

4.1 Does the Buyers Guide or Buyers List need updating?

Comment: Buyers Guide needs to be modified.

4.2 What Buyer's Guides or items have been created?

Comment: N/A

4.3 List all assembly drawing changes that have been revised in conjunction with this document.

Comment: None

4.4 If the implementation of this document requires assessment by CAP, provide details under 5

4.5 Which Power Office packages have been created, modified or removed?

Comment: None

5) CAP / LAP Pre-Qualification Process related impacts

5.1 Is an ad-hoc re-evaluation of all currently accepted suppliers required as a result of implementation of this document?

Comment: Yes

5.2 If NO, provide motivation for issuing this specification before Acceptance Cycle Expiry date.

Comment:

5.3 Are ALL suppliers (currently accepted per LAP), aware of the nature of changes contained in this document?

Comment: The suppliers shall be notified as part of the tender process.

5.4 Is implementation of the provisions of this document required during the current supplier qualification period?

Comment: No

5.5 If Yes to 5.4, what date has been set for all currently accepted suppliers to comply fully?

Comment: None

5.6 If Yes to 5.4, have all currently accepted suppliers been sent a prior formal notification informing them of Eskom's expectations, including the implementation date deadline?

Comment: No

5.7 Can the changes made, potentially impact upon the purchase price of the material/equipment?

Comment: Yes

5.8 Material group(s) affected by specification: (Refer to Pre-Qualification invitation schedule for list of material groups)

Comment: NECRT's

6) Training or communication

6.1 Is training required?

Comment: Yes

6.2 State the level of training required to implement this document. (E.g. awareness training, practical / on job, module, etc.)

Comment: Suppliers are supposed provide specific product training if required.

6.3 State designations of personnel that will require training.

Comment: Engineering staff

6.4 Is the training material available? Identify person responsible for the development of training material.

Comment: Suppliers shall provide specific training material when required.

6.5 If applicable, provide details of training that will take place. (E.G. sponsor, costs, trainer, schedule of training, course material availability, training in erection / use of new equipment, maintenance training, etc.)

Comment: The supplier shall provide full details of training during tender process.

6.6 Was Technical Training Section consulted w.r.t module development process?

Comment: No

6.7 State communications channels to be used to inform target audience.

Comment: Training communications, TCIF meetings

7) Special tools, equipment, software

7.1 What special tools, equipment, software, etc will need to be purchased by the Region to effectively implement?

Comment: None

7.2 Are there stock numbers available for the new equipment?

Comment: Yes, if SAP numbers are the same as stock numbers.

7.3 What will be the costs of these special tools, equipment, software?

8) Finances

8.1 Identify all cost activities associated with implementation, e.g. labour, training, tooling, stock, obsolescence

Comment: None

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Impact assessment completed by:

Name: Adesh Singh_____

Designation: NECRT Specifiation Work Group Chairman_____

Annex B – - NEC (Zigzag Connection) and NER characteristics

(normative)

Table B.1: NEC (Zigzag Connection) and NER characteristics

Caption Eskom Standard Number	System nominal voltage U_n	NEC (Zigzag Connection) and NER characteristics							CTs fitted to the NEC neutral (as per figure 2)		Nominal power of auxiliary power transformer (Having LV = 415 V/ 240 V; vector group Dyn 11)
		Continuous nominal current	Short time current for a 10 second in the NEC neutral and resistor		Zero sequence reactance (X_o) and resistance (R_o) (Ohms/phase)				Turns ratio of class TPS multi ratio CT for REF and Diff. Protection (see 3.3)	Turns ratio of single ratio 10 VA 10P10 CT for IDMTEF (see 3.3)	
					$X_o = X_c + 3X_r$ (see note 3)		$R_o = R_c + 3Rr$ (see note 3)				
	(kV)	(A rms)	(A r.m.s.)						(N2/N1)	(N2/N1)	(kVA)
			Minimum	Maximum	Minimum	Maximum	Minimum (see note 1)	Maximum (see note 2)			
N2.2	2.2	10	300	396	4.7	5.7	9.5	11.4	2400/1	100/1	100
N3.3	3.3	10	300	396	7.1	8.5	14.2	17	2400/1	100/1	100
N6	6,6	10	300	396	14,2	17,0	28,4	34,1	2400/1	100/1	100
N11a	11	10	300	396	23,7	28,4	47,3	56,8	2400/1	100/1	100
N22a	22	10	300	396	47,3	56,8	94,7	113,6	2400/1	100/1	100
N33a	33	10	300	396	71	85,2	142	170,4	2400/1	100/1	100
N44	44	10	300	396	94.8	113.7	189	227.2	2400/1	100/1	100

NOTE 1: The minimum value of Ro refers to the value of R_c and R_r at 100 °C (45 °C ambient + 60 °C rise of metallic resistor due to continuous nominal current of 10 A) (see 4.2.6)).

NOTE 2: The maximum value of Ro results from the increase of Rc and Rr due to manufacturing tolerances and the temperature rise (above 100 °C, see 4.2.6)) after a 10 second fault starting at the maximum fault current of 396 A.

NOTE 3: X_c and R_c refer to one phase of NEC winding, Xr and R_r refer to the metallic resistor. The condition $R_o/X_o \geq 2$ must be met, preferably $R_o/X_o = 2$.

Annex C – - NEC (Zigzag Connection) and NER characteristics

(normative)

Table C.1: NEC (Zigzag Connection) and NER characteristics

Eskom Standard Number	System nominal voltage U_n	NEC (Zigzag Connection) and NER characteristics							CTs fitted to the NEC neutral (as per figure 2)		Nominal power of auxiliary power transformer (Having LV = 415 V/ 240 V; vector group Dyn 11)
		Continuous nominal current	Short time current for 10 second in the NEC neutral and resistor		Zero sequence reactance (X_o) and resistance (R_o) (Ohms/phase)				Turns ratio of class TPS multi ratio CT for REF and Diff. Protection (see 3.3)	Turns ratio of single ratio 10 VA 10P10 CT for IDMTEF (see 3.3)	
					$X_o = X_c + 3X_r$ (see note 3)		$R_o = R_c + 3Rr$ (see note 3)				
	(kV)	(A rms)	(A r.m.s.)						(N2/N1)	(N2/N1)	(kVA)
			Minimum	Maximum	Minimum	Maximum	Minimum (see note 1)	Maximum (see note 2)			
N11b	11	10	800	1056	8,9	10,7	17,8	21,3	2400/1	800/1	100
N22b	22	10	800	1056	17,8	21,3	35,5	42,6	2400/1	800/1	100
N33b	33	10	800	1056	26,6	31,95	53,3	63,9	2400/1	800/1	100

NOTES 1 The minimum value of Ro refers to the value of R_c and R_r at 100 °C (40 °C ambient + 60 °C rise of metallic resistor due to continuous nominal current of 10 A) (see 4.2.6)).

NOTE 2 The maximum value of Ro results from the increase of Rc and Rr due to manufacturing tolerances and the temperature rise (above 100 °C, see 4.2.6)) after a 10 second fault starting at the maximum fault current of 396 A.

NOTE 3 X_c and R_c refer to one phase of NEC winding, Xr and R_r refer to the metallic resistor. The condition $R_o/X_o \geq 2$ must be met, preferably $R_o/X_o = 2$.