



Standard

Technology

Title: **SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: **240-68973110**

Alternative Reference Number: **<n/a>**

Area of Applicability: **Engineering**

Documentation Type: **Standard**

Revision: **2**

Total Pages: **80**

Next Review Date: **February 2023**

Disclosure Classification: **Controlled Disclosure**

Compiled by

Sidwell Mtetwa  
Transformer Corporate Specialist

Date: 14/09/2019

Approved by

Bheki Ntshangase  
Senior Manager – PDE HV Plant Engineering

Date: 17/7/2017

Authorized by

Danie Odendaal  
Senior General Manager – Engineering (Acting)

Date: 19/7/2017

Supported by SCOT/SC

Bheki Ntshangase  
SCOT PE Chairperson

Date: 17/7/2017

## Content

	Page
Executive Summary.....	7
1. Introduction.....	8
2. Supporting clauses.....	8
2.1 Scope.....	8
2.1.1 Purpose.....	8
2.1.2 Applicability.....	9
2.2 Normative/informative references.....	9
2.2.1 Normative.....	9
2.2.2 Informative.....	10
2.3 Definitions.....	10
2.3.1 General.....	10
2.3.2 Disclosure classification.....	11
2.4 Abbreviations.....	11
2.5 Roles and responsibilities.....	12
2.6 Process for monitoring.....	12
2.7 Related/supporting documents.....	12
3. Specification Minimum Requirements.....	12
3.1 Design Reviews.....	12
3.2 Site Conditions.....	13
3.3 Network Conditions.....	14
3.3.1 Frequency.....	14
3.3.2 Voltage Unbalances.....	14
3.3.3 Harmonic Pollution.....	14
3.3.4 Geomagnetic Induced Currents.....	14
3.4 Ratings.....	15
3.4.1 Rated Power.....	15
3.4.2 Rated Current.....	15
3.4.3 Rated Voltage.....	15
3.4.4 Maximum Continuous Rated Voltage.....	15
3.4.5 Maximum Temporary Overvoltages.....	15
3.4.6 Overfluxing.....	15
3.4.7 Impedance.....	15
3.4.8 Ability to Withstanding Short Circuit.....	20
3.4.9 Clearances in Air.....	20
3.5 Core.....	22
3.5.1 Design.....	22
3.5.2 Materials.....	23
3.5.3 Clamping.....	23
3.5.4 Earthing.....	23
3.5.5 Temperature Rise.....	23
3.5.6 Electrical Continuity.....	23
3.5.7 Stack-stack Resistance.....	24
3.6 Coils/Windings.....	24
3.6.1 Design.....	24

**ESKOM COPYRIGHT PROTECTED**

---

3.6.2	Materials.....	24
3.6.3	Hot Spot Calculations .....	24
3.6.4	Insulation.....	24
3.6.5	Joints and Internal Connections .....	25
3.7	Transformer Construction and Assembling.....	27
3.7.1	Winding Arrangement .....	27
3.7.2	Sizing and Compressing .....	27
3.7.3	Terminal Arrangement .....	28
3.7.4	Termination on bushings.....	28
3.7.5	Clamping.....	29
3.7.6	Drying.....	29
3.8	Bushings.....	29
3.9	Tap Changers.....	29
3.9.1	Type of tap changers .....	29
3.9.2	On Load Tap Changers .....	29
3.9.3	Off Circuit Tapping Switches.....	29
3.9.4	Tapping Range .....	29
3.9.5	Electrical Location (Positioning) of the Tap Changer .....	30
3.9.6	Ratings.....	30
3.9.7	Design Requirements .....	30
3.9.8	Other Tap Changer Requirements .....	31
3.9.9	Driving mechanism, control and indicating equipment .....	32
3.9.10	Drawings and technical data.....	35
3.10	Tank and Parts .....	38
3.10.1	Tank Design .....	38
3.10.2	Tank Base .....	38
3.10.3	Tank Main Top Cover .....	39
3.10.4	Tank Strength and Oil Tightness .....	39
3.10.5	Access openings and covers .....	40
3.10.6	Handles .....	40
3.10.7	Lifting lugs.....	40
3.10.8	Valves and oil sampling devices .....	41
3.10.9	Jacking Pads.....	44
3.10.10	Lifting Lugs.....	45
3.10.11	Centre of Gravity.....	45
3.10.12	Manholes and Handholes .....	46
3.10.13	Provisions for earthing .....	46
3.10.14	Brackets for Surge Arrestors.....	47
3.10.15	Permanent Ladder .....	47
3.10.16	Partial Draining .....	48
3.11	Auxiliary Supplies, Terminal Boxes, Wiring and Cabling .....	48
3.11.1	Supply Voltage .....	48
3.11.2	Marshalling and Terminal Boxes.....	48
3.11.3	Earthing terminal.....	52
3.11.4	Spare terminals.....	52
3.11.5	Incoming auxiliary circuits .....	52
3.11.6	Provision for outgoing cables.....	52
3.11.7	Cabling and Wiring.....	52
3.11.8	Insulation.....	52

---

3.11.9	Insulation test voltage .....	52
3.11.10	Type of conductor .....	53
3.11.11	Supporting and securing of cables .....	53
3.11.12	Identification of wiring .....	53
3.11.13	Cabling by the Purchaser.....	53
3.11.14	Identification of fuses and circuit breaker .....	53
3.11.15	Identification of equipment.....	53
3.12	Rating and Diagram Plates .....	53
3.12.1	General .....	53
3.12.2	Materials and methods of marking.....	54
3.12.3	Mounting .....	54
3.12.4	Information to be displayed.....	54
3.13	Painting of Tanks and Parts .....	56
3.14	Special Auxiliaries .....	56
3.14.1	Buchholz Relay .....	56
3.14.2	Pressure relief devices.....	56
3.14.3	Rapid Pressure Rise Relay.....	57
3.14.4	Thermometers for Oil and for Winding Temperatures .....	57
3.14.5	Fibre optic temperature probes.....	57
3.14.6	Oil Level Indicators .....	57
3.14.7	Fans, Pumps and Radiators .....	58
3.14.8	Air Bag .....	58
3.14.9	Air Bag Leak Detector.....	58
3.14.10	Dehydrating Breathers .....	59
3.14.11	Optional digital secondary plant interface .....	59
3.15	Insulating Oil.....	59
3.16	Cooling .....	59
3.16.1	General .....	59
3.16.2	Cooling Systems .....	59
3.17	Current Transformers .....	60
3.17.1	Number and Location.....	60
3.17.2	Transformer Short-circuits and Overload.....	60
3.17.3	Insulation levels and short circuiting for testing. ....	60
3.17.4	Tests for current transformers.....	60
3.17.5	Terminal Connections .....	61
3.17.6	Termination of Leads - Internal .....	61
3.17.7	Turns Compensation.....	61
3.17.8	Required Data .....	61
3.17.9	CT Designation .....	61
3.17.10	Current Transformers for Delta-connected Windings .....	61
3.17.11	CT for Winding Temperature Indication for Delta Windings .....	61
3.17.12	Type and Accessibility .....	61
3.17.13	Data for Rating and Diagram Plates .....	62
3.17.14	Terminal Markings .....	62
3.18	Transformer Testing.....	69
3.18.1	Active Part and General testing .....	69
3.18.2	Transformer Tank Testing.....	69
3.19	Transformer Transportation .....	70
3.19.1	General Conditions .....	70

---

3.19.2	Impact Recorders.....	71
3.19.3	Testing During Transport .....	71
3.19.4	Sea Transport .....	72
3.19.5	Road Transport .....	72
3.19.6	Transport support brackets .....	72
3.20	Erection .....	72
3.20.1	General .....	72
3.20.2	Foundation Tolerances and Transformer Layout Details .....	72
3.20.3	Site Installation.....	72
3.20.4	Functional Tests.....	72
3.20.5	Electrical Tests According to IEC.....	73
3.21	Condition Monitoring .....	73
3.21.1	Gas Analysers.....	73
3.21.2	On line drying system .....	74
3.21.3	Fibre optic temperature sensors .....	74
3.21.4	General .....	74
3.22	Documentation .....	74
3.23	Adjudication of Tenders .....	75
3.23.1	Failure Rates, Reliability and Manufacturing Experience of <i>Contractors</i> .....	75
3.23.2	Population .....	75
3.23.3	Factory Failure .....	75
3.23.4	Factory Failure Rate .....	75
3.23.5	In-service Failure .....	75
3.23.6	In-service Failure Rate.....	75
3.23.7	On Time Delivery .....	75
3.23.8	On Time Delivery Rate.....	76
3.24	Quality Assurance .....	76
3.25	Loss Evaluation .....	76
3.25.1	Guaranteed losses.....	76
3.25.2	Non Conformance on losses.....	77
3.26	Training of Purchaser's staff .....	77
3.27	Local Support .....	78
3.27.1	Local Support's Requirements.....	78
3.28	Safety on Transformers.....	78
4.	Authorisation.....	78
5.	Revisions .....	80
6.	Development team (Working Group).....	80
7.	Acknowledgements .....	80

**Figures**

Figure 1:	Classes of transformers in Eskom.....	8
Figure 2:	External connections, clearances from lines of approach.....	22
Figure 3:	Illustration of Position of HV terminals .....	28
Figure 4:	Control circuits for all three-phase OLTC motor drives .....	36
Figure 5:	Common circuits for OLTC control.....	37
Figure 6:	Oil sampling flange interfaces .....	43

**ESKOM COPYRIGHT PROTECTED**

---

Figure 7: Arrangement of jacking pads.....	45
Figure 8: Surge arrester bracket dimensions .....	47
Figure 9: Typical Rating and Diagram plate .....	55
Figure 10: Terminal Markings for 'Class 1' 2-winding transformers .....	63
Figure 11: CT Terminal Markings for 3 winding auto transformers .....	64
Figure 12: Built-in Current Transformers .....	65

**Tables**

Table 1: Standard MVA ratings and impedances for transformers of Class 1 .....	17
Table 2: Standard MVA and impedances for Class 2 and above transformers used in the transmission voltage level applications .....	19
Table 3: Electrical clearances in air.....	21
Table 4: Conversion factors for insulation stresses analysis.....	24
Table 5: Minimum insulation, fault and creepage levels for Class 1 power transformers – These should match IEC requirements.....	26
Table 6: Winding Arrangement configurations .....	27
Table 7: Tap position encoder contact state at each tap position .....	38
Table 8: Minimum thickness of transformer tank base plates — mild steel .....	39
Table 9: Jacking pad dimensions .....	45
Table 10: Standard layout for Marshalling Interface Box fitted to transformers .....	49
Table 11: For Autotransformers of 13B and 20MVA .....	65
Table 12: In-built current transformers for 13D (Star/delta transformers up to 20 MVA) .....	66
Table 13: Built-in CTs for 13A configuration.....	67
Table 14: Built-in current transformers for star-delta units above 20MVA (13D) .....	67
Table 15: Built in Current Transformers for star-star transformers (13F).....	68
Table 16: Built-in current transformers (Class TPS core details) .....	68
Table 17: Maximum permanent deflection of steel tank panels between stiffeners.....	70

## Executive Summary

This transformer specification document was the work produced by the Eskom SCOT Transformer Care Group. The Care Group started a Working Group to review the existing divisional transformer specifications and look at the possibility of merging the documents. There was 90% alignment between the Transmission's and Distribution's specification documents. There was also more than 70% alignment between the Generation's specification and the WG concluded that these documents could be aligned, including the specification documents for the auxiliary components.

This document incorporates the best applicable requirements from the previous divisional documents and integrated the recent learnings from the Eskom business, the international bodies, and the experts from around the world, including suppliers from various continents. In the past Eskom purchased transformers which experienced shortened lifespans, with an average failure age of about 18 years instead of the expected 35 years and 40 years for generator-step-up and the network transformers, respectively. Three separate teams of international consultants were employed by Eskom to look at the root cause of the premature failures observed at that time. The results of the work of these consultants were incorporated into this technical specification document. These include, but are not limited to, the following:

- Composite bushings – to reduce failure and fire risks plus maintenance requirements
- Enamelled windings on certain classes of transformers – to eliminate corrosive sulphur effects and other chemical problems
- Winding arrangements – to reduce radial forces during short circuits,
- Specific oils – to reduce corrosive sulphur failures,
- Reductions in load and no load losses – to reduce life cycle costs,
- Introduction of maintenance free vacuum tap-changers technology
- Environmental considerations, including oils
- Climate change considerations

Continually as technologies evolve these are researched and considered by Eskom SCOT Transformers Care Group who are continually optimizing the designs as required. The new designs have reduced the high failure rate experienced prior to introduction of these points.

## 1. Introduction

This specification document gives the requirements for all new transformers procured by/for Eskom for use in the Gx OUs, Tx OUs, and Dx OUs. This document was compiled by the SCOT WG which was a cross divisional and multi-disciplinary team. This work was produced with the intentions mentioned below in mind

- Acquiring transformers that are fit for purpose and can remain reliable to the expected life of 35 (GSU) and 40 years (for all others).
- Achieving optimized standardization thereby allowing a wide range of interchange-ability.
- The Eskom drive for low maintenance, tending towards maintenance free technologies.
- Support Eskom’s drive for reducing the carbon footprint, zero harm to people and to the environment and BPP initiatives.
- Minimizing the total cost of ownership.

## 2. Supporting clauses

### 2.1 Scope

This Specification applies to all Eskom oil-filled new power transformers, having a highest voltage winding operating at or above 2.2 kV, and a rating above 1.25 MVA. This excludes the conventional power reactors, HVDC converter transformers, and HVDC smoothing reactors. The transformers covered in this specification document are generally classified as follows in Eskom

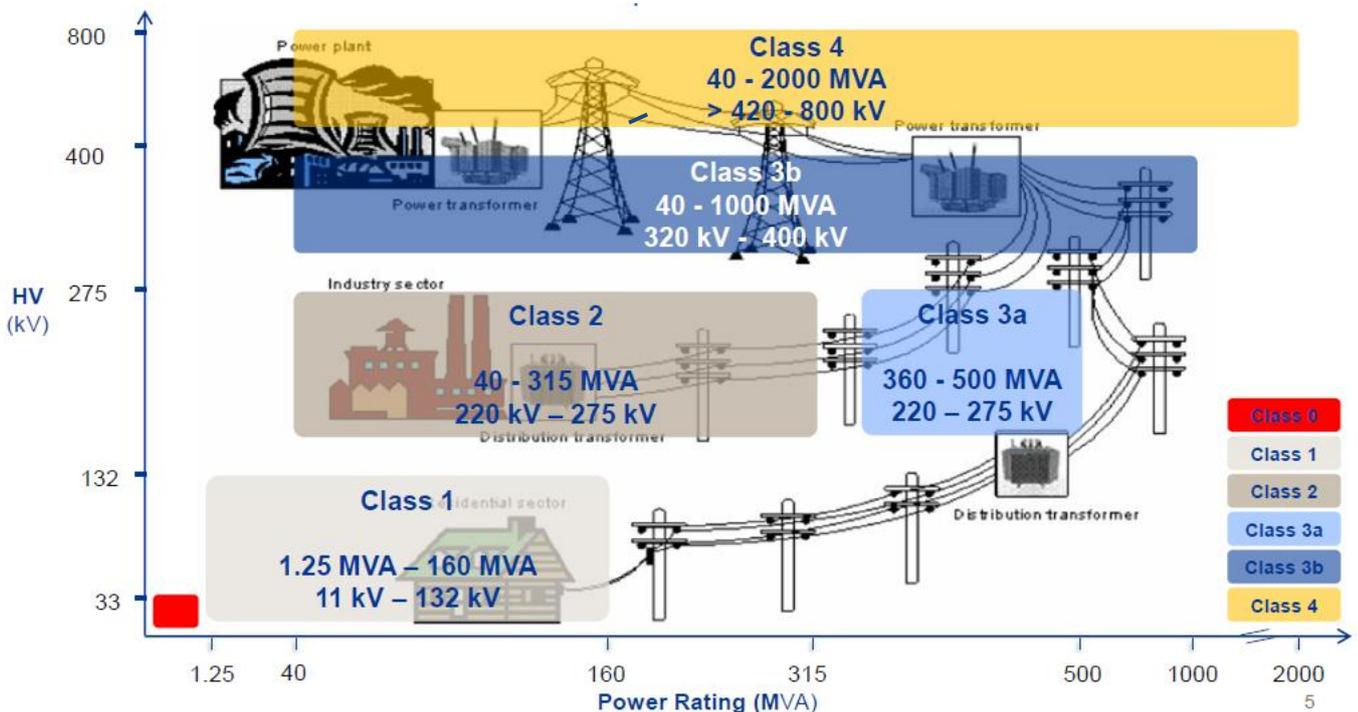


Figure 1: Classes of transformers in Eskom

#### 2.1.1 Purpose

This document was produced in order to record the standardized requirements that shall be applied when procuring new transformers for Eskom to be used in the Eskom network. This covers both transformers procured directly by Eskom and those purchased under turn-key projects

**ESKOM COPYRIGHT PROTECTED**

## **2.1.2 Applicability**

This document shall apply throughout Eskom Holdings Limited Divisions. It is applicable to all the *Contractors* that shall be tendering to supply transformers to Eskom.

## **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 60076-1, Power transformers — Part 1 General.
- [3] IEC 60076-2, Power transformers — Part 2 Temperature rise.
- [4] IEC 60076-3, Power transformers — Part 3 Insulation levels and dielectric tests.
- [5] IEC 60076-4, Power transformers — Guide to Lightning and Switching Impulse.
- [6] IEC 60076-5, Power transformers — Part 5 Ability to withstand short circuit.
- [7] IEC 60076-7, Power transformers — Part 7 Loading guide for oil-immersed power transformers.
- [8] IEC 60076-8, Power transformers — Part 8: Application guide.
- [9] IEC 60076-10, Power transformers — Part 10 Determination of sound levels.
- [10] IEC 60076-10-1, Power transformers Part 10-1: Determination of sound levels - Application guide
- [11] IEC 60076-13, Power transformers Part 13: Self-protected liquid-filled transformers
- [12] IEC 60076-14, Power transformers Part 14: Design and application of liquid- immersed power transformers using high-temperature insulation materials
- [13] IEC 60076-18, Power transformers Part 18: Measurement of frequency response.
- [14] IEC 60085, Thermal evaluation and classification of electrical insulation.
- [15] IEC 60137, Insulating bushings for alternating voltages above 1 000 V.
- [16] IEC 60156, Insulating liquids – Determination of the breakdown voltage at power frequency.
- [17] IEC 60185, Current transformers.
- [18] IEC 60214, On-load tap-changers.
- [19] IEC 60034, Rotating electrical machines.
- [20] IEC 61850 (All parts) Communication network and systems in substations
- [21] 32-9 Definition of Eskom documents.
- [22] ESP32-644 Eskom documentation management standard
- [23] 474-65 Operating Manual of the Steering Committee of Technologies (SCOT)
- [24] 240-56063843 Winding and oil temperature specification
- [25] 240-56063908 Oil and gas actuated (buchholz) relays fitted to transformers and reactors
- [26] 240-56063886 Dehydrating breathers fitted on transformers, reactors, and on-load tap changers
- [27] 240-56356191 Transformer and reactor oil level indicators
- [28] 240-56063867 Rapid Pressure Rise Relay Specification
- [29] 240-56063871 Pressure Relief Devices (PRD) Fitted to Transformers and Reactors Specification

- [30] 240-56356202 Bag Leak Detector Specification
- [31] 240 – 56535946 Transformers and Reactors cooling fans standard
- [32] 240 -64917195 Technical standard for dissolved gas analysers for application in power transformers for all Eskom divisions.
- [33] 240-59083215 Permanent online oil drying system used on transformers and reactors.
- [34] 240-56062799 Technical Specification for Capacitor Bushings for Application in Power Transformers and Shunt Reactors in Eskom
- [35] 240-56030674 Corrosion Protection of new and in-service power & station auxiliary transformers
- [36] 32-406 Mineral insulating oils (uninhibited and inhibited) part 1: purchase, management, maintenance and testing
- [37] 240-56062726 Standard for Intrusive work and Oil filling, under vacuum of transformers and reactors on site
- [38] QM 58 Eskom Quality Procedure
- [39] D-DT-3202 Eskom Drawing MV and LV cable box
- [40] EST32-136: Contractor Health and Safety Requirements
- [41] Eskom 10TB-018: Technical Bulletin for Loss Evaluation
- [42] TPC 41-246: Management of manufacturers and suppliers equipment drawings
- [43] 240 – 53902530 Substation automation – data concentrator for data retrieval and remote access
- [44] 240 – 64038621 Remote device communication standard for data retrieval and remote access
- [45] 240 – 46264031 Fibre optic design standards – Part 2 – Substations
- [46] 240-56062720 Oil Sample point labelling standard
- [47] TB 204 Cigre Publication, Guidelines for transformer design reviews
- [48] South African National OHS act
- [49] Eskom ORHVS
- [50] TPC 41-246 Management of manufacturers and suppliers equipment drawings

**2.2.2 Informative**

- [51] TSP 41-87
- [52] DSP 34-1092
- [53] GGS 1074

**2.3 Definitions**

**2.3.1 General**

Definition	Description
<b>Appointed bodies</b>	Refers to persons, beside Eskom employees, appointed by Eskom to provide professional services to Eskom.
<b>Contractor</b>	This refers to the party that received a purchase order from Eskom
<b>Employer / Purchaser</b>	These refer to Eskom and it is interchangeably used to refer to the customer

Definition	Description
<b>GSU</b>	Generator Step Up transformer, a transformer used at power stations to step up the output voltage of the generator to a transmission line voltage for power evacuation. These units tend to be loaded to 100%.
<b>Network Transformer</b>	This refers to a transformer typically used in a transmission and distribution network for coupling different voltage levels, these transformers typically are configured in redundant pairs.
<b>Partial Drain</b>	The phrase refers to draining the transformer or reactor in such a way that the HV insulation and the active part remains fully immersed in oil and vacuuming will not be necessary after completion of work
<b>Power Transformer</b>	This refers to all the transformers from class 1 and to class 4 as detailed in this specification, including the generator-step-up transformers.
<b>Service Life</b>	This refers to the expected lifetime of the transformer operating incident free.

### 2.3.2 Disclosure classification

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

## 2.4 Abbreviations

Abbreviation	Description
<b>A</b>	Amperes
<b>BPP</b>	Business Productivity Program
<b>CT</b>	Current Transformer
<b>CW</b>	Common Winding (also called PW – Parallel Winding)
<b>DGA</b>	Dissolved Gas Analysis
<b>GIC</b>	Geomagnetically Induced Currents
<b>GSU</b>	Generator Step-Up transformer
<b>HV</b>	Highest Voltage / High Voltage
<b>HVDC</b>	High Voltage Direct Current
<b>kW</b>	Kilo Watt
<b>LV</b>	Lowest Voltage / Low Voltage
<b>MV</b>	Medium (Middle) Voltage
<b>MVA</b>	Mega Volt Ampere
<b>MW</b>	Mega Watt
<b>ODAF</b>	Oil Directed Air Forced
<b>ODAN</b>	Oil Directed Air Natural
<b>ONAF</b>	Oil Natural Air Forced
<b>ONAN</b>	Oil Natural Air Natural
<b>PRD/V</b>	Pressure Relief Device / Valve
<b>RW</b>	Regulating Winding (Tapping Winding)

**ESKOM COPYRIGHT PROTECTED**

Abbreviation	Description
SFRA	Sweep Frequency Response Analyses
SW	Series Winding
THD	Total Harmonic Distortion
TOV	Temporary Over Voltages
TW	Tertiary Winding (also called TV for Tertiary Voltage)
UV	Ultra Violet

## 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. Specification Minimum Requirements

This specification defines the minimum requirements for the site survey and assessment, design, design-review, manufacturing, factory testing, transporting, delivery to site, off-loading, assembly, installation, in-transit and on-site testing, and commissioning, and performance of the said transformers. The transformer shall at a minimum be designed for the environment where it will be utilized. The transformer manufacturer shall apply the best internationally benchmarked engineering and manufacturing practices to produce a transformer, including accessories, which in conjunction with minimal maintenance, will result in a safe and reliable service throughout the expected lifespan under the rigors of service in the Eskom power system. The transformer, when in service, shall not exhibit unsafe or any uncertain condition, e.g. stray excessive gassing, partial discharge, etc. Engineering practices or techniques that have no measurable quality control shall not be accepted for correction of deviations.

The transformer and the associated accessories shall be risk free to Eskom.

### 3.1 Design Reviews

A design review shall be done on the first transformer of each type. A design review in a planned exercise is envisaged to ensure that there is a common understanding of the applicable standards and specification requirements, and to provide an opportunity to scrutinize the design to ensure the requirements meet the Employer's requirements.

**ESKOM COPYRIGHT PROTECTED**

The objective is to review specific aspects of the electrical, mechanical, magnetic and thermal design to:

- Ensure there is a clear and mutual understanding of the technical requirements.
- Verify the system and project requirements and to indicate areas where special attention may be required.
- Verify that the design complies with the technical requirements.
- Identify any prototype features and evaluate their reliability and risks.

A design review meeting is required before the procurement of any materials or manufacturing proceeds. The purpose of the design review is to allow Eskom to understand the basic design, construction and installation of the transformer and to make sure that interchangeability requirements are met. Eskom shall not be obliged to accept components and/or materials procured prior to the design review and without a written agreement from Engineering. The design review shall follow an internationally benchmarked process.

The manufacturer shall design the transformer in order that it performs satisfactorily under all service conditions specified in this document.

The manufacturer has to demonstrate that all the decisive design parameters are well within the manufacturer's design limits based on proven research, or relevant limits specified in standards or internationally benchmarked criteria.

Eskom reserves the right to reject the design when the manufacturer fails to demonstrate the capability for design and manufacturing of the transformer under review. This can happen when the presented design does not meet internationally and Eskom's accepted criteria and the manufacturer cannot prove his design by previously tested transformers of the same concept and voltage class.

The manufacturer shall inform Eskom twelve (12) weeks prior to the design review. All the discussions and final decisions taken during the design review must be recorded, signed by all the parties, and submitted to Eskom.

Eskom's participation in the design review will in no way relieve the manufacturer of any of their duties in terms of any contract.

Preliminary design review details must be supplied to Eskom, two weeks before the design review meeting.

### **3.2 Site Conditions**

The *Contractor* shall take note that the equipment shall operate under the following site conditions

- Outdoor installation
- Altitude above sea level – 1800m
- Ambient temperatures
  - Maximum + 40°C
  - Monthly average +28°C
  - Yearly average + 25°C
  - Minimum - 10°C
- Average humidity of 90%.
- Solar radiation 2500kWh/m<sup>2</sup>
- Atmospheric UV radiation = High
- Seismic conditions at a minimum of 0.3g, this requirement must be proved by calculation.
- Symmetrical three phase network supply voltages, negative and zero phase sequence voltages up to 2%.
- Pollution level: Very Heavy

**ESKOM COPYRIGHT PROTECTED**

In special cases the site conditions, when different from these, it shall be indicated in the AB schedules.

**NOTE:** The yearly average for South Africa is 23°C according to the SA Weather Services website, which is 3K higher than that in IEC 60076-7. A further 2K was added for climate change reasons and hence the yearly average is considered 25°C. This information is important when considering the temperature rise limits.

### **3.3 Network Conditions**

#### **3.3.1 Frequency**

The system nominal frequency is 50Hz. The transformer shall be designed for a rated frequency of 50Hz +/- 2.5Hz. The under frequency condition may last for 30 minutes and the over frequency for 10 minutes.

#### **3.3.2 Voltage Unbalances**

The transformer must be capable of normal operation without any deleterious effects when exposed to unbalanced voltages of 2% for the life of the unit.

#### **3.3.3 Harmonic Pollution**

The transformer must be capable of normal operation when subjected to harmonic pollution levels up to THD 3% throughout the life of the transformer.

#### **3.3.4 Geomagnetic Induced Currents**

This section is applicable to transformers where the Neutral of the transformer is solidly earthed and if GIC compatibility is specified in Schedule AB.

For the reason of GIC compatibility of 3 phase transformers, 3 limb cores are the requirement and where this is not possible, the return limbs must be optimized to achieve a good design for GIC withstand. The *Contractor* shall in details, during a design review demonstrate how he has taken care of the GIC effect on the design of the affected steel components.

The transformer shall be able to withstand a GIC of 10A in the neutral terminal for 30 minutes under the following operating conditions:

- Continuous Maximum System Voltage,
- Nominal System Frequency,
- Continuous Maximum Load,
- With a tap position such that the maximum number of turns are between the HV terminals and Neutral.

Under these conditions, the transformer must not be damaged. Thermal excursion during GIC phenomena must not shorten the transformers lifespan. For during the presence of the GIC storms special consideration must be given to effects such as vibration increases, increased magnetic forces, hot spot temperature rises, and localized heating due to stray flux changes. The effect of GIC currents on the transformer design must be quantified and the mitigation techniques used by the *Contractor* must be highlighted and submitted to the *Employer* as stipulated in Schedule AB. The *Contractor* includes a description of the intended design to be applied in the tender documentation. During the high-level initial design review phase, the *Contractor* presents the results of his studies of the GIC impact on his design and illustrates that the transformer withstands the criteria specified in this document and Schedules AB to the *Employer* for his approval. In addition, he shall include the proposal for the testing the transformer during the FAT to demonstrate its response to GIC and that the thermal excursions are not exceeded as per the design.

In the interest of being able to measure and monitor, the *Contractor* shall provide externally on the neutral terminal connection a proper CT that will enable the *Employer* to both measure and monitor the GIC level during service life. The proposal for this measurement shall be part of the tender returns and shall form part of the design review.

## **3.4 Ratings**

### **3.4.1 Rated Power**

The values of rated power specified in Schedule A of the enquiry document are the continuous ratings, in MVA, at which each of the windings of the transformer can operate on all tap positions at a voltage equal to the appropriate nominal system voltage,  $U_n$ , without exceeding the temperature rise limits specified in this specification.

Where mixed-cooled (transformers with radiators forming the base cooling, but also having fans and pumps that can increase cooling capability if switched on) transformers are specified, (the naturally-cooled rating (ONAN) of each of the main windings shall be at least 0.60 pu of the rated power of these windings. Class 1 transformers will have a 0.7pu ONAN rating due to their high load factor.

If a tertiary winding is specified, this shall be capable of operating under the naturally-cooled condition at any loading up to the rated power specified in Schedule A provided that the loading in the input winding does not exceed its naturally-cooled rating.

### **3.4.2 Rated Current**

The rated current corresponds to the rated power at rated voltage on the principal tap position. Power transformers shall have overloading capabilities in accordance with IEC 60076-7.

### **3.4.3 Rated Voltage**

The rated voltage of each winding of the transformer on the principal tapping as specified in Schedule AB unless otherwise stated corresponds to the system nominal voltage,  $U_n$ .

### **3.4.4 Maximum Continuous Rated Voltage**

Regardless of the actual location of the tap changer in the HV winding, the rated voltage of the HV winding on any tapping is to be equal to the rated voltage on the LV winding multiplied by the voltage ratio on that tapping. For auto transformers, the LV winding refers to the secondary winding.

### **3.4.5 Maximum Temporary Overvoltages**

Under switching conditions, the power frequency voltage may exceed the maximum system voltage ( $U_m$ ). The transformers are designed to withstand the following over-voltages without harm:

1.05  $U_n$  continuously for 400kV and above, and below 400kV – 1.1  $U_n$  continuously (this is  $U_m$ ) .

1.05  $U_m$  for 10 minutes

1.25  $U_m$  for 1 minute

1.5  $U_m$  for 5 second: and

1.75  $U_m$  for 1 second

Also see the additional requirement to comply with IEC 60076-3.

### **3.4.6 Overfluxing**

Within the prescribed maximum equipment voltage ( $U_m$ ) the transformer is able to operate continuously without damage at an overflux value as stated in IEC 60076. The  $U_m$  value shall be specified in Schedule AB.

### **3.4.7 Impedance**

The Impedance value shall be as per Schedule A of the ordering specification based on Table 1 class 1 Table 2 of this document. The impedance for the nominal tap position and tolerance on the specified value shall be within the range of  $\pm 7.5\%$ . The rest of the range shall be as per IEC specification.

**ESKOM COPYRIGHT PROTECTED**

For transformers with tertiary windings, to achieve the specified impedance values from the main windings to the tertiary winding, as specified in the schedule A in order to drop the fault level, the application of a current limiting reactor will be acceptable. The verification of the capability of such a reactor is mandatory and short circuit test results from similar units must be submitted. The reactor must be situated in such a position that failure of the reactor will not impact, nor damage the rest of the unit. The current limiting reactors must be without a magnetic core and it must not saturate during the fault conditions.

**SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE  
AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: **240-68973110**

Revision: **2**

Page: **17 of 80**

**Table 1: Standard MVA ratings and impedances for transformers of Class 1**

Nominal Voltage			Impedance Type	Standard MVA Rating								HV/MV Impedance (%) referred to primary power rating		HV/Ter Impedance (%) referred to tertiary power rating		Vector Group
Primary	Secondary	Tertiary		160	80	40	20	10	5	2.5	1.25	Nom tap 5 @ Min 17	Nom tap 5 @ Min 17			
132	88	22	STD	160/2	80/2	40/2	20/2					9	8			YnA0d1
132	66	22	STD	160/2	80/2	40/2	20/2					10	9			YnA0d1
132	44	22	STD		80/2	40/2	20/2					11	10			YnA0d1
88	44	22	STD		80/2	40/2	20/2					9	8			YnA0d1
132	11		HIGH			X						22	20			YNd1
132	6,6		HIGH				X					22	20			YNd1
88	11		HIGH			X						22	20			YNd1
88	6,6		HIGH				X					22	20			YNd1
66	6,6		HIGH				X					22	20			YNd1
44	6,6		HIGH				X					22	20			YNd1
132	33		STD		X	X	X					11	10			YNd1
132	33		STD					X				10	9			YNd1
132	22		STD			X	X					11	10			YNd1
132	22		STD					X				10	9			YNd1
132	11		STD			X	X					11	10			YNd1
132	11		STD					X				10	9			YNd1
132	6,6		STD					X				10	9			YNd1
132	6,6		STD				X					11	10			YNd1
88	44		STD			X	X					11	10			YNd1
88	33		STD		X	X	X					11	10			YNd1
88	33		STD					X				10	9			YNd1
88	22		STD			X	X					11	10			YNd1
88	22		STD					X	X			10	9			YNd1

**ESKOM COPYRIGHT PROTECTED**

**SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE  
AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: 240-68973110

Revision: 2

Page: 18 of 80

Nominal Voltage			Impedance Type	Standard MVA Rating								HV/MV Impedance (%) referred to primary rating		HV/Ter Impedance (%) Referred to tertiary power rating		Vector Group
Primary	Secondary	Tertiary		160	80	40	20	10	5	2.5	1.25	Nom @ tap 5	Min @ tap 17	Nom @ tap 5	Min @ tap 17	
88	11		STD			X	X					11	10			YNd1
88	11		STD					X	X			10	9			YNd1
88	6,6		STD				X					11	10			YNd1
88	6,6		STD					X	X			10	9			YNd1
66	22		STD			X	X					11	10			YNd1
66	22		STD					X	X			10	9			YNd1
66	11		STD				X					11	10			YNd1
66	11		STD					X	X	X		10	9			YNd1
66	6,6		STD				X					11	10			YNd1
66	6,6		STD					X	X			10	9			YNd1
44	22		STD				X					11	10			YNd1
44	22		STD					X	X			10	9			YNd1
44	11		STD				X					11	10			YNd1
44	11		STD					X	X	X		10	9			YNd1
44	6,6		STD					X	X	X		10	9			YNd1
33	22		STD					X	X	X	X	6	5			YNyn0
33	11		STD				X	X	X	X	X	6	5			YNyn0
33	6.6		STD					X	X	X	X	6	5			YNyn0
22	11		STD				X	X	X	X	X	6	5			YNyn0
22	6.6		STD					X	X	X	X	6	5			YNyn0

**ESKOM COPYRIGHT PROTECTED**

**Table 2: Standard MVA and impedances for Class 2 and above transformers used in the transmission voltage level applications**

Standard Number	Nominal Voltage (kV)			Ratings Main/Tertiary (MVA/MVA)			Impedance (%)			Tolerance, on nominal tap	Vector Group
	HV	MV	Tertiary /LV	1	2	3	Extr +	Nom	Extr -		
A13	765	400	33	2000/3 <sup>2</sup>	-	-	13.9	14	14.4	± 7.5 %	YNa0d1
A12	400	275	22	1000/3 <sup>2</sup>	-	-	12.24		10.26	± 7.5 %	
A11	400	275	22	800/2	400/2	-	12.24		10.26	± 7.5 %	YNa0d1
A10	400	220	22	630/2	500/2	250/2	11		14.3	± 7.5 %	YNa0d1
A9	400	132	22	500/2	250/2	125/2	13.5		15.5	± 7.5 %	YNa0d1
D1	400	88	22	315/2	160/2	80/2	13.5		17	± 7.5 %	YNyn0d1
A8	275	132	22	500/2	250/2	125/2	11.6	11.4	12.6	± 7.5 %	YNa0d1
A7	275	88	22	315/2	160/2	80/2	12.5	13	15.4	± 7.5 %	YNa0d1
A6	220	132	22	500/2	250/2	125/2	10.3	10.5	11.7	± 7.5 %	YNa0d1
A5	220	66	22	160/2	80/2	40/2	10.6	11.2	13.3	± 7.5 %	YNa0d1
A4 <sup>3</sup>	400		50	60	40	-	13.7	13.47	13.3	± 7.5 %	YNd1
A3	400		30	250	-	-	15			± 7.5 %	YNa0d1
A2	400		15	45	-	-	12.3		11.9	± 7.5 %	YNa0d1
A1-1	275		50	60	40	-	13.7	13.47	13.3	± 7.5 %	YNd1
A1	275		22 or 11	65 <sup>4</sup>	40	-	12.3	12.5	12.2	± 7.5 %	YNa0d1

<sup>2</sup> The units are banks of single phase transformers

<sup>3</sup> Based on the sizes already requested by the customer

<sup>4</sup> SVC transformer 275/11kV

**ESKOM COPYRIGHT PROTECTED**

For Generator Step-Up transformers, unit transformers, and service transformers the sizes vary from power station to power station and will be indicated in the relevant schedules AB

### 3.4.8 Ability to Withstanding Short Circuit

The ability of a transformer to withstand short circuit forces shall form part of the discussion of the design review meeting.

For network transformers, and notwithstanding the over current limits tabulated in IEC 60076-5, the transformer with the standard minimum percentage impedances given in tables 1 and 2 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  $1.1U_n$ ;
- b) Source impedance shall be assumed to be infinite bus;
- c) Fault duration of 2s
- 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. For conductors with a radial thickness of 5mm and below, the stress shall not exceed 30% of the copper conductor yield strength. Whenever a reasonable application of Epoxy Bonded CTC is possible, this would be the preferred solution. The conductor yield strength that shall provide safety margins of more than 50% (i.e.  $> 1.5pu$ ) of the corresponding stresses. See also 3.6.7.
- e) All material used for the radial build up of the insulation system between windings shall be pre-dried and pre-impregnated with oil prior to use.
- f) The blocks located above the clamping rings, which are used to apply the axial compression shall be pinned to the clamping ring/system. All other axial pressure transition elements shall be fixed (which can be by gluing or pinning) to positions

The manufacturer shall submit with its tender a complete listing of similar transformers that have been short circuit tested and manufactured by the facility where the tendered transformers will be manufactured, the list to include the outcome of the short circuit test, the facility where tested and the date of the test. The *Contractor* shall also include a typical test certificate for a unit similar to the unit to be purchased. Upon request a complete description of the transformer characteristics shall be provided. Calculations for short circuit withstand capability shall be submitted with the tender. All the internal current limiting reactors shall be able to withstand the magnitude of the short circuit currents without damage; this must be verified by short circuit testing and calculation.

### 3.4.9 Clearances in Air

When assembled with the connections as in service, electrical clearances in air shall be adequate to withstand the assigned impulse withstand test voltages and TOVs at the prescribed altitude. This is to be demonstrated by impulse voltage type tests specified in Schedule AB, during the performance of which all relevant fittings are in position as for service conditions. Care is to be taken to ensure that fittings are located such that there is no interference with the external connection to the bushing terminals, and the clearances to such connections are not less than the appropriate minimum phase-to-earth clearance given in IEC 60076-3.

For class 1 transformers, care shall be taken to ensure that fittings are located so as not to interfere with the external connection to the bushing terminals, and the clearances to such connections shall not be less than the appropriate minimum phase-to-earth clearance given in column 2 of Table 3. The lines of approach of these connections may lie anywhere within the limits indicated in Figure 2, and the required phase-to-earth clearance shall apply at all points along these lines, as shown at the points marked 'L'. In addition, the minimum vertical working clearances from floor level to live metal shall be as listed in column 3 of Table 3

For other transformers not listed above, this shall be specified in schedules AB and be clarified during the mechanical design review meeting.

The voltage rating for the insulation external to the transformer should be assumed to be the same as the insulation ratings internal to the transformer.

**Table 3: Electrical clearances in air**

System highest voltage Um (kV)	Minimum phase-to-earth clearance 'L' (mm)	Minimum vertical working clearance from ground level to live metal (see note 1) (mm)	'X'-Dimension (2,5 x L) (*Min 3 000 mm) (mm)	'Y'-Dimension (L + 3000) (mm)
3,6	80	2 580	3 000	3 080
7,2	150	2 650	3 000	3 150
12	200	2 700	3 000	3 200
17,5	230	2 730	3 000	3 230
24	320	2 820	3000	3 320
36	430	2 930	3 000	3 430
48	540	3 040	3 000	3 540
72	770	3 270	3000	3 770
100	840	3 340	3 000	3 840
145	1 200	3 700	3 000	4 200
<b>NOTES:</b>				
1) The minimum distance from the transformer base or ground level to the flange base of a bushing (or surge arrester) shall be 2 500 mm.				

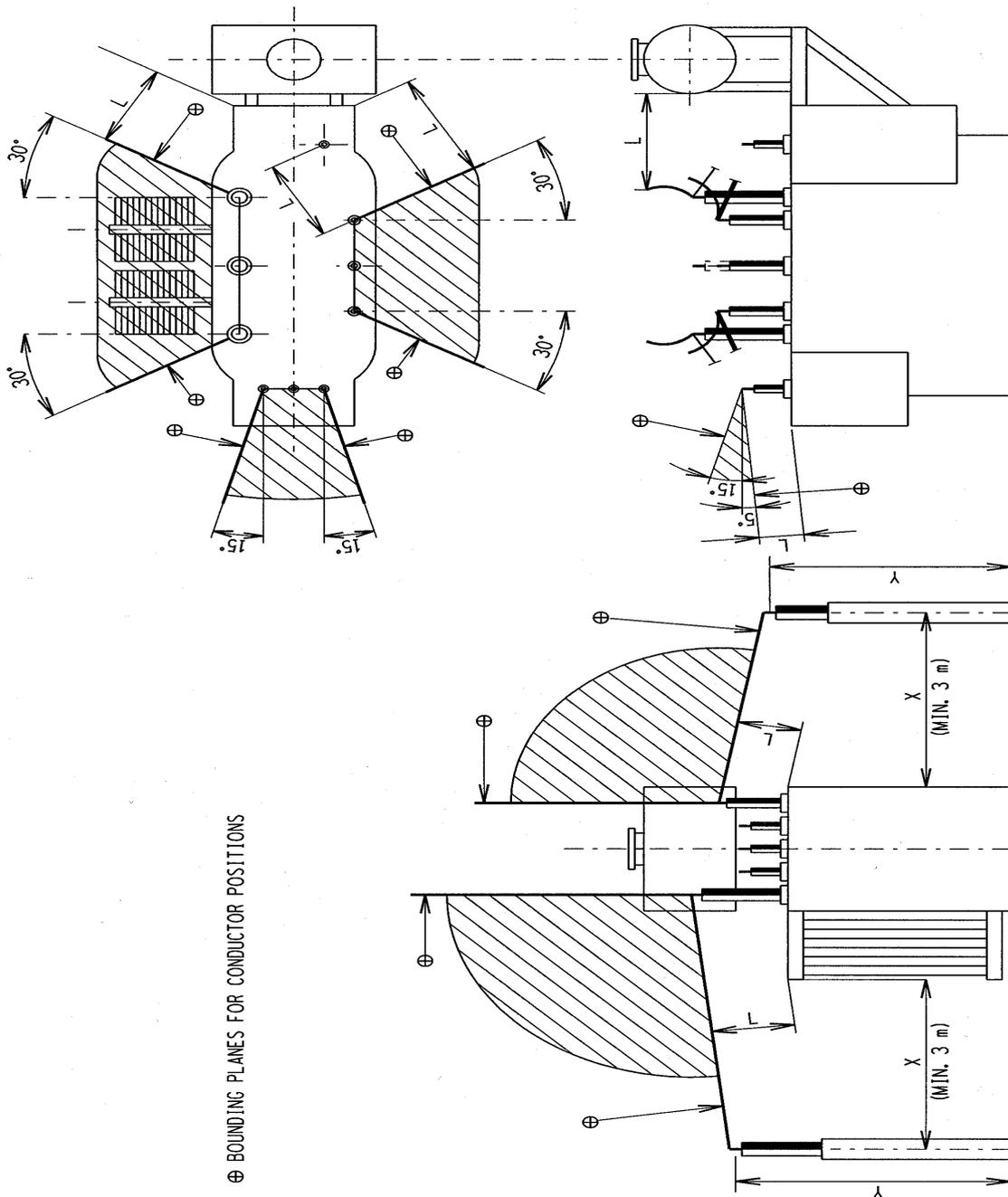


Figure 2: External connections, clearances from lines of approach

### 3.5 Core

#### 3.5.1 Design

For the 3 phase power transformers the 3-limb core designs are the requirement for GIC control. In the cases where this is not possible, it shall first be agreed to by the *Employer*, and the *Contractor* shall demonstrate that the return limbs have been optimized for GIC purposes.

**ESKOM COPYRIGHT PROTECTED**

For rated voltage and rated frequency, the maximum core flux density in the limbs and in the yokes shall not exceed 1.75 at nominal tap. For transformers used in the compensator circuits e.g. STATCOMs and SVCs, care should be taken that the flux density does not exceed the above value at nominal voltage and taking into consideration the fully capacitive mode of operation.

The maximum temperature rise of the core surface in contact with oil and cellulose insulation above the average ambient temperature of 25°C should not exceed 80K for all possible rated in service conditions. The core surface temperature must be limited to the temperature capability of the material in contact with the core using average ambient specified. The material used in core cooling ducts, and between the core and frames, and between the core and the tie plates shall have a continuous temperature rating of 150°C minimum.

### **3.5.2 Materials**

The core shall be manufactured of high permeability; non-ageing cold rolled grain oriented steel sheet laminations having smooth, insulated surfaces. The maximum allowable size of burrs on the slit or cut edge of the electromagnetic steel shall not be capable of causing damage to the insulation between sheets. For all transformers core shall be of mitred construction. The core sheets shall be properly stacked in the step-lap configuration and all the insulation designed in a way that no detrimental changes in physical or electrical properties will occur during the lifetime.

### **3.5.3 Clamping**

For the core clamping, no bolts through the limbs and yokes shall be used. The limbs should be fastened with non-metallic bands/belts. Non continuous steel straps or rods used around the yokes must be insulated from the yokes to prevent short circuits to the core and circulating currents. The pressure of the yokes shall be adequate to prevent movement of the lamination during shipping accelerations. All the return limbs shall be vanished to improve the mechanical stability during shipment/ transportation.

### **3.5.4 Earthing**

The main magnetic core shall be directly grounded via a bushing on top of the cover with a removable external ground connection. The core shall be bonded to the core clamping structure at one point only, which is easily accessible, and protected to allow testing after installation of the transformer.

No core earthing connection shall have a cross-sectional area smaller than 80 mm<sup>2</sup>, with the exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 mm<sup>2</sup>, where they are clamped between the laminations.

The core earth grounding point shall be clearly marked with a permanent label. The factory core insulation resistance value(s) shall be permanently marked at the core earth grounding point together with **“CORE EARTH MUST ALWAYS BE CONNECTED WHEN EQUIPMENT IS ENERGISED”** and indicating the terminal identification.

### **3.5.5 Temperature Rise**

Hotspot rise above ambient of metal parts in contact with oil shall not exceed 80K under the most extreme operating circumstance. Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or other thermally non-conducting material should not exceed the safe operating temperature of that material. Adequate safety margins should be included when determining these criteria.

### **3.5.6 Electrical Continuity**

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.

### 3.5.7 Stack-stack Resistance

The resistance between the core stacks shall be such that no dangerous or detrimental voltages arise. The control of the stack to stack resistance shall be done using engineering techniques where quality control is measurable and adjusting is possible. Scratching of the core laminations to reduce the inter-stack resistance is not allowed.

## 3.6 Coils/Windings

### 3.6.1 Design

Core form windings shall be of circular concentric type. All the conductor joints within the winding must be minimized and are only permissible at locations on the outer surface of windings. Multiple strand joints shall only be applied in areas of low stray flux density. Shell form windings are not preferred and can only be considered in special circumstances and when approved by Eskom in writing.

### 3.6.2 Materials

All windings shall be constructed with copper conductors only. Continuously Transposed Conductors (CTC) shall be free from inter-strand shorts after the winding has been completed. For all the transformers of class 2 and above the windings shall be varnished/enamelled conductor to prevent corrosive sulphur effects between the insulation and the conductor. Where the varnish is removed to make joints in the conductor, special arrangements must be made to ensure no corrosive sulphur damage can take place. The shear or tear strength of the bond and base of enamel/ epoxy shall not be less than 40% of the room temperature strength when heated to 125°C after curing. This requirement excludes the tertiary windings of the auto transformers made from non-CTC conductors, and there non-enamelled conductor can be used.

### 3.6.3 Hot Spot Calculations

The calculated hot spot shall be based on the maximum calculated localized losses in the windings, the insulation on the points with maximum losses, and the oil rise in the windings. If the designer is not able to determine the oil rise in the windings, an added 5K will be made at the design review to allow for the difference between the oil rise in the windings and bulk top oil in the tank.

The maximum hot spot in the leads shall not be more than 1K above the maximum calculated hot spot in the windings.

Winding hot spot shall be measured directly during a heat run test at the factory before release.

### 3.6.4 Insulation

When determining the equivalent power frequency for impulse voltages i.e. Design Insulation Level (DIL) for analysis of insulation stresses, the Employer considers the following conversion factors as reasonable.

**Table 4: Conversion factors for insulation stresses analysis**

Type of waveform	Conversion factor
Lightning impulse	2.5 – 2.9
Switching Impulse	1.8 – 2.1
Power frequency	1.633U <sub>m</sub>
AC Long duration	1.22U <sub>test</sub>

For the purpose of controlling the oscillations in the windings, especially the regulating windings, the use of adequate metal oxide surge arrestors is acceptable. Such a design must ensure that the surge arrestors are clamped using a spring loaded mechanism to ensure that they remain intact for the expected life.

All conductor insulation shall be thermally upgraded paper, except when it is otherwise stated.

The expected life of the paper insulation is 35 to 40 years and the processes implemented in the factory during the manufacturing of the transformer shall not reduce the paper life to less than 950 DP value. The *Contractor* shall demonstrate this for each transformer using a direct DP measurement method. The test must be done using an adequate paper sample. The *Employer* may from time to time request a physical paper sample for verification purposes by an independent or internal laboratory. This must be catered for during the production activities. DP values below the indicated value will entitle the *Employer* to a compensation event.

### **3.6.5 Joints and Internal Connections**

Copper conductor shall be used throughout, for the windings and for the leads.

There shall be no soldered joints or terminals in the transformer. All internal lead connections shall be brazed, welded, or compression type. If compression type is used, then the method employed must be approved by the *Purchaser*.

No joints are permitted internal to the windings unless it involves a single strand of a multiple strand (5 or more strands) conductor. Joints shall be permitted at crossovers and leads external to the windings. The manufacturer shall have an established quality assurance program to detect, prevent and repair nicks, dents, burrs and other imperfections in the conductor material. The manufacturer shall have an established quality assurance program to ensure that all joints comply with the requirements.

All internal connections shall be designed so that bushings can be removed or installed without exposing the paper/ winding block. Inspection covers must be available to enable verification of tightness of connections. Where there are joints in adjacent leads they may not overlap but must be staggered. All leads must be securely supported and braced.

**Table 5: Minimum insulation, fault and creepage levels for Class 1 power transformers – These should match IEC requirements**

System highest voltage $U_m$ (kV <sub>rms</sub> )	System nominal voltage $U_n$ (kV <sub>rms</sub> )	System fault level (kA)	Lightning/switching impulse voltage withstand level at sea level (BIL) / (SIL) (kV peak)		60 s power frequency voltage withstand level at sea level (60s 50Hz)		Bushings					Tap changer		
			Line Terminal	Neutral Terminal	Separate source	Induced	Line		Neutral		Creepage (31mm/kV)			
							BIL (kV peak)	60s 50Hz (kV <sub>rms</sub> )	BIL (kV peak)	60s 50Hz (kV <sub>rms</sub> )			System nominal voltage ( $U_n$ ) (kV <sub>rms</sub> )	BIL (kV peak)
3.6	3.3	20	40	40	10	6,6	200	70	200	70	110	3.3	45	16
7.2	6.6	25	75	75	20	13,2	200	70	200	70	220	6.6	75	22
12.0	11	25	95	95	28	22	200	70	200	70	375	11	95	28
17.5	16	20	125	110	38	32	200	70	200	70	540	16	110	38
24	22	20	150	150	50	44	200	70	200	70	740	22	150	50
36	33	20	200	200	70	66	<b>See 240-56062799 for full requirements</b>					33	200	70
48	44	20	250	200x	70x	95						33	200	70
72	66	20	350	250x	95x	140						44	250	95
100	88	25	450	250x	95x	150						44	250	95
145	132	40	550	250x	95x	230						44	250	95
145	132	40	550	110+	38+	230						NOTE 1: Phase-to-phase values specified in this table for all transformer windings shall be designed to withstand the appropriate test voltages, and shall be tested as specified in <b>Error! Reference source not found..</b> NOTE 2: 145kV values specified in the last table are for Auto Transformers only.		
245	220	65	1050 /840			460	To be discussed during design review meeting and to meet IEC requirements							
300	275	65	1050 /840			460								
420	400	65	1425 /1050			630								
800	765	50	1950 /1425			900								

**Non uniform insulation** + Fully graded insulation  
x Partially graded insulation

**ESKOM COPYRIGHT PROTECTED**

---

**Surge protection of non earthed HV neutral of YNd1-connected transformers**

The neutral ends of the HV windings of all YNd1-connected transformers with partially graded HV winding insulation (132 kV, 88 kV, 66 kV and 44 kV HV windings) shall have surge arrester protection in cases where their neutral terminals are not earthed (see note below).

**Arrester rating**

This following information shall appear on the rating and diagram plate and shall bear the following cautionary instruction:

"HV winding insulation partially graded. HV neutral shall be solidly earthed or protected by a ..... kV r.m.s. continuously rated (MCOV) metal oxide surge arrester with a ..... kV peak residual voltage (10 kA)".

The continuous voltage rating and residual voltage (10 kA) of the required surge arrester shall be inserted as follows:

- a) For a 66 kV, 88 kV and 132 kV partially graded insulation transformer the values shall be a minimum of 48 kV r.m.s. and shall not exceed 165 kV peak, respectively.
- b) For a 44 kV partially graded transformer the values shall be a minimum of 36 kV r.m.s. and shall not exceed 125 kV peak, respectively.

**NOTE:** This reduction in insulation has been adopted in order to effect a worthwhile saving in the cost of these transformers, whose neutrals would generally be earthed but may occasionally be unearthed.

The insulation levels chosen are adequate to meet the voltages impressed on the neutrals of these transformers during the works tests, but may be inadequate to ensure the safety of these windings in the case of transformers whose neutrals are unearthed in service, e.g. In the case of simultaneous voltage surges entering the star windings from two or more HV line terminals. For this reason provision is made for surge arrester protection.

**3.7 Transformer Construction and Assembling**

**3.7.1 Winding Arrangement**

The transformer winding arrangement shall be indicated in the schedules AB issued with the enquiry and it shall take precedence to the arrangements indicated below. The preferred winding arrangements are as in Table below

**Table 6: Winding Arrangement configurations**

<b>Transformer Class</b>	<b>Winding Arrangement</b>
Two-winding transformers	Core/LV/HV/RW
Three-winding transformers	Core/TW/CW/RW/SW

**3.7.2 Sizing and Compressing**

Each winding shall be compacted with a minimum pressure of 7.5N/ mm<sup>2</sup> on the spacers, for helical and disc windings. It is expected that the windings will be dried under constant pressure. All windings shall be sized using a maximum tolerance of -0 + 2mm. The sizing pressure after final vapour phase drying shall not be less than 5N/ mm<sup>2</sup> on the transformer board spacers.

The manufacturer will be responsible for proposing methods for checking the pressure on the windings after the assembly is completed to ensure that it is not less than 5N/mm<sup>2</sup> on all spacers.

The *Contractor* shall fully demonstrate the adequate clamping of the windings as required at all stages of manufacturing. The clamping pressure shall be sufficient even for the maximum forces assumed occurring during the coldest conditions of the unit.

### 3.7.3 Terminal Arrangement

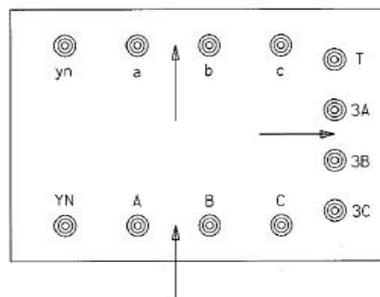
The interchangeability of transformers requires that main terminals are arranged in a standard layout.

All terminal groups shall be arranged so that when viewed in the direction of power flow, the neutral terminal appears on the left, followed by the line terminals in alphabetical order, as shown in the illustration below. The power shall always be assumed to flow from the winding having the highest voltage rating towards all other windings.

LV winding terminals shall appear on the right-hand end of the transformer when viewed from the HV side. In the case of delta-connected stabilising windings, the "T" - terminal shall occupy that position. For Generator step up transformers, this shall be indicated in the schedules AB and be discussed during the design review meeting.

Tertiary winding terminals shall appear on the right-hand end of the transformer when viewed from the HV side.

In the case of delta-connected stabilising windings, the "T" - terminal shall occupy that position (see Figure 3).



THE ARROWS INDICATE THE DEFINED DIRECTION OF POWER FLOW

ESKOM DRG No 0.54/4369 sh 5

**Figure 3: Illustration of Position of HV terminals**

### 3.7.4 Termination on bushings

Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions without jeopardizing the in-service integrity of the transformer.

The winding-end termination, insulation system and transport fixings shall be so designed that the integrity of the insulation system is not easily compromised during repeated work in this area.

Allowances shall be made for accommodating up to 100 mm tolerance on bushing axial dimensions and the fact that bushings may have to be rotated to get oil level inspection gauges to face in a direction that allow easy inspection from ground level. In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads from the winding onto the termination surfaces of the bushing.

Suitable inspection and access facilities into the tank shall be provided to minimize the possibility of creating faults during the installation of bushings.

**ESKOM COPYRIGHT PROTECTED**

### **3.7.5 Clamping**

The *Contractor* shall fully demonstrate that adequate clamping of the windings as required at all stages of manufacturing is controlled.

### **3.7.6 Drying**

The *Contractor* shall fully demonstrate that adequate drying and moisture ingress into the winding as required in all stages of manufacturing is controlled.

## **3.8 Bushings**

The bushings used shall be of technology that provides safe operation of the transformer, maintenance free or at most minimum maintenance, environmentally friendly, and as far practically possible does not add fire risk. Only the dry technology of bushings is acceptable except in exceptional cases which shall be agreed with Eskom during a tender stage and shall be indicated in Schedules AB. One such case is when such a technology does not exist at all or is not mature enough in the category of the required bushings. The outer body shall be made with composite insulator in grey colour.

The bushings shall comply with the requirements of the bushings specification 240-56062799 and as stipulated in schedules AB of a given purchase order. For units going to long-term storage (spares) the bushings shall be sealed on the oil side as a preparation for such a storage.

## **3.9 Tap Changers**

### **3.9.1 Type of tap changers**

Tap changers can be specified as both On-Load Tap Changers (OLTC) and Off-Circuit Tapping Switches (OCTS). The required tap changer shall be indicated in the relevant schedules AB.

### **3.9.2 On Load Tap Changers**

On load tap changing equipment shall be designed and constructed in accordance with the latest revision of IEC 600214. The OLTC should be of the resistance bridging type. The tap changer supplied must present no risk to the transformer during any operating condition, albeit on load or on no-load, both oil type and vacuum type will be considered. The offered solution is desired to provide 300 000 intrusive maintenance free operations. All tap changers must have undergone adequate testing to demonstrate their capability to perform under expected operational and loading conditions as per IEC. Eskom, in its discretion and based on the experience, may require additional testing to the ones specified in IEC 600214.

### **3.9.3 Off Circuit Tapping Switches**

When specified, the transformer shall be provided with a ganged off-circuit tapping switch, operated by an external handle situated in an unobstructed position, not more than 1,5 m above ground level.

The contacts shall be positively self-locating in each tapping position without constraint from the operating mechanism, which shall provide for padlocking in each position.

The tapping positions shall be indelibly marked to correspond with the data given on the rating-and-diagram plate and these markings shall be legible by a person standing at ground level.

Off circuit tap switches shall be fitted with direct or gear driven operating mechanisms.

### **3.9.4 Tapping Range**

The tapping range is specified taking into consideration the requirements of standardizing and interchangeability. The required tapping range shall be specified in Schedules AB of the ordering specification. For transmission and distribution class transformers, the regulation is normally selected as:

**ESKOM COPYRIGHT PROTECTED**

All on-load regulated transformers have on-load taps from +5% to -15% of the HV terminal voltage in 16 equal steps of 1,25% each. This excludes the transformers with the HV of 400kV and above, for these transformers no plus (+) range is required and only -15% is required.

When an off-circuit tap switch is specified, the range shall be +5% to -5% of the HV terminal voltage in 4 steps of 2,5% each.

For each transformer enquiry, the requirements shall be indicated in schedules AB

### **3.9.5 Electrical Location (Positioning) of the Tap Changer**

For double-wound transformers (Y-connected and Primary assumed to be the HV winding) the tap changer shall be positioned on the neutral side of the primary winding.

Tap-changers shall be installed in the H.V. series winding (MV potential) at the line end of common winding (auto transformers only).

### **3.9.6 Ratings**

#### **3.9.6.1 Current Rating**

The rated through current of the tap changer, as defined in of IEC 60214, shall not be less than that resulting from the highest value of continuous maximum load in the tapping winding of the transformer (It shall be able to operate at the emergency and overload ratings of the transformer without harm.

It is permissible that tap changing be inhibited during transformer overload conditions above 1,5 p.u.

#### **3.9.6.2 Short Circuit Currents**

In addition to the requirements of 8.3 of IEC 60214 for on-load tap changers, tap changing equipment shall be capable of carrying the same currents, due to external short-circuit, as the transformer windings with which they are associated.

#### **3.9.6.3 Insulation Level Requirements**

Notwithstanding the requirements of 8.6 and table V of IEC 60214, on-load tap changing equipment, including all insulating and barrier boards, shall withstand the impulse and dielectric test voltages applicable to the part of the transformer windings with which they are associated, as specified in schedule A & B of this Specification.

If any specific critical phase to phase insulation situations exist in the transformer it should be noted that the Employer's surge arresters will only limit incoming surges on a phase to ground basis and that phase to phase insulation will therefore be protected by two arresters in series. This particularly applies to three-phase line end tap changers and their leads, as well as the leads of single-phase tap changers. The Contractor must design for this situation.

### **3.9.7 Design Requirements**

The voltage class of tap changers located at the line end terminals shall be a minimum of one voltage class higher than the class of the terminal.

The rated current shall comply with the requirements of IEC 60076-7 loading guide. The tap changer should not limit the overload design of the transformer.

The OLTC voltage ratings shall be specified in the schedule B of the ordering specification. The voltage withstand capability of the OLTC has to be selected by the transformer manufacturer.

### **3.9.8 Other Tap Changer Requirements**

#### **3.9.8.1 Replacement of current switching contacts**

The current breaking contacts of diverter switches shall be easily replaceable.

#### **3.9.8.2 Diverter and selector switch compartments**

Drop-down tanks that necessitate the provision of pits in the foundations are unacceptable.

Each diverter and selector switch compartment shall be provided with an oil drain valve or plug.

Care shall be taken to close the drain valve or plug of the diverter compartment before operating the tap-changers on load in the factory or after installation. Failure to do so will require full reprocessing of the oil in the transformer at the Contractor's cost.

Current breaking switches (e.g. diverter and selector switches as distinct from tap selectors and change-over selectors) shall not operate in the insulating oil of the main transformer.

The insulating oil for these switches shall be completely segregated in a oil and gas-tight compartment separate from that in the main transformer tank and the oil conservator for maintaining the oil level in the compartments containing such switches, shall be separated from the main transformer oil conservator. Where a common conservator tank construction is employed to serve both the main tank and the tap-changer switching compartment, the two bodies of oil shall be segregated by an oil and gas tight steel partition. Each body shall have its own separate dehydrating breather and oil level indicator, that shall be clearly labelled to relate it to the corresponding oil body. A protection for the loss of oil in the tap changer compartment of the conservator shall be provided.

#### **3.9.8.3 Protective devices for diverter and selector switch compartments**

Protective functions provided for the diverter switch and selector switch compartments shall effect the tripping of the circuit-breakers controlling the transformer in the case of:

low oil level (may be omitted if a surge relay, that fulfills this function, is provided).

a surge of oil produced by a fault inside the compartment, or a rise in pressure or temperature resulting from such a fault, whichever one of these three is most appropriate to the design of the apparatus.

Where a pressure sensitive device is provided, the associated contacts shall close under a steady increase of pressure. The operating pressure level shall not be less than 100 kPa or as recommended by the manufacturer, taking the static head of oil into consideration.

#### **3.9.8.4 The Breather**

The oil in the diverter switch and selector compartments shall only communicate with the atmosphere through a dehydrating breather containing a silica gel charge of at least 1 kg. The breather shall comply with the requirements of the breather specification 240-56063886. Self dehydrating breathers are acceptable.

#### **3.9.8.5 Buchholz relay/Surge Protection for selector compartment**

Where tap selectors and change-over selectors are contained in compartments separate from current breaking switches, those compartments shall be protected by the Buchholz relay serving the main transformer tank, unless separate oil surge and low-oil level relays are provided. Provisions shall be made for filtering and draining the oil in those compartments.

#### **3.9.8.6 Alarm and tripping contacts for protective devices**

These contacts shall comply with the requirements of 3.9.10.2.

The requirements are that for all trip and alarm information to be duplicated (2 x potential free contacts per function). E.g. Buchholz Trip, Buchholz Alarm, Winding Temp Trip, Winding Temp Alarm, Pressure Relief Trip, Rapid Pressure Relief Trip, etc.

### **3.9.8.7 Strength of tap-changer compartments and insulating barriers**

Tap-changer compartments and insulating barriers shall have adequate strength to resist, without suffering permanent distortion or damage of any sort, from the forces resulting from the application of a full internal vacuum at sea level.

In the case of insulating barriers, the vacuum is unequalized (i.e. applied from one side only, against atmospheric and oil pressure on the other side), and applied internally from either side, with the following provisions:

- a) in the case of tap-changers energized at voltages below 88 kV, the vacuum requirement applicable to the tap-changer compartment will be limited to that which produces a pressure differential between the tap-changer compartment and the atmosphere of not more than 65 kPa; and
- b) where such insulating barriers serve tap-changers mounted wholly within the transformer tank, (e.g. diverter switch cylinder) the application of the vacuum or pressure may be equalized on both sides of a diverter switch compartment by interconnecting the two conservators.

### **3.9.8.8 Sealing of tap-changer parts for transport**

Where it is necessary to remove parts or the whole of the on-load tap changer for transport purposes, it shall be possible, unless otherwise approved, to complete erection on site with the transformer windings and terminal insulation covered with oil.

## **3.9.9 Driving mechanism, control and indicating equipment**

### **3.9.9.1 Enclosures of apparatus**

The driving mechanism shall be enclosed in a ventilated, dust-proof, weather-proof and vermin-proof cubicle provided with an adequate 50Hz supply, separately fused, anti-condensation heater and switch (with a solid withdrawable link in its neutral lead), and, at its lowest point, with a 25 mm diameter gauze covered drain hole. The internal surface corrosion proofing and finishing shall comply with 240-56030674 Corrosion Protection of new and in-service power & station auxiliary transformers.

Where a gland plate for cables is provided, ample space shall be allowed from the terminal strip for arranging the entry of the cable cores (see also 3.10)

**Note:** Unless specified to the contrary, the automatic and remote control panels and equipment for the on-load tap-changer (those to be installed in the Eskom control room only) will be supplied and installed by the *Purchaser*.

### **3.9.9.2 Design of driving mechanism: synchronism and limit stops**

The driving mechanism shall be so designed that once a tap-changing operation has been initiated, the diverter switch or selector switch contacts will not remain in an intermediate position should the power supply for the driving unit fail.

The design shall include means to ensure that tap-changers fitted to three single-phase units, or units operating in parallel, remain in step. Mechanical stops shall be provided to prevent the mechanism from overrunning its end position.

### **3.9.9.3 Manual operation**

For maintenance and emergency operation of the tap-changing equipment, a readily detachable handle shall be provided for manual operation. Adequate provision shall be made to prevent the diverter switch or selector switch contacts being left in an intermediate position when operated manually.

To prevent power operation with the handle in position, a normally closed contact in the control or motor circuits shall be provided that opens when the handle is inserted.

The tap-changer controller shall be accessible from ground level ( $\pm 1,2$  m from base plate), i.e. all operating inspection points shall not be positioned higher than 1.8 meters from base as to ensure that the operator does not have to leave ground level.

**ESKOM COPYRIGHT PROTECTED**

All risks or special requirements related to this operation shall be clearly indicated in the manual and on the physical box such that they catch the attention of the reader or operator.

#### **3.9.9.4 Electrical operation**

The following are the minimum requirements which shall be mounted in the driving mechanism enclosure or other suitable kiosk, mounted near the transformer (see also Figure 2, Figure 3, Figure 4 and Table 1).

Control relays shall only respond to control initiation pulses of 150 ms duration or longer.

The rating of control relay contacts shall be in accordance with 3.9.10.2.

All contactor operating coils and trip coils shall be rated at dual voltage of 220V d.c. and 110 V d.c, unless otherwise specified.

a) Tap-changer drive motor

See motor "a" on Figure 4.

A tap-changer drive motor rated at: 400 V a.c, three-phase, 50 Hz shall be fitted.

b) Tap-in-progress indication

A terminal shall be provided for the neutral of the 400V a.c supply and one terminal of the motor shall be connected to an external terminal for a "tap-in-progress" lamp. (Refer to Figure 4)

Or alternatively, a "tap-in-progress" indication contact similar to contact 'A' of 0, shall be provided.

c) Circuit-breaker for motor protection

See "b" on Figure 4.

- 1) For a three-phase drive motor, a circuit-breaker fitted with three-phase thermal overload protection and single-phasing protection and a separate d.c. shunt trip coil shall be provided. The trip coil shall be provided with a contact to break its own current if the coil rating exceeds 50 W. The trip coil rating in watts shall be stated on the OLTC drive schematic diagram.

- 2) Where "raise" and "lower" contactors are fitted, both the circuit-breaker and the d.c. shunt trip coil shall be provided.

d) Protection of tap-changer during system faults

A self-resetting contactor shall be provided in the motor circuit for overcurrent blocking of the tap-changer drive under system fault conditions. The contactor shall be fitted with a d.c. operating coil, and normally closed contacts capable of interrupting motor starting currents. Contactors with normally open contacts that require the coil to be continuously energized are not acceptable.

e) Local control

"Raise" and "Lower" push-buttons or a control switch for the local control, mechanically or electrically interlocked, shall be provided (see "d" on Figure 4).

As shown in Figure 3, these raise/lower control devices shall be connected to separate terminals for use in the *Purchaser's* control scheme. They shall not be connected for direct control of the OLTC drive.

f) "Raise and Lower" motor-operating contactors

Direct-current operated "Raise" and "Lower" contactors for controlling motor direction shall be provided (see "e" on Figure 4).

g) Completion of tap-change operations

Auxiliary contacts shall be provided for sealing "Raise" and "Lower" contactors and mechanism contact "A" for controlling the sealing of the "Raise" and "Lower" contactors (see "f" and "g" in Figure 4) (see d)).

h) Step-by-step and parallel operation

See "h" and "i" on (Figure 3 and Figure 4). The manufacturer shall provide and install all the appropriate equipment and circuitry inside the driving mechanism i.e. contacts, relay(s) etc. in order to perform within the mechanism box the full step-by-step function (see fig. 8 step-by-step typical circuit). For operation of step-by-step relay(s) and single or two contacts shall be provided. When single contact is used this must close in either "Raise" or "Lower" direction, when two contacts are used, one contact shall close only when the drive moves in the "Raise" direction and the other shall close only when the drive moves in the "Lower" direction.

These contacts may take the form of mechanism contacts or, alternatively, auxiliary contacts on the "Raise" and "Lower" contactors may be used.

In the latter case an additional mechanism contact, similar to 'A' in g) above shall be provided for the step-by-step circuit if the 'A'-contact is the normally open type, i.e. if the mechanism contact through which the "Raise" and "Lower" contactors are sealed is the type that is open in the rest position and closed during operation.

The essential features of the contacts provided for the step-by-step circuit are that they shall not operate the step-by-step relays before the "Raise" and "Lower" contactors have had time to seal themselves in, and that they shall remain closed throughout a tap-change operation, and, preferably, also throughout a transition step. If they do not remain closed throughout a transition step, then a spare mechanism contact shall be provided and wired to separate terminals.

i) Tap position indication, supervision and monitoring

Two spare sets of coded, voltage free contacts shall be provided (see Figure 3).

Tap position switch for use in parallel checking circuit. This switch may take the form of either a change-over switch that changes its position at the end of each tap-change operation or a multi-position rotary switch with as many contacts as there are taps on the transformer. These switches shall be of the break-before-make type. (see l on Figure 5).

j) Limit switches

See "n" on Figure 4

Limit switch contacts, to prevent the tap-changer from overrunning the end positions, shall be provided.

These contacts shall be provided where indicated in the initiating circuits and shall preferably be provided in the motor circuits as well if, in the case of single-phase motors, motor contactors are provided.

**NOTE:** The preceding clauses list the *Purchaser's* minimum requirements, but if the *Contractor* wishes to add further relays (e.g. for step-by-step control), this is acceptable though not desirable.

k) Approval of components

All contactors, switches, circuit-breakers, relays and contacts incorporated in the electrical control of tap-changers, shall be subject to the *Purchaser's* approval.

### 3.9.9.5 Mechanical tap position indicators

An externally visible mechanical tap position indicator shall be provided on the driving mechanism.

### 3.9.9.6 Diverter and selector switch compartments

Maximum and minimum tap position indicators arranged for manual resetting shall be fitted to the driving mechanism to register the operating range encountered in service.

### 3.9.9.7 Operation counters

Externally visible mechanical counters (e.g. cyclometers) shall be provided to register the number of tap-change operations. These recorders shall have at least six (6) digits, and shall have no provision for resetting. These counters shall be of suitable quality for at least  $10^6$  operations. This shall be supported by a type test certificate.

### 3.9.10 Drawings and technical data

a) Details on transformer outline drawings

The main features of tap-changers, including the fittings and protective devices specified, shall be indicated on the transformer outline drawings.

b) Schematic diagrams

Transformer on-load tap changer drive schematic diagrams showing the rating in watts of the d.c. shunt trip coils fitted to the driving motor circuit breakers, shall be supplied. The *Contractor* shall indicate on this diagram which of the requirements, detailed in 3.9.9.4 above, each device will fulfil.

c) Timing charts

A diagram or chart showing the relative timing of all contacts during both a regular tapping step and a transition step shall be provided.

#### 3.9.10.1 Tap position numbering

For both off-circuit and on-load tapping arrangements the tap position shall be numbered so that an increase in tap position number represents an increase in the controlled, or outgoing voltage. Controlled secondary voltage is defined as the voltage that is changed as a result of the change in tappings. In the case of interconnection or coupling transformers involving power flow in both directions the controlled voltage will be specified in schedule A of an enquiry document

**NOTE:** Transition steps that give the same outgoing voltage should all take the same tap position number, distinguished in each instance by a lower case letter; e.g. 9(a), 9(b) and 9(c) where there are three transition steps.

#### 3.9.10.2 Alarm, control and tripping contacts

Alarm and tripping contacts shall be provided with electrically independent and unearthed circuits and shall be insensitive to vibration and earth tremors. This insensitivity shall not depend on the method of mounting, but shall be an inherent feature of the contact assembly.

Auxiliary relays shall not be used.

a) Alarm and control contacts

Contacts providing alarm output shall be rated as follows:

Make and carry for 200 ms:	5 A @ d.c. 250 V
Carry continuously	2 A @ d.c. 250 V
Break (inductive L/R = 40 ms):	30 W or 0.2A @ d.c. 250 V

b) Tripping contacts

Contacts providing trip outputs shall be rated as follows:

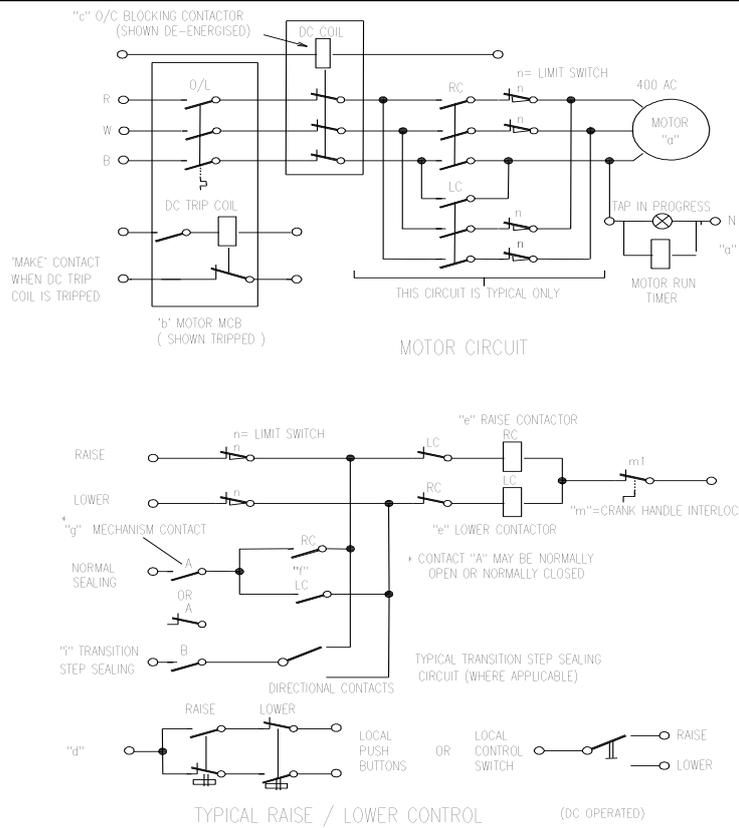
- Make and carry for 200 ms 30 A @ d.c. 250 V
- Carry for 1s: 10 A @ d.c. 250 V
- Carry continuously: 5 A @ d.c. 250 V
- Break (Inductive L/R = 40 ms): 30 W or 0.2A @ d.c. 250 V

c) Tests

Devices fitted with alarm and tripping contacts shall be tested as specified in 3.17 and as per IEC 60076 applicable parts.

Standard on-load tap-changer control schemes: minimum requirements for driving mechanisms:

**ESKOM COPYRIGHT PROTECTED**



**Figure 4: Control circuits for all three-phase OLTC motor drives**

**NOTES to Figure 4**

- 1) If the motor is continuously rated for the stalled condition, the thermal overload protection may be omitted.
- 2) Where 'raise' and 'lower' contactors are not provided and the motor current does not exceed 5A when starting or running, the separate d.c. shunt trip coil may be omitted.
- 3) In the case of single-phase motors continuously rated for the stalled condition and with a motor current not exceeding 5 A when starting or running, the circuit-breaker may be omitted entirely, provided no 'raise' or 'lower' contactors are fitted.

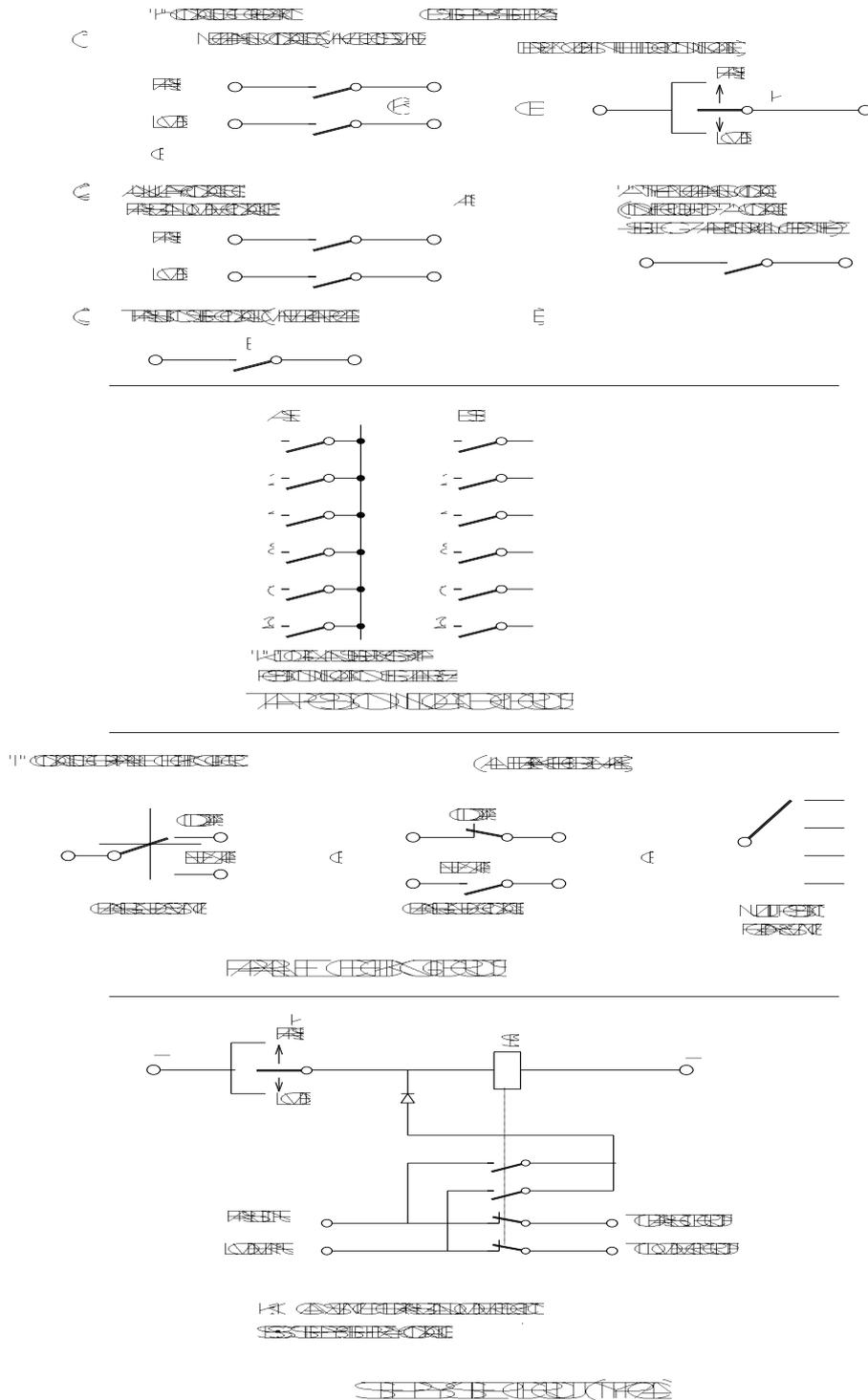


Figure 5: Common circuits for OLTC control

ESKOM COPYRIGHT PROTECTED

**Table 7: Tap position encoder contact state at each tap position**

Position	20	10	8	4	2	1
1	0	0	0	0	0	1
2	0	0	0	0	1	0
3	0	0	0	0	1	1
4	0	0	0	1	0	0
5	0	0	0	1	0	1
6	0	0	0	1	1	0
7	0	0	0	1	1	1
8	0	0	1	0	0	0
9	0	0	1	0	0	1
10	0	1	0	0	0	0
11	0	1	0	0	0	1
12	0	1	0	0	1	0
13	0	1	0	0	1	1
14	0	1	0	1	0	0
15	0	1	0	1	0	1
16	0	1	0	1	1	0
17	1	1	0	1	1	1

0 = contact open                      1 = contact closed

### 3.10 Tank and Parts

#### 3.10.1 Tank Design

The shape of the transformer tank and fittings, including the underbase 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.

The tank and cover shall be designed so that local heating due to stray flux in any structural part shall not exceed the top oil temperature limit specified for the transformer, by more than 10 °C.

Heating, due to stray flux, shall also not cause local temperature elevations of more than 15 °C relative to the oil temperature at that level.

Thermometer pockets shall be located so as to avoid errors in temperature indication due to the heating effects resulting from stray flux. Thermometer pockets shall be located in a position where the least traffic is during activities such as OLTC maintenance and bushing replacements.

The general design of the tank and the turrets must be always be such that the maintenance activities and replacement of components (e.g. all bushings, PRVs and etc) can be carried out by only partially draining the unit. This must be demonstrated during a design review.

#### 3.10.2 Tank Base

The underbase shall be suitable for the movement of the transformer in any direction, by sliding on greased rails. For the class 1 transformers, the tank base shall be provided with four hauling eyes not less than 50 mm in diameter, as near as possible to the extremities of the length and width of the tank.

Unless otherwise approved, transformer underbase shall be of a thickness not less than that specified in this document. Fabricated bases shall not retain water. Skid bases are not accepted, except in special cases where they may be needed, it shall be so indicated by the *Employer*. The position of the axial and transverse centre lines as shown on the dimension and foundation drawings shall be accurately stamped onto the tank at the base level, on both sides and at both ends, and indicated by means of a red enamelled mark at each point.

**Table 8: Minimum thickness of transformer tank base plates — mild steel**

Length of tank (m)	Minimum plate thickness (mm)
<b>Fabricated bases,</b> not exceeding 2,5 exceeding 2,5	10
	12
<b>Flat bases,</b> not exceeding 2,5 over 2,5m but less than 5 over 5m but less than 7,5 exceeding 7,5	12
	20
	26
	32

### 3.10.3 Tank Main Top Cover

The top cover of the tank shall be the welded type unless stated otherwise in the schedule AB or during the mechanical design review. The positioning of the auxiliary components and pipes on the top cover must take into considerations the need to walk on the top of the tank during the maintenance activities. Preferably the conservator tank should not be on the top cover as it makes movement extremely difficult to almost impossible during inspection and maintenance activities. The top cover shall be painted with a non-slippery paint to enhance safety of personnel.

### 3.10.4 Tank Strength and Oil Tightness

#### 3.10.4.1 Rigidity

Transformer 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.

#### 3.10.4.2 Internal Pressure and Vacuum

Transformer 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. When empty of oil they shall withstand the full vacuum test. In the case of type tests for strength and oil tightness the fittings (e.g. pressure relief devices and bushing stems) may be tested separately. The ability of the tank to withstand overpressure shall be co-ordinated with the pressure relief valves.

The tank shall be designed to withstand full vacuum for vacuum filling. If barrier boards are installed between the main tank and any other tank (selector tank) the barrier board shall be designed to withstand full pressure of the main tank filled with oil on the one side of the barrier board with full vacuum on the on the other side of the board

#### 3.10.4.3 Joints

A transformer tank and accessories shall be designed and constructed in such a manner that minimum points of possible leaks exists. Only valves and inspection covers of specific purpose shall be provided.

- a) All gasketed joints shall be designed, manufactured and assembled to ensure long term leak-free and maintenance free operations.
- b) Joints that need not be removed for normal maintenance or transport shall be welded.
- c) Details of all gasketed joints shall be submitted for approval during the mechanical design review meeting.

#### **3.10.4.4 Gasket Types**

- a) Subject to clause b), all gasketed joints shall be of the O-ring and groove type. The O-ring shall be manufactured from nitrile rubber or better.
- b) Bolt-on type tap-changers and selector tanks that have to be removed for transport or maintenance are specifically excluded for the use of O-ring type gasket joints. In these applications rectangular cord and groove joints where the nitrile rubber cord is not joined but passed twice around the perimeter with the loose ends at the bottom, are acceptable. Alternatively a flat nitrile rubber gasket with stoppers to prevent over compression will be acceptable.
- c) Approved non O-ring gaskets that need re-tightening in order to avoid oil leaks as a result of shrinkage, shall be retightened in the second 6 months of service by the *Contractor* at no extra cost to the *Purchaser*. All costs to maintain the system leak free shall be for the *Contractor's* account during the guarantee period.

#### **3.10.4.5 Attachments to the transformer tank**

Attachments to the transformer tank shall only be fixed by bolting them to the prepared flat surface of a flange facing, either integral with or welded to the tank and sealed by a gasket or O-ring to the mating flange of the attachment. Joints dependent on the sealing of screw threads, and direct welding of fittings to the tank will not be accepted.

#### **3.10.4.6 Pipe joints**

Oil pipes above 15 mm bore shall have flanged, gasketed and bolted joints. Flexible compression joints will not be accepted unless specifically approved. Joints dependent on the sealing of screw threads will not be accepted.

#### **3.10.4.7 Drilling of pipe flanges**

Except where otherwise stated, the drilling and bolting of pipe flanges and the mating flanges of fittings shall comply with BS 4504 or DIN 2631.

### **3.10.5 Access openings and covers**

An appropriate number of suitably proportioned handholes and manholes shall be provided for easy access to the upper portions of the core and windings assembly, the lower ends of bushings, internal current transformers and the oil side of their terminal boxes (see 3.6.3). Manholes for the purpose of internal inspection are preferred to be as close as to ground level as necessary to eliminate the need of climbing.

The following minimum inspection covers shall be provided on the main tank:

- At each bushing terminal where the bushing is connected to the winding
- On the tank wall, a minimum of one accessible from ground level to allow access for active part inspection at least 600 mm in diameter. The inspection cover shall be located to allow for maximum access to the active part and the tap changer. Where this is not possible more than one inspection cover shall be provided.
- On the top cover, a minimum of one to allow access for active part inspection at least 600 mm in diameter.

#### **3.10.6 Handles**

Manhole covers shall be provided with stout handles to facilitate their removal.

#### **3.10.7 Lifting lugs**

Covers with a mass greater than 25 kg shall be provided with symmetrically arranged lifting lugs.

### **3.10.8 Valves and oil sampling devices**

#### **3.10.8.1 Isolating valves**

Suitably dimensioned isolating valves shall be provided:

- a) at each point of connection to detachable cooling apparatus; and
- b) at each point of connection to tap-changer compartments, cable disconnecting chambers and cable sealing boxes supplied from the transformer tank.
- c) Isolating valves shall provide effective sealing at 100 kPa pressure and full vacuum at sea level.
- d) Radiator isolating valves shall be freely accessible for opening and closing with the transformer fully assembled.
- e) No special tools or tools shall be required to open or close radiator valves.
- f) Radiator valves shall be fitted to allow replacement of individual radiators.

#### **3.10.8.2 Filtering and drain valves**

Two 50 mm double-flange valves shall be provided for filtering purposes. At least one valve shall be located at the top of the tank adjacent to the oil conservator, and another at the bottom of the tank on the opposite end to give a cross current of oil during filtration. The lower valve shall be a combined drain and filtering valve and, as such, shall be positioned so that it drains, as far as possible, all the oil from the transformer tank. For class 2 and above transformers, the top filtration valve shall be routed inside the transformer tank and be brought out on ground level, and shall be clearly marked. The intake of the pipe for the top filtration valve shall be positioned at the allowable partial drain level.

All valves shall be painted with the same colour as the transformer tank.

No valves shall be fitted by means of stud welding or welding to the main tank.

The tap-changer diverter chambers shall be fitted with 20 mm (¾ inch) drain valves for maintenance purposes. If inaccessible from ground level, they shall be piped down to 1,5 m above ground level.

All drain valves shall be protected against mechanical damage. The means of mechanical protection shall be indicated on the general arrangement drawing.

#### **3.10.8.3 Oil sampling devices**

If specified in AB schedule, an oil sampling device consisting of a flange and drain plug as per the Oil sampling specification 240-56062720 or other approved device shall be provided in the following locations where applicable:

- a) at the bottom of the transformer tank, bolted and fitted with O-rings to the free flange of the 50 mm drain valve specified in 3.10.8.2;
- b) at the bottom of each separate tap-changer selector compartment;
- c) on the free flange of the tap-changer diverter chamber; and
- d) at the end of the main Buchholz relay sample pipe. A ¼" needle valve shall be provided on the Buchholz pipe for oil sampling.

These points shall all be numbered on the sampling point with the number corresponding to the same point on the valve function plate (see 3.10.8.8).

The tap changer diverter chambers shall be fitted with 25 mm individual drain valves for maintenance purposes. If inaccessible from ground level, they shall be piped down to 1.5 m above ground level.

Each diverter shall be fitted with individual sampling points.

The sample pipes shall be copper tubing with an ID of at least 7 mm (3/8" or 10 mm copper tubing). All fittings used shall be 3/8" brass or stainless steel. Only SAE 45-degree flares must be used on the copper tubing - compression fittings are not acceptable. The tubing shall be protected against physical damage by appropriate routing, fastening and / or protective conduit. Provision shall be made to secure oil sample copper tubing with rails welded to the tank and structures. At no point shall the copper tubing make contact with any steel surfaces.

A sample valve shall be provided and located approximately 1.5 m above ground level and be easily accessible from the transformer plinth. The sample valve shall be a needle type valve of 3/8" or 10 mm size – ball valves may not be used. Only brass or stainless steel needle valves shall be used. A stopper plug shall be provided to seal the open end of the sample valve.

All oil sampling devices to be accessible from ground level.

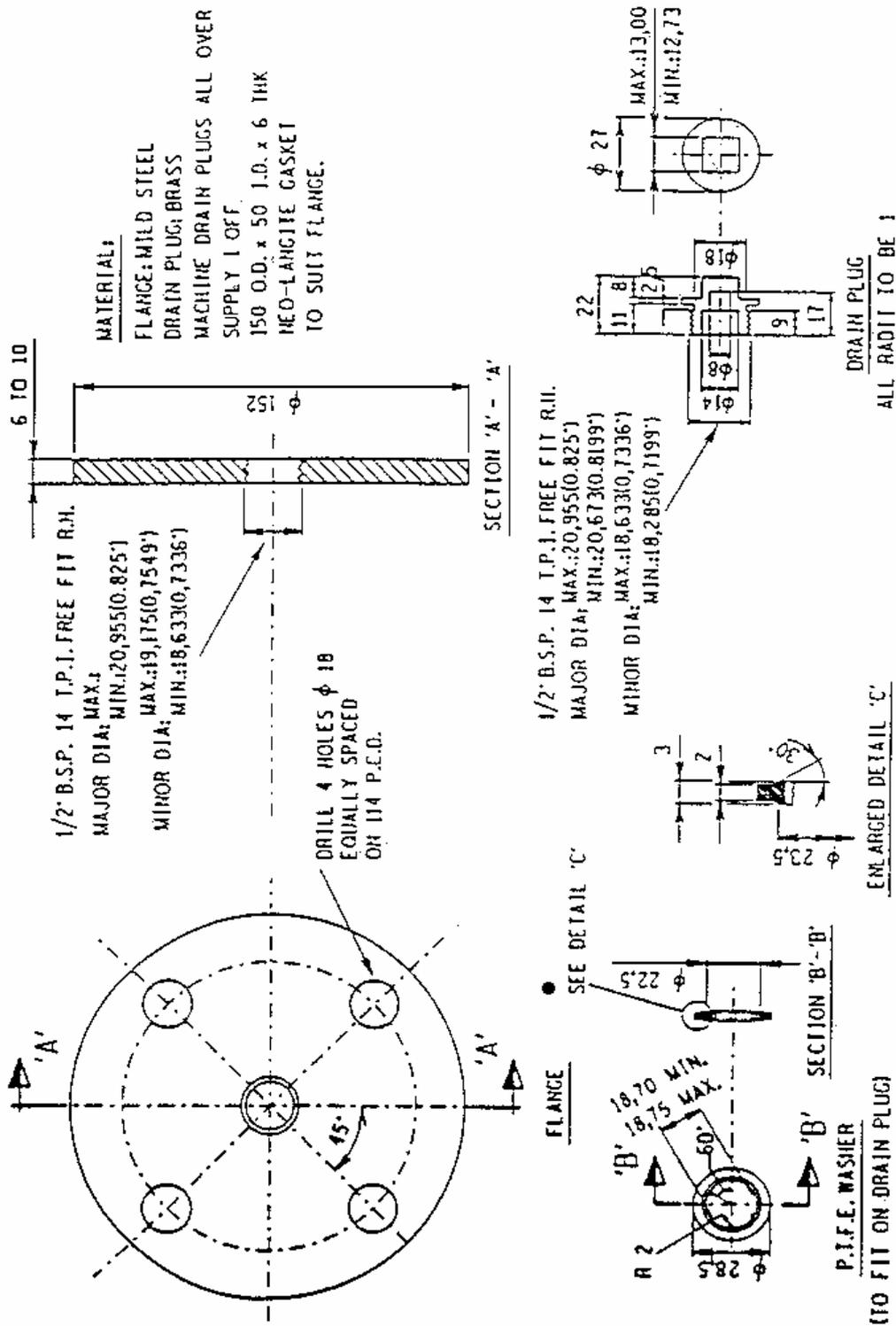


Figure 6: Oil sampling flange interfaces

#### **3.10.8.4 Strength and oil tightness**

Valves and oil sampling devices shall be of adequate strength to withstand the hydraulic and mechanical loads imposed upon them during testing, processing and transporting of the transformer and in service. Pewter and similar low strength materials will not be accepted.

Valve discs, wedges, wedge facing rings, seats and seat rings, stems and spindles shall be of approved non-corrodible material. Valves and oil sampling devices shall withstand the 3.18 test requirements,

#### **3.10.8.5 Valve stem seals**

Valve stem seals shall be capable of adjustment in service without draining the transformer oil. In this connection, and generally, aluminium (or aluminium alloy) threads shall not mate with threads of brass valve stems.

#### **3.10.8.6 Padlocking**

Suitable means shall be provided for padlocking valves in both the open and closed positions. This is applicable only to class 1 transformers.

#### **3.10.8.7 Blanking plates**

All valve entries communicating with the atmosphere shall be sealed using bolted and gasketed ( "O" rings accepted) blanking plates, or captive screwed caps, or plugs as the case may be. The O rings of viton material or type are preferred to the traditional nitrile ones.

#### **3.10.8.8 Valve function plate**

A schematic diagram plate indicating all valves, vent plugs and sampling points shall be provided in the same manner as the rating and diagram plate. This plate shall also indicate the position of all valves in operation, and out of operation.

#### **3.10.8.9 Valve position indication**

The position of each valve, i.e. either fully open or fully closed, shall be clearly and unambiguously visible on inspection. Where this is not so, e.g. in the case of lever operated valves, the "open" and "closed" positions of the lever in relation to a clearly recognizable part of the transformer shall be depicted on the valve function plate specified in 3.10.8.8.

#### **3.10.8.10 Labelling of oil sampling devices**

All the oil sampling points shall be numbered the same as on the valve function plate with exception of the two routine sampling points that shall also be labelled. The labels shall comply with the requirements of the labelling specification 240-56062720

### **3.10.9 Jacking Pads**

Four suitably and symmetrically placed jacking pads shall be provided in positions that shall be accessible when the transformer is loaded on to the transport vehicle, except where jacking pads are used as transport pads on vehicles with built-in jacking.

The position of the jacking pads shall be such that they do not restrict the direction in which the transformer could be moved (forward, backward and sideways) once off-loaded on site.

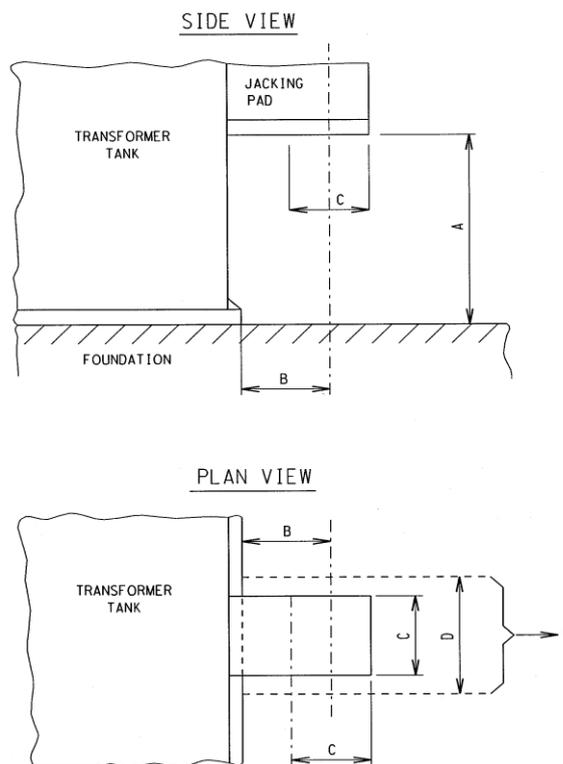
Each jacking pad shall be designed to support, with an adequate factor of safety at least half of the total mass of the transformer filled with oil, allowing maximum possible misalignment of the jacking force in relation to the centre of the working surface.

Unless otherwise approved, the heights of the jacking pads above the bottom of the transformer base, and the unimpeded working surface of the jacking pads shall be as in Table 8 (read in conjunction with Figure 7).

**Table 9: Jacking pad dimensions**

Transformer mass complete with oil (metric tons)	Min/max height of jacking pad above base "A" (mm)	Overhang to centre of jacking pad "B" (mm)	Unimpeded working surface of pad "C" (mm)	Width of symmetrical unimpeded access to jacking pad "D" (mm)
60 and below	460/530	115	170 x 170	230
Above 60	650/700	150	210 x 210	300

Access in direction 'E' shall be unrestricted.



**Figure 7: Arrangement of jacking pads**

**3.10.10 Lifting Lugs**

Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete transformer when filled with oil without structural damage to any part of the transformer. 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.

**3.10.11 Centre of Gravity**

Centre of gravity shall be clearly visible and indicated on all sides of the transformer tank.

### **3.10.12 Manholes and Handholes**

At least one manhole shall be provided on the sidewall, to allow access for internal inspections not higher than 500 mm from the base of the tank. Manholes shall be round with a diameter of not be less than 600 mm.

Hand holes shall be provided to facilitate the removal and installation of bushings. Lesser dimensions are acceptable for class 1 transformers due to their physical size.

### **3.10.13 Provisions for earthing**

Provision shall be made for earthing the transformer and associated apparatus as follows:

#### **3.10.13.1 Transformer tank earthing**

At a height not less than 300 mm from the base of the transformer tank and near each end of each of the two major sides of the tank (i.e. in four positions).

These provisions shall take the form of earthing pads integral with the tank walls; where the pads are attached by welding, such welding shall be continuous around the perimeter of the pads. Earthing pads shall be stainless steel and allow installation of 50 x 3 mm flat copper straps.

#### **3.10.13.2 Transformer neutral(s) earthing (direct)**

A stainless steel pad having the same clamping arrangement as the transformer earthing pads and integral to the transformer tank shall be provided for each transformer neutral terminal for earthing.

- 1) This pad shall be mounted as near as possible to its corresponding neutral terminal in order to ensure a short and steady connection to earth. The pads shall be mounted on the side of the tank from the top to ground at 800 mm intervals.
- 2) The manufacturer shall supply a suitably rated corrosion protected connection between the neutral bushing and the earth, insulated from the tank and metal.

#### **3.10.13.3 Transformer surge arrester earthing (line and neutral surge arresters)**

The surge arrester mounting brackets shall be used as the earth path for surge arrester discharging to earth via the transformer tank (i.e. copper earth tails shall not be used for surge arresters).

Where brackets for phase and neutral surge arresters are to be fixed to the tank using tank mounted bolts, stainless steel pads (similar to the transformer tank earthing pads that form an integral part of the tank) shall be used. When these pads are attached by welding such welding shall be continuous around the perimeter of the pads.

Where brackets are not directly mounted onto the tank (on radiators) a separate suitably rated corrosion protected connection shall be provided to the earthing pad on the tank.

**Note:** Bolted down surface contact areas of transformer surge arrester support brackets and earthing pads shall be free of any paint or metal spray coatings.

- All tank attached apparatus, including cable marshalling boxes, tap-changer operating gear and mechanism boxes, pipes, fan and pump motors shall be bonded to their supporting structures.
- Earthing pads, as specified in 3.10.13, shall also be provided on each end of the supporting structures for all separately mounted cooler banks and oil conservators and on all free-standing cubicles.
- No copper shall be used as connections for the purpose of earthing.

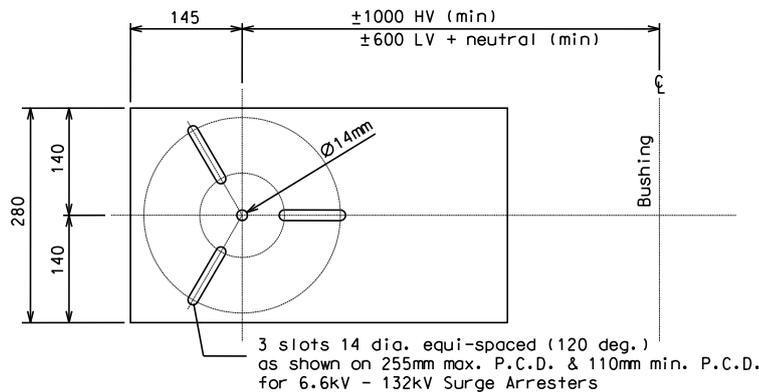
**NOTE:** Integral pads to suit the fault levels specified.

**3.10.14 Brackets for Surge Arrestors**

For terminals of 132kV and below, the surge arrester brackets used to mount the Primary, Secondary and Tertiary surge arrestors to the transformer shall comply with the following requirements:

- a) The surge arrester mounting brackets shall be provided to suit the dimension shown in Figure 8. The outline and dimension drawings provided in terms of a contract, shall show the surge arresters mounted on the transformer with all necessary clearances and sizes dimensioned.
- b) Universal surge arrester mounting details, fully dimensioned, shall be shown in an inset on these general arrangement drawings.
- c) Refer to 3.10.13 for the earth continuity requirements of the surge arrester brackets.

Surge Arrester Bracket



Notes :

- 1. All steel work shall comply with SABS 1200H. All steel work shall be hot dip galvanised to SABS ISO 1461. no cutting, welding or drilling shall be done after the galvanising process is completed. Tolerance - on dimensions +/- 2 - on hole centres +/- 1
- 2. Steel plate 10mm thick.

Voltage	No. of f	Phase spacing	HV / MV
132 kV	3	*	HV
88 kV	3	*	HV
66 kV	3	*	HV
44 kV	3	*	HV
33 kV	3	700mm C/C	MV
22 kV	3	700mm C/C	MV
11 kV	3	700mm C/C	MV
6.6 kV	3	700mm C/C	MV

\* = Centre phase inline outer phases, bushing centres + 450mm min.

**Figure 8: Surge arrester bracket dimensions**

The surge arrester bracket arrangement must be finalised during the mechanical design review meeting.

**3.10.15 Permanent Ladder**

A permanent steel ladder shall be welded to the main tank in a position to provide unrestricted access to the top of the transformer with the unit fully assembled. The ladder shall not interfere with or restrict maintenance activities and routine inspections. It shall not cover or restrict access to inspection / manhole covers and interfere with fitting of monitoring and on-line drying equipment.

A safety harness securing point shall be positioned at the landing space immediately above the steel ladder on the top cover.

### **3.10.16 Partial Draining**

To facilitate oil leak repairs on inspection covers and header pipes, transformers shall be designed to allow partial draining to a level of at least 150 mm below the top lid cover without exposing any cellulose insulation. Refilling of the transformer shall not trap air under inspection covers or top lid. Where necessary, bleeding points shall be provided to vent trapped air.

The tank side wall shall be permanently marked by welded sign or labelling to indicate the minimum oil level allowed for partial draining without exposing any cellulose insulation. The labelling shall be submitted to the purchaser for approval. This mark shall be located on the side wall i.e. same face where the bottom drain valve is located.

## **3.11 Auxiliary Supplies, Terminal Boxes, Wiring and Cabling**

### **3.11.1 Supply Voltage**

The auxiliary power supply will be rated at 400/230 Vac, three phase, 4-wire, 50 Hz. The unearthed DC supply will be 110 V or 220 V nominally as specified in Schedule A.

### **3.11.2 Marshalling and Terminal Boxes**

The Marshalling box shall be mounted on the transformer main tank. It shall be mounted in a position that it can remain fitted to the transformer tank during transport and installation. The Marshalling box shall be mounted on vibration reducing mountings to prevent damage or malfunction of internal accessories. The base of the Marshalling box shall not be lower than 300 mm from the base of the transformer but limited to 400 mm. All parts inside the marshalling box must be accessible from ground level.

Marshalling boxes and terminal boxes shall be vermin-, dust- and weather-proof and shall be provided with easily removable covers fixed by not more than two screws.

Covers for terminal boxes may be of the slip-on type, and those for Marshalling boxes shall be hinged in a vertical plane. Marshalling kiosk access doors shall open to a minimum angle of 120 degrees and shall be provided with a door open retainer. The door retainers must be strong enough to hold the cover in the presence of wind stresses.

Covers in a vertical plane shall, in addition to a gasketed seal, be provided with a double-curved flange along the top edge and sides. The door opening in the box shall have a double-curved flange around its entire perimeter, the outer face of which shall form the gasketed joint. The top of the box shall be made to overhang the cover, except in the case of slip-on covers. These shall be double-curved and fitted with drip ledges for internal corrosion proofing.

Marshalling boxes and terminal boxes, arranged in a vertical plane, shall be provided with a 25 mm vent and drain hole covered by a fine mesh of non-corrodible wire, fitted at the lowest point. This fitting shall be flush inside to permit total drainage.

The glass windows must be made of adequate material such that they do not fade at the specified ambient conditions.

#### **3.11.2.1 Transformer Standard Interface box**

A marshalling interface box (MIB) with a standard terminal layout that includes all transformer terminals and tap change drive terminals shall be provided. The MIB shall consist of a single box that houses at least 170 terminals and shall be mounted on the side of the transformer. The supplier shall supply and terminate a cable between the tap-change drive and the MIB to transfer the tap change functions, as specified in the MIB layout, to the MIB. All normal transformer functions as specified in the MIB layout below shall also be cabled to the MIB either directly or through a transformer terminal box. A 25A 380V triple pole circuit breaker shall be supplied and wired from the Cooler Supply as specified in the MIB layout, for the tap-change drive and the supplier shall supply and terminate a cable between the tap-change drive and the MIB to provide a three phase AC supply to the tap-change drive. Earth Leakage Protected 16 Amp double pole 230V AC supply Circuit Breakers for the Drykeep and Digital Gas Analyser units shall also be supplied inside the MIB.

Spare terminals may be used by the manufacturer to terminate any extra functions that will not normally be used in an Eskom application. He may however not deviate from the prescribed terminal allocation. Terminals indicating functions that are not provided by the manufacturer shall be left open. The manufacturer shall fit partitions between terminals X1.26, X1.27, X1.28, X1.29, X1.30, X1.31, X1.32; X1.34, X1.35, X1.36, X1.37, X1.38; X5.1, X5.2, X5.3, X5.4, X5.5, X5.6, X5.7, X5.8, X5.9, X5.10, X5.11 and X5.12.

Eskom will supply and terminate two 37-core 2,5mm<sup>2</sup> and two 10-pair twisted pair telephone cables between the MIB and the transformer protection and tap change control cabinet, in the substation control room and one 4-core 35mm<sup>2</sup> cable between the MIB and the transformer distribution board. The supplier of the Drykeep will supply and install one 4-core 2,5mm<sup>2</sup> cable between the MIB and the Drykeep. The supplier of the Digital Gas Analyser will supply and install one 3-core 2,5mm<sup>2</sup>, one 4-core 2,5mm<sup>2</sup> and one 2-core 1,5mm<sup>2</sup> cable between the MIB and the Digital Gas Analyser unit.

**Table 10: Standard layout for Marshalling Interface Box fitted to transformers**

Device	Abbreviation	Terminal number	Wire Marking	Application
Gas and oil relay 1	G.O.R. 1	X1.1 - X1.2 X1.3 - X1.4	X1.1 - X1.2 X1.3 - X1.4	Trip 1 Alarm 1
Pressure relief valve 1	P.R.V 1	X1.5 - X1.6 X1.6 - X1.7	X1.5 - X1.6 X1.6 - X1.7	Normal open contact Normal closed contact
On Load Tap Change Protection	O.L.T.C. Prot	X1.8 - X1.9 X1.9 - X1.10	X1.8 - X1.9 X1.9 - X1.10	Normal open contact Normal closed contact
Oil temperature indicator	O.T.I	X1.11 - X1.12 X1.13 - X1.14	X1.11 - X1.12 X1.13 - X1.14	Trip alarm
HV Winding temperature indicator	H.V.W.T.I	X1.15 - X1.16 X1.17 - X1.18	X1.15 - X1.16 X1.17 - X1.18	Trip alarm
MV Winding temperature indicator	L.V.W.T.I	X1.19 - X1.20 X1.21 - X1.22	X1.19 - X1.20 X1.21 - X1.22	Trip alarm
Tertiary Winding temperature indicator	T.W.T.I	X1.23 - X1.24 X1.25 - X1.26	X1.23 - X1.24 X1.25 - X1.26	Trip alarm
Oil level indicator	O.L.I	X1.27 - X1.28	X1.27 - X1.28	Oil level alarm High/Low
Tap-change oil level indicator	O.L.T.C.O. L.I	X1.29 - X1.30	X1.29 - X1.30	Oil level alarm High/Low
		X1.31 – X1.32		Spare
Cooler abnormal		X1.33 - X1.34	X1.33 - X1.34	Common alarm for cooler
Fans/Pumps/Thermometer		X1.35 - X1.38	R, S, T ,N	3 φ Control supply (WFF35 stud terminals)
Fans/Pumps		X1.39 - X1.41	X1.39+ X1.40- X1.41	110/220Vdc Cooler stop and thermometer supply
MIB Heater / Earth Leakage Supply		X1.42 – X1.43	X1.42 – X1.43	AC supply for MIB heater / Plug Socket
Drykeep Earth Leakage Supply		X1.44 – X1.45	X1.44 – X1.45	AC supply for Drykeep
DGA Earth Leakage Supply		X1.46 – X1.47 X1.58	X1.46 – X1.47 90	AC supply for DGA Earth terminal

**ESKOM COPYRIGHT PROTECTED**

**SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: **240-68973110**

Revision: **2**

Page: **50 of 80**

Device	Abbreviation	Terminal number	Wire Marking	Application
Thermometer failure		X1.48 – X1.49	X1.48 – X1.49	Thermometer failure alarm
Analogue output – Oil temperature		X1.50 – X1.51	X1.50+ – X1.51-	Analogue output 4- 20mA (IDC Terminals)
Analogue output – HV Winding temperature		X1.52 – X1.53	X1.52+ – X1.53-	Analogue output 4- 20mA (IDC Terminals)
Analogue output – MV Winding temperature		X1.54 – X1.55	X1.54+ – X1.55-	Analogue output 4- 20mA (IDC Terminals)
Analogue output – Tertiary Winding temperature		X1.56 – X1.57	X1.56+ – X1.57-	Analogue output 4- 20mA (IDC Terminals)

Device	Terminal number	Wire Marking	Application
HV “A” phase CT	X2.1 – X2.2	1AS1 - 1AS2	Protection
HV “B” phase CT	X2.3 – X2.4	1BS1 - 1BS2	Protection
HV “C” phase CT	X2.5 – X2.6	1CS1 - 1CS2	Protection
MV “a” phase CT	X2.7 – X2.8	1aS1 - 1aS2	Protection
MV “b” phase CT	X2.9 – X2.10	1bS1 - 1bS2	Protection
MV “c” phase CT	X2.11 – X2.12	1cS1 - 1cS2	Protection
HV neutral CTs	X2.13 – X2.14	1YNS1 - 1YNS2	Protection
	X2.15 – X2.16	2YNS1 - 2YNS2	Protection
MV neutral CTs	X2.17 – X2.18	1ynS1 - 1ynS2	Protection
	X2.19 – X2.20	2ynS1 - 2ynS2	Protection
Tertiary “a” Phase CT	X2.21 – X2.22	1-3AS1 - 1-3AS2	Protection
Tertiary “b” Phase CT	X2.23 – X2.24	1-3BS1 - 1-3BS2	Protection
Tertiary “c” Phase CT	X2.25 – X2.26	1-3CS1 - 1-3CS2	Protection
HV “A” phase CT	X2.27 – X2.28	2AS1 - 2AS2	Protection
HV “B” phase CT	X2.29 – X2.30	2BS1 - 2BS2	Protection
HV “C” phase CT	X2.31 – X2.32	2CS1 - 2CS2	Protection
MV “a” phase CT	X2.33 – X2.34	2aS1 - 2aS2	Protection
MV “b” phase CT	X2.35 – X2.36	2bS1 - 2bS2	Protection
MV “c” phase CT	X2.37 – X2.38	2cS1 - 2cS2	Protection
<b>Tap Changer</b>	X3.1 – X3.4	R,W,B,N	3 φ Motor supply
	X3.5 – X3.6	L, N	1 φ Heater and encoder supply
	X4.1 – X4.2	+, -	Tap change control DC supply (When required)
	X4.3 – X4.4	X4.3 – X4.4	Parallel check for even taps

**ESKOM COPYRIGHT PROTECTED**

**SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: **240-68973110**

Revision: **2**

Page: **51 of 80**

Device	Terminal number	Wire Marking	Application
	X4.5 – X4.6	X4.5 – X4.6	Parallel check for odd taps
	X4.7 – X4.9	X4.7 – X4.9	Local control Switch (7 Com, 8 Raise, 9 Lower)
	X4.10 – X4.11	X4.10 – X4.11	Seal In for raise operations (When required)
	X4.12 – X4.13	X4.12 – X4.13	Seal in for lower operations (When required)
	X4.14	X4.14	Initiate raise operation
	X4.15	X4.15	Initiate lower operation
	X4.16 – X4.17	X4.16 – X4.17	Energize O/C block contactor (Negative may be commoned)
	X4.18 – X4.19	X4.18 – X4.19	Trip motor supply MCB (Negative may be commoned)
	X4.20 – X4.21	X4.20 – X4.21	Motor supply MCB has tripped
	X4.22 – X4.23 - X4.25	X4.22 – X4.23 – X4.25	Indication for tap-change in progress ( raise, lower)
	X4.24	X4.24	Motor running timer
	X5.1 – X5.6	X500, X501, X502 X504, X508, X510	Binary coded decimal output to tap position indicator
	X5.7 – X5.12	X600, X601, X602 X604, X608, X610	Binary coded decimal output remote indication

**Additional Functions**

Device	Abbreviation	Terminal number	Wire Marking	Application
Gas and oil relay 2	G.O.R. 2	X11.1 – X11.2 X11.3 – X11.4	X11.1 – X11.2 X11.3 – X11.4	Trip 2 Alarm 2
Rapid pressure rise relay 1	R.P.R. 1	X11.5 – X11.6	X11.5 – X11.6	Trip 1
Rapid pressure rise relay 2	R.P.R. 2	X11.7 – X11.8	X11.7 – X11.8	Trip 2
Conservator bag leak detector	C.B.L.D	X11.9 – X11.10	X11.9 – X11.10	Alarm
Sudden flow valve	S.F.V.	X11.11– X11.12	X11.11-X11.12	Alarm 1
Pressure relief valve 2	P.R.V 2	X11.13- X11.14	X11.13-X11.14	Normal open contact
Pressure relief valve 2	P.R.V 2	X11.15– X11.16	X11.15– X11.16	Normal closed contact
Digital Gas Analyser	DGAUA	X11.17– X11.18	X11.17– X11.18	Unhealthy Alarm
Digital Gas Analyser	DGAGC	X11.17-X11.19	X11.17-X11.19	Gas Caution Alarm
Digital Gas Analyser	DGAGA	X11.17-X11.20	X11.17-X11.20	Gas Alarm
Digital Gas Analyser	DGAACF	X11.21-X11.22	X11.21-X11.22	AC Fail Alarm (N/C contact)

**ESKOM COPYRIGHT PROTECTED**

Device	Terminal number	Wire Marking	Application	
Auxiliary Transformer Gas and oil Relay	AT G.O.R.	X11.23- X11.24 X11.25-X11.26	X11.23- X11.24 X11.25-X11.26	Trip Alarm
Auxiliary Transformer Oil Temp Indicator	AT O.T.I.	X11.27- X11.28 X11.29-X11.30	X11.27- X11.28 X11.29-X11.30	Trip Alarm

**3.11.3 Earthing terminal**

An earthing terminal of M12 to M16 shall be provided in each terminal and marshalling box with a stud on both the inside and outside.

**3.11.4 Spare terminals**

Each marshalling box shall be provided with not less than 10% spare terminals with a minimum number of twelve, unless otherwise agreed.

**3.11.5 Incoming auxiliary circuits**

To prevent entry of water, the auxiliary wiring from the gas- and oil-actuated relay, current transformers and other auxiliary apparatus, shall be arranged for side or bottom entry into the marshalling or terminal box. If bottom entry is adopted, the gland plate used shall be independent of that provided for the *Purchaser's* outgoing cables. If cables enter the terminal boxes or marshalling kiosk from the side, drip-loops shall be provided to prevent water from entering the cable gland.

**3.11.6 Provision for outgoing cables**

The marshalling box shall be provided with a separate, removable, undrilled plate to take the *Purchaser's* cable glands, mounted at least 100 mm below the bottom of the terminal blocks, or other equipment, in such a manner as to facilitate the entry of the *Purchaser's* cables. The gland plate shall be of 6 mm thick brass sheet. Steel plates are not accepted

The gauze covered drain and vent hole may be fitted to this gland plate. The gauze covered drain hole must be in the lowest part of the kiosk and must not be on the gland plate.

**3.11.7 Cabling and Wiring**

Only UV stable, heat and oil resistant PVC SWA (steel wire armouring) cable shall be used on transformers. Only corrosion resistant cable glands for armoured cables shall be used. Plastic compression type cable glands shall not be used on armoured cables. Heat, oil and UV resistant cable shrouds shall be fitted to all cable glands.

All cable terminations shall be provided with cable numbers fitted to the cables on both ends. Only permanently engraved, non-corrodible, UV, oil and heat resistant material shall be used for cable numbering. These labels shall be permanently fixed to the cable ends just before the glands on the outside of the terminal box.

The cable armouring shall be earthed at least one side. Earthing shall be by means of the steel cable gland.

**3.11.8 Insulation**

Wiring insulation shall be oil- and moisture proof, and, where affected by temperatures above that of the ambient air, shall have thermal characteristics at least equal to class 'A' of IEC 85.

**3.11.9 Insulation test voltage**

All auxiliary circuits shall withstand a test voltage of 2 kV DC for 60 seconds to earth and to all other circuits.

**ESKOM COPYRIGHT PROTECTED**

### **3.11.10 Type of conductor**

All secondary wiring used on the transformer for current transformer secondary and other auxiliary equipment shall have a minimum cross-section of 2, 5 mm<sup>2</sup>, and shall be limited to 30 strands per cable, flexible, 660/1000 V grade wire in accordance with SABS 1507 or to the *Purchaser's* approval.

As far as possible, only cables with the correct number of strands shall be used. Where this is not possible the free strands shall not be cut, but effectively earthed on one side of the cable.

### **3.11.11 Supporting and securing of cables**

All cables shall present a neat appearance and shall be supported on cable rails elevated 20 – 30 mm from the tank surface. The rails shall be welded to the transformer tank surface. Similar rails shall be provided to route and secure cables to auxiliary components, i.e. oil level indicators, Buchholz relays, cooling fans, etc.

Cables shall be secured to cable rails by means of stainless steel strapping with a minimum width of 6 mm and not exceeding 10 mm.

Routing of cables shall be done to eliminate the cable from touching sharp edges on the transformer tank structure.

No cables in steel conduit will be accepted.

### **3.11.12 Identification of wiring**

All equipment boundary/interface terminals and the equipment wires connected to those terminals shall have a unique wire/terminal number in accordance with the manufacturer's drawings approved by the *Purchaser's*. The wires shall be marked with black letters impressed on a white background or black letters on a yellow background providing that the colour selected is consistent throughout the panel and/or suite of panels and is to the *Purchaser's* approval.

For heavy conductors and very light wiring (telephone type) where the preferred type of marking ferrules is not available, other methods may be approved.

Ferrules shall be arranged to read upright on cable terminal strips and to read from terminal to insulation in the case of relay apparatus and instrument connections.

### **3.11.13 Cabling by the Purchaser**

Multi-core cabling to the remote control point will be provided by the *Purchaser*. Where a separately mounted outdoor control cubicle is provided near the transformer and where the *Contractor* is responsible for erection, he shall provide and connect all cabling between this control cubicle, the transformer marshalling box and the auxiliary apparatus on the transformer together with all necessary cable fittings, attachments and identification of cables and cable cores.

### **3.11.14 Identification of fuses and circuit breaker**

All fuses and circuit breakers shall be labelled indicating the rating and circuit.

### **3.11.15 Identification of equipment**

All equipment identification labels in marshalling kiosks and control cubicles shall be fixed on permanent surfaces next to the equipment (above, underneath or next to) and not on removable covers or on the equipment itself.

## **3.12 Rating and Diagram Plates**

### **3.12.1 General**

Rating and diagram plates shall comply with the requirements of IEC 60076 except where otherwise stated in this specification.

### **3.12.2 Materials and methods of marking**

Rating and diagram plates shall be of stainless steel not less than 1,2 mm in thickness.

The required information shall be engraved on the plate and the engraving filled with glossy black, baked enamel.

Other arrangements shall be specifically approved.

### **3.12.3 Mounting**

The rating and diagram plates shall be mounted on the door of the marshalling interface box for all tank mounted boxes. If otherwise, the plates must be mounted on the tank. The plates must be finished in accordance with 240-56030674 situated in an accessible position not more than 1,5 m above ground level, and secured by stainless steel screws.

### **3.12.4 Information to be displayed**

The minimum information to be displayed on the rating and diagram plate shall be in accordance with the requirements of IEC 60076 with addition of the following as detailed in 9.

- a) the tapping current values shall be shown for HV, MV and tertiary terminals for all tapping positions;
- b) the capability of the transformer (including bushings and tap-changers) to carry overloads in accordance with the emergency duties detailed in IEC 60076-7 shall be shown;
- c) the system fault levels in kA for which the transformer is designed
- d) the zero sequence impedances in the case of three-winding auto transformers;
- e) the current transformer data shall be shown;
- f) a statement that the manufacturer deems it necessary for the transformer to be oil-filled under vacuum;
- g) a statement that the transformer will withstand full vacuum at sea level;
- h) the *Purchaser's* reference number shall appear on the rating and diagram plate;
- i) values for all relevant parameters used by the digital temperature gauge for the winding hot-spot and transformer lifetime calculations as per IEC 60354 or IEC 60076-7
- j) The temperature probe hole diameter/s and depths.
- k) a blank space for the *Purchaser's* asset number shall be provided;
- l) the type, make and designation numbers of all bushings, to enable full identification (relating to stock spares) while the transformer is energised;
- m) the valve and oil sampling point functions and positions;
- n) a warning statement that the conservator contains a bag or other sealing systems if it is the case; and
- o) the type of corrosion protection: Corrosive or low corrosive.
- p) Initial DP value
- q) Tie-in resistor schematic and value (if used).
- r) Vector Group
- s) Surge Arrestors on regulating winding
- t) Tertiary Reactor

**SPECIFICATION FOR POWER TRANSFORMERS RATED FOR 1.25MVA AND ABOVE AND WITH HIGHEST VOLTAGE OF 2.2KV OR ABOVE**

Unique Identifier: 240-68973110

Revision: 2

Page: 55 of 80

Whilst a single plate is preferred, separate plates mounted adjacent to the main plate are acceptable for the information required by items (f), (g), (h), (m), (n), and (o).

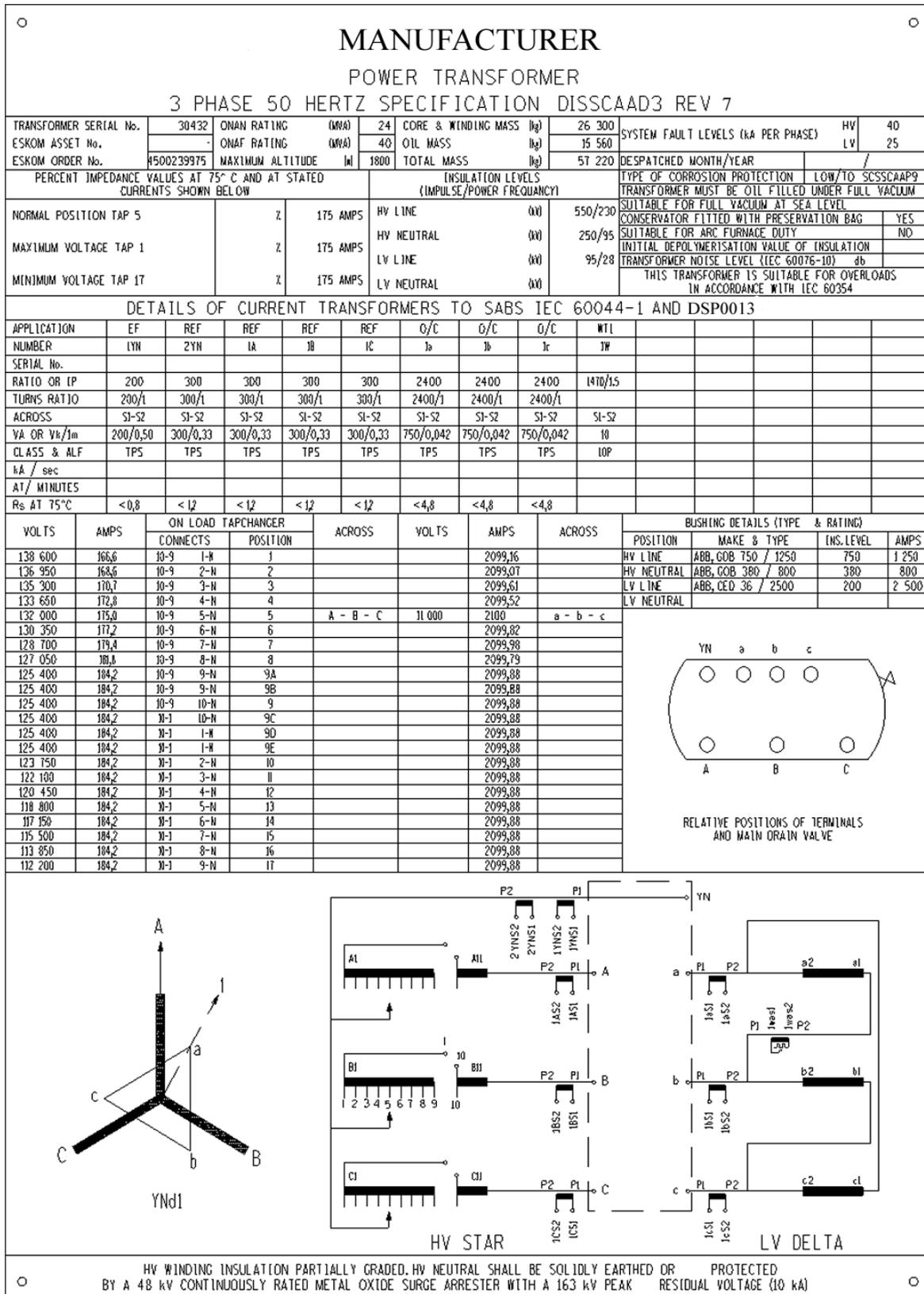


Figure 9: Typical Rating and Diagram plate

ESKOM COPYRIGHT PROTECTED

### **3.13 Painting of Tanks and Parts**

The painting of the transformer tank, the conservator tanks, the piping, the covers, the turrets and all other items that need to be painted or galvanized shall be done according to the requirement of the Eskom painting specification 240-56030674. The following items shall also be painted:

- the flange facing surfaces.
- the blanking plates that are used during transportation.

### **3.14 Special Auxiliaries**

All auxiliary components used in the Eskom transformers shall comply with the relevant specification and must be approved by Eskom. An auxiliary component will be declared approved when it has been technically evaluated by a relevant specialist and the approval is in writing. Auxiliary components shall comply with 240-62773019 as applicable.

#### **3.14.1 Buchholz Relay**

An oil and gas actuated relay suitable for operation in transformer oil as specified over the temperature range from - 10°C to + 115°C shall be interposed in the connecting pipe between the oil conservator and the transformer tank. The relay shall be fitted in such a manner that all the gasses from the tank pass through and are trapped by the relay as the gasses move towards the oil conservator. The mounting angle shall be as per the relay OEM instruction so as not to compromise the reliability of the relay.

For the purpose of redundant protection, transformers and reactors having a voltage rating of 220 kV and above or a rating of 100 MVA(r) and above shall be provided with two Buchholz relays. The relays shall be installed in series in the connecting pipe between the oil conservator and the transformer tank, mounted at least five pipe diameters apart - measured from facing flanges.

The oil and gas actuated relay shall comply with the requirements of 240-56063908. A valve must be fitted between the Buchholz relay and the conservator.

#### **3.14.2 Pressure relief devices**

Transformers rated below 100 MVA shall be equipped with one spring operated pressure relief device and those of 100MVA and above shall have two devices.

Pressure Relief Devices (PRD) shall comply with the requirements of 240-56063871 and shall be mounted so as not to entrap gases that may be generated or released inside the transformer. These devices shall be fitted directly to the side walls of the transformer tank at a level as near as possible to the top of the windings. Where one device is fitted it shall be positioned as close as possible to the centre phase. Where there are two devices they shall be arranged on opposite sides of the transformer, i.e. between 'A' and 'B' phases on one side and between 'b' and 'c' phases on the other. Alternative mounting positions, such as on the tank cover, may be considered if adequate mechanical protection can be provided to avoid inadvertent damage by erecting personnel. All mounting positions shall be such that the PRD(s) is(are) positioned above the partial drain mark. This shall be subject to approval by the *Purchaser* and be discussed during a mechanical design review meeting.

A combined weather guard and oil deflector shall be fitted to ensure free deflection of the oil towards the ground and provide adequate protection from the environmental elements. These must however not reduce the oil evacuation capability of the device.

Despite any testing requirements in this specification the overpressure device shall not be influenced to generate invalid trip signals by tank vibrations and the magnetic fields generated during normal operation and through faults.

### **3.14.3 Rapid Pressure Rise Relay**

Each new transformer and reactor rated  $\geq 80$  MVA and  $\geq 132$  kV shall be provided with at least one rapid pressure rise relay. In the case of large units  $\geq 500$  MVA and  $\geq 400$  kV, two units, one on each of the longitudinal end shall be fitted. The function of the rapid pressure rise relay is to detect dynamic over-pressure conditions caused by abnormal activity inside the main tank and to provide a trip signal to remove the equipment from service. A suitable double flanged gate valve shall be fitted between the relay and the transformer tank to allow for maintenance without the need to drain the transformer oil. The position of the relay shall be such that maintenance and/or replacement of the components (valve and relay) can be done with partial drain. The position shall be discussed during a mechanical design review and submitted for approval. The relay shall be provided with seal in and reset feature and test facilities.

This component shall comply with the requirements of 240-56063867.

### **3.14.4 Thermometers for Oil and for Winding Temperatures**

Oil temperature indicators (OTI's) and winding temperature indicators (WTI's) are fitted to transformers to measure the oil and winding temperatures. The indicators do not only display the temperature but are also used to start / stop forced cooling, provide high temperature alarm and trip signalling. The winding temperature gauges shall be provided for all the windings i.e HV, MV, and LV, where applicable.

These shall comply with the requirements of 240-56063843.

Class 1 Transformers shall be fitted with a Digital Temperature instrument in accordance with 240-75763120 for ambient, and oil and winding temperature measurements, fan control and alarm/tripping. The digital instrument shall be augmented by a conventional device as per 240-56063843 for oil temperature measurement and alarm and tripping.

The choice of the instrument technology shall be concluded during a design review meeting.

### **3.14.5 Fibre optic temperature probes**

For all transformers when specified in the Schedules AB, for identification of hot spot temperatures, fibre optic temperature probes have to be installed based on mutual agreement between the *Contractor* and Eskom during the design reviews. The sensors will be installed permanently for future use with the connection points easily accessible 1.5m from ground level. A redundant sensor will be installed near the primary sensor.

For all the units fitted with fibre optic sensors, the units should have a through wall plate fitted at the top of the transformer tank (above the partial drain level) and extensions pre-fitted (factory supplied) terminating in to the marshalling kiosk. The position of the through wall plate and the internal extensions pathway within the tank must not follow a path whereby personnel entering the interior of the transformer would easily be able to damage them; furthermore the cover used for the plate must be a dedicated one and not an inspection cover.

### **3.14.6 Oil Level Indicators**

Each conservator tank (main tank and OLTC) shall be provided with a dial-type oil level indicator that will show the correct oil level inside the tank. Direct reading fluid type oil level indicators shall not be used.

The indicators shall be suitable for the design of the conservator, i.e. free-breathing or bag type conservators.

Expected design life of the oil level indicator shall match the design life of a transformer, at least 40 years.

The oil level indicator shall comply with all the requirements of 240-56356191

### **3.14.7 Fans, Pumps and Radiators**

Transformers and reactors are fitted with radiators to reduce operating temperatures. Where forced air cooling is required, fans are installed beneath the radiators and air is forced in a vertical direction to increase cooling of the oil. The fan motors shall be of the standard induction motor. The GSUs will be fitted with coolers. Pumps may be fitted in the event of forced oil cooling.

All radiators shall be mounted onto the main tank of the transformer. Each radiator shall be provided with top and bottom shut-off valves and shall be detachable from the main tank. The radiators shall be hot dipped galvanised only. The galvanising shall comply with SANS 1461. Radiators shall not be positioned over manholes, hand holes or inspection covers.

Radiators shall be equipped with stainless steel type DIN 42 558 bleeding and drain plugs. Seals shall be UV, heat and oil resistant. The bleed points shall have a double seal system.

Radiators shall have the necessary lifting eye connections. For shipping and storage, all flanged openings shall be permanently sealed by means of a blank, bolted and gasketed cover.

The fans and the radiators shall comply to the requirements of 240-56535946 and the requirements indicated in Schedules AB.

The transformer shall be supplied with cooler control equipment including:

- a) an isolating switch rated to carry and break full-load current for each group of fan and pump motors;
- b) a "manual"/"auto" change-over switch;
- c) a contactor for each group of fan and pump motors. A set of normally open contacts shall be provided to initiate an alarm circuit if the contactor is tripped by its overload element. All such contacts of the various groups shall be paralleled and wired to a pair of terminals in the control cabinet.
- d) contactors shall maintain supply to motors at supply voltage down to 0,85 pu of the rated supply voltage at their terminals. Tripping shall only occur on a controlled basis and there shall be automatic restarting in the staggered mode if the voltage recovers while the transformer is in service; and
- e) provision for disconnection of all cooling pumps and fans on the closure of a contact provided by the purchaser. The "fan/pump stop" facility shall be provided via a latching relay, with the operate coil set by the application of 110V or 220Vdc (user selectable) via the purchaser's Master trip relay. A reset push button shall be provided in the Marshalling Interface Box for resetting the latching relay. The operating coil of the latching relay shall be continuously rated as it will be activated by a latched input function.

### **3.14.8 Air Bag**

As indicated in Schedules AB certain units shall be fitted with an air bag in the conservator. The details of the airbag, including the dimensions shall be included in the manual and the drawings documentation. This should be such that it makes it easier for Eskom to order a replacement bag, should it become necessary, in the future.

### **3.14.9 Air Bag Leak Detector**

Each transformer and reactor fitted with an air bag shall be provided with a bag leak detector. The function of the bag leak detector is to detect a leaking air bag. The abnormality will be detected by this detector and an alarm will be signalled to the control panel of the respective transformer or reactor. A contact will provide an alarm signal that the bag leak detector has operated to alert maintenance staff.

The air bag leak detector shall comply with the requirements of 240-56356202, and shall be positioned about 100 mm from the top of the conservator tank, without compromising reliability. The proposal for the installation shall be submitted at tender stage and shall form part of the mechanical design review. A bleed pipe and valve must be brought to ground level and fitted with a locking device to prevent unauthorised opening of the valve. A tag complying with the requirements of 240-56062720 shall be provided written : **“BAG LEAK DETECTOR AIR RELEASE”**.

A second valve to get the trapped air from the conservator must be provided. The associated text should read **“CONSERVATOR TANK AIR RELEASE”**. Both valves should have mechanical tamper proof covers.

### **3.14.10 Dehydrating Breathers**

The dehydrating breathers used in the transformers shall comply with the requirements of 240-56062529. Self dehydrating breathers are acceptable and can be discussed during a mechanical design review.

### **3.14.11 Optional digital secondary plant interface**

An option shall be provided for a digital interface to the power transformer’s auxiliary and control circuits based on IEC 61850 GOOSE messaging. The digital interface shall be achieved via Intelligent Electronic Devices (IEDs) to be referred as Process Interface Units (PIUs).

The digital interface shall be applicable to binary controls, binary status signals, temperature measurements and the tap position indication number. Analogue instrument transformer signals shall be retained, that is implementation of IEC 61850 Sampled Measured Values is not required.

The digital interface shall be an add-on option to the standard wiring interface of the power transformer (including the on-load tap changer), and shall be installed within the marshalling interface box, or in an additional bolt-on enclosure which shall be provided. All wiring between the PIUs and the MIB interface terminal strips shall be provided.

## **3.15 Insulating Oil**

The *Contractor* shall approve the oil to be used, and such oil must comply with the requirements of the latest revision of the Eskom Oil specification 240 - 75661431 and must be from the list of the approved oils. The list is available from Commercial. In support of the Eskom drive for environmentally friendly products, the so called green oils shall be considered for acceptance and they must comply to IEC 62770.

The *Contractor* shall also ensure that the oil used during manufacturing and testing at the factory is mixable with the intended oil for use in service. The mixing of the two oils should not expose Eskom to any risk and this must be approved during design review.

## **3.16 Cooling**

### **3.16.1 General**

Temperature limits as specified in IEC 60076. Unless otherwise specified differently in Schedule A of the purchasing specification, the weighted annual average ambient temperature of 30°C has to be taken into account.

With reference to 30 °C ambient temperature the temperature rise specified in IEC has to be reduced by 10°C.

### **3.16.2 Cooling Systems**

Depending on the MVA rating and as specified in Schedule A of the specification, the following cooling systems can be applied: ONAN, ONAN/ONAF, ONAN/ONAF/ODAF, ONAN/ODAN, and ONAN/ODAF.

In cooling systems where forced oil cooling (OF) is in combination with natural oil cooling (ON), the core cooling has to be incorporated in the forced oil flow system.

When directed oil (OD) cooling is incorporated in the cooling system, low oil speed pumps (i.e. propeller pumps with low hydraulic resistance) have to be applied to ensure the directed oil flow.

Oil flow indicators shall be located so they are visible and can be easily read from the ground level.

Where only ONAF cooling is used, it must be capable of 100% of the capacity requirements.

Where ONAN as a cooling combination is used, natural cooling must be capable of at least 70% of the cooling capacity requirements.

For Generator-step-up transformers the cooling combination is either OFAF or ODAF as specified in Schedule AB. For special applications OFWN or OFWF type cooling may be specified. In order to eliminate the possibility of ingress of water into the oil, the maximum total pressure head of water at any point within the primary oil/water heat exchanger is kept below the static head of the oil at that point. In the case of OFWN (or ODWN) cooling, this can be achieved by providing pressure break tanks open to the atmosphere and fitted with balance type float valves for water level control. In the case of OFWF (or ODWF) cooling, the two stage cooling is provided in the form of double tube primary oil/water heat exchangers whose cooling water is circulated through low/high pressure heat exchangers (intercoolers).

**NOTE** – The water side of the water to water and / or water to oil cooling are provided with sacrificial anodes in the water boxes

### **3.17 Current Transformers**

All current transformers shall comply in all respects with the requirements specified in Schedule AB and/or the following

#### **3.17.1 Number and Location**

It is the intention to increase the number but decrease the power rating of CT's built into the bushing turrets. It is expected that up to 8 CT-s may be required because the functions of the traditional free -standing HV and MV CTS will be built into the transformer. The final number, type and ratings of built-in current transformers shall be clarified with Eskom during the design review at the latest. The positioning of the CTs in the transformer turret must not compromise the safe operation of the transformer. The *Contractor* shall demonstrate by field calculations that the CTs and the associated wiring are positioned / traversing in a very low field or no field area.

The number, ratings and location of current transformers associated with each power transformer, shall be as specified in Table 13, Table 14, Table 15, and Table 16)

#### **3.17.2 Transformer Short-circuits and Overload**

Current transformers shall be capable of withstanding mechanically and thermally the same loading and overload, as specified in this document for the power transformer.

#### **3.17.3 Insulation levels and short circuiting for testing.**

Current transformers shall withstand all dielectric tests applied to the power transformer windings, and shall be in position and in circuit during the power transformer voltage withstand and impulse tests. Open circuits shall be avoided during testing of the transformer. All current transformers shall be short circuited in the factory and so delivered to site.

#### **3.17.4 Tests for current transformers**

The current transformer shall be tested as per the latest IEC 61869-2 specification and test certificates provided.

### **3.17.5 Terminal Connections**

Current transformer secondary terminals, where applicable, shall comply with the requirements described below, and they shall be indelibly marked for identification. All current transformer terminals inside the power transformer shall be of the stud type and all connections shall be securely locked by means of lock nuts or locking plates. Steel lock washers are not acceptable.

### **3.17.6 Termination of Leads - Internal**

Particular attention shall be paid to the termination of leads inside the transformer tank with a view to ensuring secure connection of current carrying lugs, and the elimination of all possible tension in the leads plus any possible risk due to the presence of the electric field as stated in 13.14.1 of this document.

### **3.17.7 Turns Compensation**

Protective current transformers shall not be turns compensated.

### **3.17.8 Required Data**

The following information relating to protective current transformers shall be submitted for approval:

- magnetization curve;
- secondary winding resistance (temperature compensated to 75°C); and
- secondary winding leakage reactance.
- insulation resistance

### **3.17.9 CT Designation**

Where more than one protective current transformer is provided in any one phase, the current transformer designated "main protective current transformer" shall be located furthest from the transformer windings. In addition, protective current transformers together with current transformers in general, shall be given designations as indicated in figures 9 and 10 below

### **3.17.10 Current Transformers for Delta-connected Windings**

The arrangement of protective current transformers associated with delta-connected power transformer windings, is indicated below in figures 11 to 13 and Tables 9 to 13.

### **3.17.11 CT for Winding Temperature Indication for Delta Windings**

Where the current transformer for a winding temperature indicator is associated with a delta-connected winding, it shall be located inside the delta so that it can detect all over current conditions of the delta winding, including those circulating current conditions resulting from external earth faults on the associated power systems.

### **3.17.12 Type and Accessibility**

Current transformers shall preferably be of the bushing type. Separately mounted CT's shall be located above the transformer core and winding assembly and be provided with adjacent hand holes in the tank side or cover of a size adequate for their removal and replacement, which must be capable of taking place without the lowering of the oil and exposure of the paper insulation. The terminal box shall be positioned in the area outside the zone of high electric field of the associated bushing. This shall be demonstrated during a design review meeting and be verified during production.

### **3.17.13 Data for Rating and Diagram Plates**

Where current transformers are built into the transformer, the combined rating and diagram plate shall provide full details of each current transformer's location, polarity, secondary terminal markings and also all the information required by IEC 61869-2 as applicable, with the provision that no information be duplicated.

The following symbols may be used on rating and diagram plates:

IL = Secondary insulation Level (2 kV DC)

Hz = Rated frequency

I<sub>th</sub> = Rated short-time current and rated time kA-s;

R<sub>s</sub> = Secondary winding resistance at 75 °C;

N = Turns ratio

V<sub>k</sub> = Kneepoint voltage

I<sub>m</sub> = Magnetising current

I<sub>p</sub> = Primary current

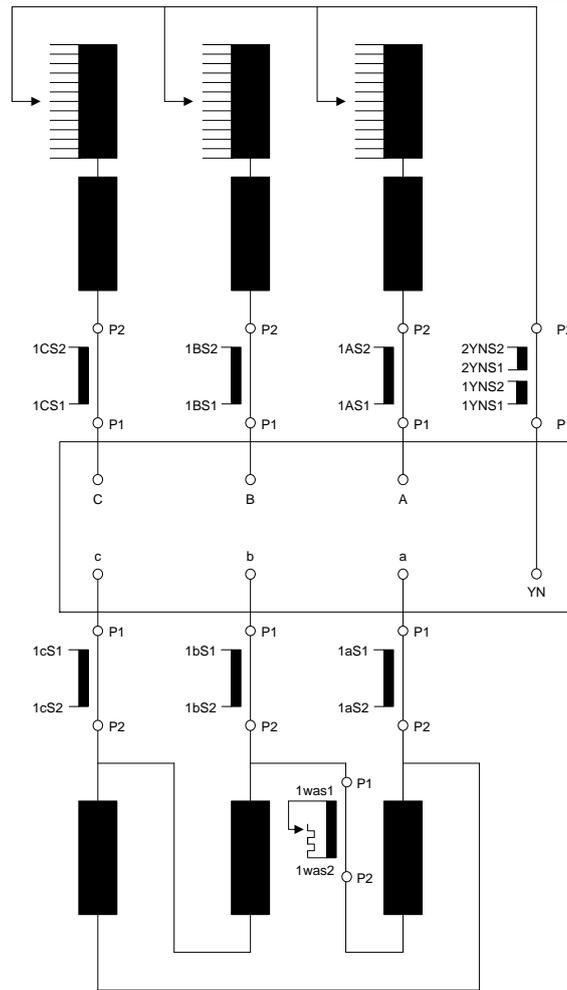
I<sub>s</sub> = Secondary current

VA = Output in (VA).

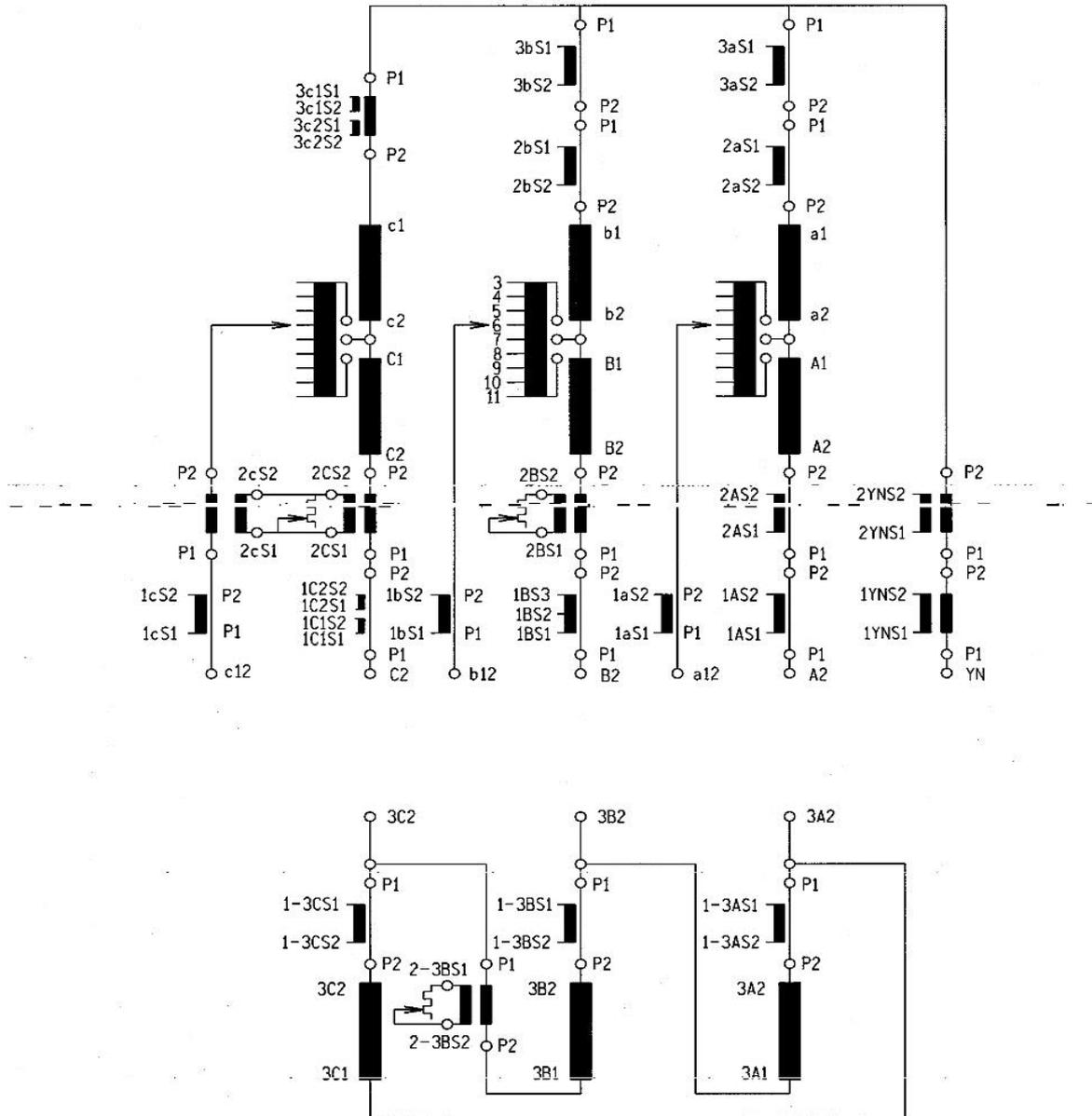
### **3.17.14 Terminal Markings**

The system of marking for identifying the terminals for current transformers supplied with power transformers, shown in figures 9 and 10, indicates: the polarity of the primary and the secondary terminals, or, where no primary terminals exist as such, the orientation of the current transformer; and the current transformer designation, viz. the connection in which it appears (e.g. a phase or neutral connection); the sequence relative to other current transformers appearing in the same connection. The current transformer winding (primary and/or secondary) and its polarity shall be denoted by the letter P and/or S and the Annexure 1 & 2 as specified in IEC 61869-2. The convention to be used always places P1 (and/or S1) nearer the external terminal of the transformer and P2 (and/or S2) nearer the winding.

The winding alpha-numeric and the polarity alpha-numeric shall be prefixed by letters denoting the phase or neutral connection in which the current transformers appear and these alpha-numeric shall be prefixed by numerals giving the sequence of the current transformers relative to other current transformers in the particular phase or neutral connection, as indicated below. These numbers shall be counted in the case of star-connected windings, from the power transformer external terminal towards the neutral point connection, and in the case of delta-connected windings in a direction from the external terminal through the particular phase winding towards the junction with another phase.



**Figure 10: Terminal Markings for 'Class 1' 2-winding transformers**

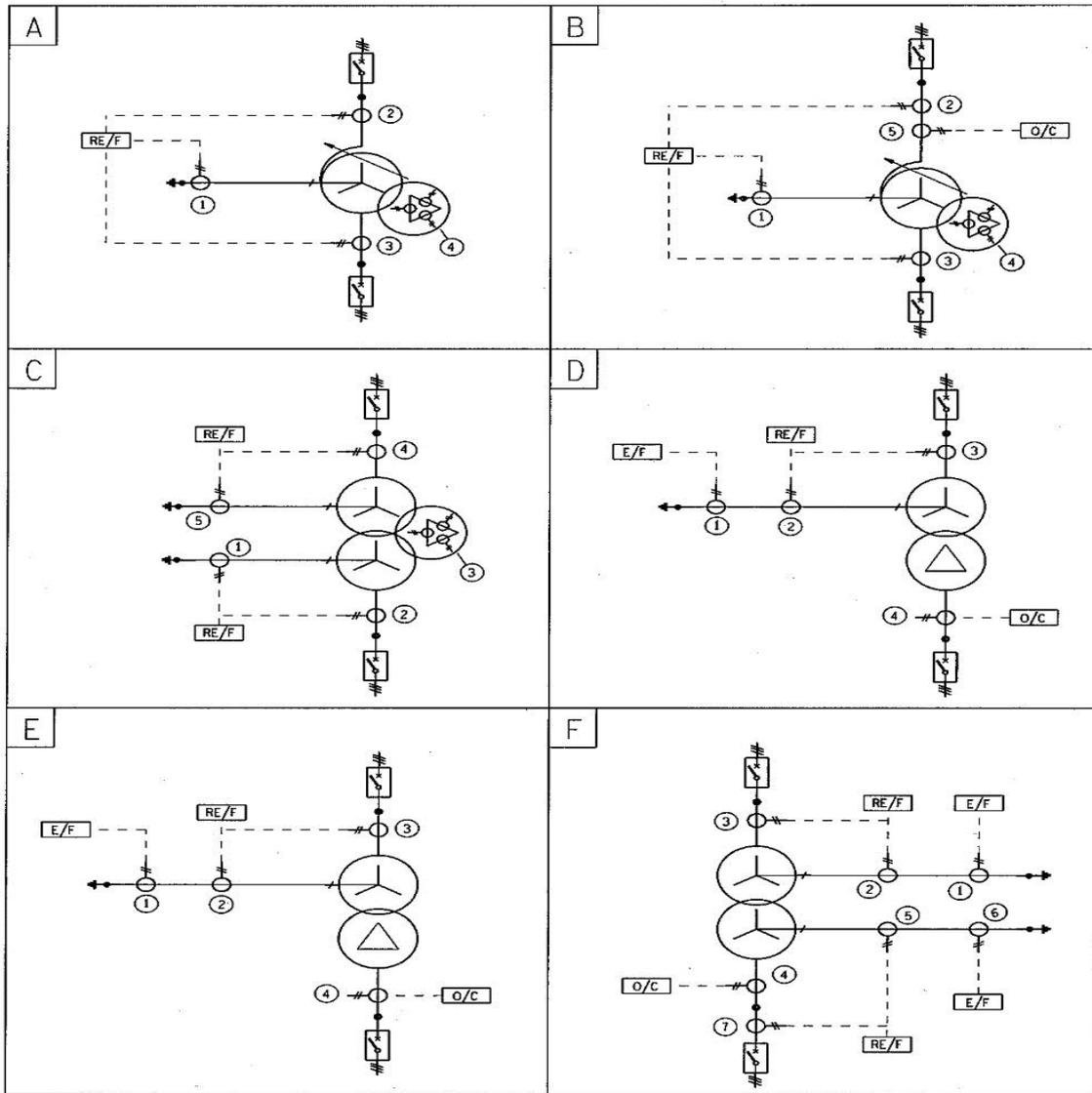


ESKOM DRG No 0.54/4369 sh 6

**Figure 11: CT Terminal Markings for 3 winding auto transformers**

**ESKOM COPYRIGHT PROTECTED**

When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.



**Figure 12: Built-in Current Transformers**

**Table 11: For Autotransformers of 13B and 20MVA**

TRANSFORMER		IN-BUILT CURRENT TRANSFORMERS RATIOS		
kV	MVA	Cores 1, 2, 3(class TPS/X)	Core 4(class 10p10)	Core 5 (class10P10)
132/44	20/5	400/1	200/1	100/1
88/44	20/5	400/1	200/1	200/1

**ESKOM COPYRIGHT PROTECTED**

**Table 12: In-built current transformers for 13D (Star/delta transformers up to 20 MVA)**

Transformer		In-built current transformer ratios		
kV	MVA	Core 1	Core 2, 3	Core 4
132/33	20	200/1	300/1	400/1
	10	200/1	300/1	200/1
132/22	20	200/1	300/1	600/1
	10	200/1	300/1	300/1
132/11	20	200/1	300/1	1200/1
	10	200/1	300/1	600/1
132/6.6	20	200/1	300/1	2400/1
	10	200/1	300/1	1200/1
88/44	20	100/1	300/1	300/1
88/33	20	100/1	300/1	400/1
	10	100/1	300/1	200/1
88/22	20	100/1	300/1	600/1
	10	100/1	300/1	300/1
	5	100/1	100/1	200/1
88/11	20	100/1	300/1	1200/1
	10	100/1	300/1	600/1
	5	100/1	100/1	300/1
88/6,6	20	100/1	300/1	2400/1
	10	100/1	300/1	1200/1
	5	100/1	300/1	500/1
66/22	20	200/1	300/1	600/1
	10	200/1	300/1	300/1
	5	200/1	100/1	200/1
66/11	20	200/1	300/1	1200/1
	10	200/1	300/1	600/1
	5	200/1	100/1	300/1
	2,5	100/1	100/1	200/1
66/6.6	20	200/1	300/1	2400/1
	10	200/1	300/1	1200/1
	5	200/1	100/1	600/1
44/22	20	100/1	300/1	600/1
	10	100/1	300/1	300/1
	5	100/1	300/1	200/1
44/11	20	100/1	300/1	1200/1
	10	100/1	300/1	600/1
	5	100/1	300/1	300/1
	2,5	100/1	300/1	200/1
44/6,6	20	100/1	300/1	2400/1
	10	100/1	300/1	1200/1
	5	100/1	100/1	600/1
	2,5	100/1	100/1	300/1

**NOTE:** For these ratings the 100/1 ratio has been selected as the lowest ratio to avoid wound primary current transformers on the basis that modern low burden protection can be set with adequate sensitivity using these current transformers.

**Table 13: Built-in CTs for 13A configuration**

TRANSFORMER		IN-BUILT CURRENT TRANSFORMER CORES	
kV	MVA	Cores 1, 2, 3 (class TPS/X)	Core 4(Class 10P10)
400/275	800/40	2400/1	1600/1
	400/40	1000/1	1600/1
400/220	630/40	2400/1	1600/1
	315/40	1000/1	1600/1
400/132	500/40	2400/1	1600/1
	250/40	1600/1	1600/1
	125/20	1000/1	800/1
275/132	500/40	2400/1	1600/1
	250/40	1600/1	1600/1
	125/20	1000/1	800/1
275/88	315/40	2400/1	1600/1
	160/20	1600/1	800/1
	80/10	1000/1	400/1
220/132	500/40	2400/1	1600/1
	250/40	1600/1	1600/1
	125/20	1000/1	800/1
220/66	160/20	2400/1	800/1
	80/10	1600/1	400/1
	40/10	400/1	400/1
132/88	315/40	2400/1	1600/1
	160/20	1600/1	800/1
	80/10	1000/1	400/1
132/66	80/10	1600/1	400/1
	40/10	1000/1	400/1
132/44	80/10	1600/1	400/1
	40/10	1000/1	400/1
88/44	80/10	1600/1	400/1
	40/10	1000/1	400/1

**Table 14: Built-in current transformers for star-delta units above 20MVA (13D)**

Transformers		In-built current transformer ratios		
kV	MVA	Core 1	Cores 2,3	Core 4
132/33	80	300/1	500/1	1 600/1
	40	200/1	300/1	800/1
132/22	40	200/1	300/1	1 200/1
132/11	40	200/1	300/1	2 400/1
88/44	40	200/1	400/1	600/1
88/33	80	300/1	500/1	1 600/1
	40	200/1	400/1	800/1
88/22	40	200/1	400/1	1200/1
88/11	40	200/1	400/1	2 400/1
66/22	40	200/1	400/1	1 200/1

**ESKOM COPYRIGHT PROTECTED**

**Table 15: Built in Current Transformers for star-star transformers (13F)**

Transformer		In-built current transformer turns ratio				
kV	MVA	Core 1	Cores 2 & 3	Core 4	Cores 5	Core 6
132/11	40	200/1	200/1	2400/1	2400/1	2400/1
	20	100/1	100/1	1200/1	1200/1	1200/1
66/11	40	400/1	400/1	2400/1	2400/1	2400/1
	20	200/1	200/1	1200/1	1200/1	1200/1
33/22	5	100/1	200/1	150/1	200/1	150/1
33/11	20	400/1	800/1	1200/1	1600/1	1200/1
	10	200/1	400/1	600/1	800/1	600/1
	5	100/1	200/1	300/1	400/1	300/1
	2,5	100/1	200/1	200/1	200/1	300/1
33/6,6	10	400/1	800/1	1200/1	1600/1	1200/1
	5	200/1	400/1	600/1	800/1	600/1
	2,5	100/1	200/1	300/1	400/1	300/1
22/11	20	400/1	800/1	1200/1	1600/1	1200/1
	10	200/1	400/1	600/1	800/1	600/1
	5	100/1	200/1	300/1	400/1	300/1
	2,5	100/1	200/1	200/1	200/1	300/1
	1.25	100/1	200/1	100/1	200/1	300/1
22/6,6	10	200/1	400/1	1000/1	1000/1	800/1
	5	100/1	200/1	500/1	500/1	400/1
	2,5	100/1	200/1	300/1	400/1	200/1
33/3,3	5	100/1	200/1	1000/1	1000/1	300/1
	2,5	100/1	100/1	500/1	500/1	400/1
22/3,3	5	100/1	200/1	1000/1	500/1	400/1
	2,5	100/1	200/1	500/1	500/1	400/1

**Table 16: Built-in current transformers (Class TPS core details)**

TURNS RATIO Np/Ns	CLASS "X" CORE SPECIFICATION		
	Im (mA) (MAX)	Vk(Volts) (MIN)	Rs(Ohms) (MAX)
1/ 100	500	150	0,4
1/ 200	500	200	0,8
1/ 300	330	300	1,2
1/ 400	250	400	1,6
1/ 500	200	500	2
1/ 600	170	600	2,4
1/ 800	125	600	3,2
1/1000	100	650	4
1/1200	83	650	4,8
1/1400	71	650	5,6

**ESKOM COPYRIGHT PROTECTED**

	CLASS "X" CORE SPECIFICATION		
URNS RATIO Np/Ns	Im (mA) (MAX)	Vk(Volts) (MIN)	Rs(Ohms) (MAX)
1/1600	63	700	5,6
1/2000	50	700	8
1/2400	42	750	9,6
1/3000	35	780	12
1/4000	25	860	16
Im = CT excitation current Vk = knee-point voltage			
The knee-point of the excitation curve is the point where an increase of 10 % of the secondary emf results in a 50 % increase of excitation current.			
Class TPS-to meet requirements of the latest revisions of NRS 029-CT's rated for AC voltages from 3,6-420Kv as well as IEC 60044 Part 1 and Part 6.			

### 3.18 Transformer Testing

#### 3.18.1 Active Part and General testing

All transformers shall be tested to the latest IEC requirements. Special requirement is however applicable for the switching impulse test. Rated switching impulse withstand voltages are assigned to the winding with highest Um. Test stresses in other windings are proportional to the turns ratio and are adjusted by selecting appropriate tappings to come as close as possible to the assigned value in Table of the addendum. The switching impulse stresses in other winding shall be limited to approximately 80% of the assigned lightning impulse withstand voltages at those terminals. Lightning impulse shall include chopped wave testing, unless it is otherwise stated.

The Employer shall indicate in the schedules AB the required tests and the classification thereof. Eskom representative shall participate in the testing of each transformer as shall be indicated in the applicable document viz, Inspection and test plan, Product/Process Quality Plan or any equivalent. It is required that for the non-South African factories, the notification of such tests be given in writing at the latest of 10 weeks before date of testing. This date will be a preliminary date that can change by a few days as the time gets closer.

After a successful testing, it is required that the Contractor carries out an internal inspection on each unit and where it is possible, and shall confirm through a report to the Employer that he is satisfied that all is still in order. This inspection shall be carried out when a transformer is in a cold condition. The transformer can only be shipped or transported once an official release from Eskom has been obtained by the Contractor in writing.

#### 3.18.2 Transformer Tank Testing

##### 3.18.2.1 Tank and fittings

Each transformer tank complete with all the fittings and attachments normally in contact with the transformer oil, and filled with oil with a viscosity not greater than that specified in 32-406, shall withstand, for 24 h, at room temperature, without leakage, a hydraulic pressure that is not less than 35 kPa above the maximum working pressure at every point in the transformer.

##### 3.18.2.2 Pressure relief valve

One pressure relief valve of each make and type, set to open at the specified pressure, shall withstand, for 24 h, at room temperature, an internal pressure of oil of 20 kPa above the maximum working pressure at the position of the valve, without leakage.

**3.18.2.3 Internal hydraulic pressure withstand**

One tank, radiators and oil conservator of each type and size shall be subjected, for 1 min, to an internal hydraulic pressure equal to 70 kPa or the maximum operating pressure plus 35 kPa whichever is the greater, without suffering permanent deflection, measured after a first application greater than the amounts specified in the schedules of this specification.

After a second application no further permanent deflection shall be measurable.

**3.18.2.4 Vacuum withstand**

One tank, radiators and oil conservator of each type and size, both empty of oil, shall be subjected, for 1 min, to an absolute internal pressure of 1,5 kPa, against atmospheric pressure at sea level on the outside, without suffering permanent deflection, measured after a first application greater than the amounts specified in Table 14 of this specification. After a second application no further permanent deflection shall be measurable.

**NOTE:** The above two tests may, by agreement, be combined.

**Table 17: Maximum permanent deflection of steel tank panels between stiffeners**

Maximum permanent deflection (mm)	Major dimension of fabricated assembly (mm)
16	> 3 000
14	> 2 700 ≤ 3 000
12	> 2 300 ≤ 2 700
10	> 2 000 ≤ 2 300
8	> 1 650 ≤ 2 000
6	> 1 300 ≤ 1 650
4	> 950 ≤ 1 300
3	> 750 ≤ 950
2	> 600 ≤ 750
1	> 450 ≤ 600
0	≤ 450

**3.18.2.5 Dye-penetration testing**

To avoid leaks, dye-penetration testing shall be done prior to corrosion proofing of the tank and other manufactured fittings after any welding.

**3.19 Transformer Transportation**

**3.19.1 General Conditions**

It shall be the *Contractor's* responsibility to make all arrangements for transport with the appropriate authorities. Eskom will only accept delivery from the *Contractor* on site. It shall be the *Contractor's* responsibility to co-ordinate the arrangements for all stages of the transport of the transformer from the manufacturer's works to site, including trans-shipping where necessary. Where off-loading is required, all apparatus, materials and packages shall be addressed to the *Contractor*, who shall take delivery of the same at site.

The dimensions of the transformer 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 max transport dimensions are limited to the following, otherwise indicated in the relevant purchase order.

Height 5 000 mm

Width 4 300 mm

Length 10 500 mm

All metal blanking plates and covers which are specifically required to transport the particular transformer, shall be considered part of the transformer and be handed over to Eskom after completion of erection. A listing of all these items and relevant drawings shall be included in the manuals, to enable Eskom to have the plates manufactured if required. The dimensions and quantity of each item required for transport shall be on the drawings. Where the supply of oil is included in the contract and where transport weight limitations permit, the transformers shall be transported with sufficient oil to cover the core and windings during all transport and storage conditions. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not applicable, the transformer shall be maintained continuously under positive pressure of dry air of at least 20 kPa during transport and storage until final installation. The pressure and the temperature at the time of filling shall be documented as part of the quality system. A pressure gauge, suitably protected shall be fitted to each transformer to facilitate checking of gas pressure during transit and on site. The pressure gauge shall be situated at ground level not higher than 1.5 m. The gauge, pipework and other accessories shall be protected against transportation and handling damage. The pressure gauge shall be clearly visible for routine checks without having to remove protective covers. A non-return valve shall be provided at the point of entry into the transformer to prevent loss of dry air due to pressurising equipment failure. The dry air cylinder shall be located at ground level fixed to the side of the main tank.

The total duration that the unit is filled with dry air shall be limited to six months where after the transformer must be appropriately processed and filled with oil as for service. Every precaution shall be taken to ensure that the transformer arrives at site in a satisfactory condition so that after proper oil processing and filling it may be put into service without the necessity for extensive drying out.

Full details of the proposed method of transport shall be submitted for approval.

The costs of any necessary extensions and/or improvements to existing facilities for transporting to site and escort and permit fees shall be included in the *Contractor's* prices.

### **3.19.2 Impact Recorders**

The supplier shall attach to each transformer an impact recorder, which shall be capable of recording shocks in three axes. One impact recorder shall be mounted inside the tank on the active part and the other one on the tank wall. This shall remain the property of the *Contractor* and will be returned by the purchaser with transportation charges collect. The chart, or three copies of it, shall be delivered to Eskom.

The *Contractor* shall inspect the impact recorder charts before unloading, and provide a report to the *Employer*.

### **3.19.3 Testing During Transport**

Procedure 240-56030661 Requirements for transportation and movement of large electrical equipment shall be used.

The Contractor shall perform SFRA test and Core Insulation Resistance Test (500 V DC for one minute) during the following transport stages:

- a) At the factory before loading into the transport
- b) Alongside ship prior to loading
- c) Before offloading from ship
- d) After offloading from ship when on ground (in case of not loading direct to the road transport)
- e) After loading on road transport, before start moving (Insulation resistance only for d) and e))
- f) On arrival at destination port before loading for road transport
- g) On arrival at site after final positioning

All test results shall match the original factory test results for acceptance. The results of the above tests shall be documented, signed off as part of the quality process and included in the transformer manuals, both hard copies and soft copies where applicable.

### **3.19.4 Sea Transport**

The *Contractor* shall make the necessary arrangements for suitable slings or lifting tackle to be available for off-loading at the quay-side and may make use of the equipment provided under the contract, on the condition that it is handed over to Eskom in good order.

### **3.19.5 Road Transport**

The transport arrangements shall include any necessary extensions and/or improvements to road routes, bridges, and civil works, and also the assurance that any abnormal loads comprising the transformers, their transporters, ancillary apparatus and plant and equipment required for erection shall pass without obstruction throughout the selected route.

### **3.19.6 Transport support brackets**

Attention is drawn to the necessity of receiving approval from the transport contractor of the design and spacing of transport support brackets to avoid overstressing of the relevant trailer carrying beams.

## **3.20 Erection**

### **3.20.1 General**

Erection shall include off-loading, installation, full assembly, oil treatment and testing of the transformer.

All equipment provided for erection shall be removed from site when erection is completed and the site cleaned of any debris and oil spillage.

### **3.20.2 Foundation Tolerances and Transformer Layout Details**

Foundation tolerances and layout details shall be submitted for prior approval by Eskom. When the foundation has been constructed, before installation begins, the *Contractor* or his appointed representative shall inspect and confirm the suitability of it to handle the intended transformer.

### **3.20.3 Site Installation**

Site installation shall be performed by the OEM.

All installation projects shall comply with the OSH Act No. 83 of 1993 and ORHVS.

Before commencement of site / store installation a Scope of Work shall be compiled and agreed upon between the OEM and the *Purchaser*. Compiling of the SOW shall be the responsibility of the *Contractor*. The requirements of the Eskom document 240-56062726 *Standard for Intrusive work and Oil filling, under vacuum of transformers and reactors on site* shall be the minimum requirements for handling the transformer during works on site. OEM requirements that are betterment of these requirements will be welcomed. An internal inspection, where possible, will be done by an Eskom employee at the completion of all the intrusive work to ensure that there is no risk when the unit returns into service. This activity does not relieve the supplier/ *Contractor* from his obligation to provide a risk free unit to Eskom.

### **3.20.4 Functional Tests**

Functional tests shall be done on site after complete erection to verify that all the systems are working in harmony. These tests shall include but are not limited to

- Fan and oil pump direction and setting of overload protection relays.
- Correct operation and indication of tap changers.

**ESKOM COPYRIGHT PROTECTED**

- All valves in service position.
- Functional test for all alarm and tripping contacts.
- Pump start not tripping buchholz
- Cooling system philosophy

### **3.20.5 Electrical Tests According to IEC**

The onsite testing shall include, but not limited to, the:

- Voltage ratios on all winding sets, tap positions and on all phases
- Impedance test at all tap positions
- Vector group
- Three-phase 380 V magnetising currents
- Winding insulation test – minimum 5kV
- Core insulation test (500 V DC for 1 minute)
- CT polarities, function and insulation
- Fan- and oil pump motor insulation test
- Control/power cabling insulation (minimum 1 kV)
- Tap changer continuity test
- Winding & bushings insulation integrity test (Doble M4000 instrument)
- SFRA after final assembly and oil filling (Doble M5000 instrument)
- Zero sequence impedance

All the required tests shall be indicated in the relevant ITP or PQP document which shall be finalized between the *Employer* and the *Contractor* before installation commences.

## **3.21 Condition Monitoring**

Condition monitoring is a very valuable tool for transformer life management. For a smart grid network it is important that transformer visualization is achieved at its best. It is preferred that all the condition monitoring signals from the transformer and from the components are available from one central point right at the transformer. These signals will then be sent to appropriate points where the operator can see them as well as to the APM tool for automated life assessment. The communication channels must comply with the requirements of IEC61850.

### **3.21.1 Gas Analysers**

An option for a gas analyser to be provided & installed together with the transformer should be given on the tender return for all transformers of 80MVA or higher and highest voltage above 132kV, and it should meet all the requirements of 240-64917195. Two valves shall be provided, one as an intake from the transformer tank to the gas analyser and the other as the outlet back to the transformer from the gas analyser. The oil intake shall be from the top oil expanse level, with the pipe routed inside the main tank against the tank wall to the intake valve. These valves shall be 25mm double flanged gate valves and be at ground level (1.5m or below).

For transformers with power rating below 80MVA and with highest voltage of 132kV and below, only the valves will be required but not the gas analyser itself.

### **3.21.2 On line drying system**

An option for an on line drying system to be provided & installed with the transformer must be given on the tender return, it should meet all the requirements of 240-59083215. Provision for online dryer system shall be made with two gate valves installed for supply and return oil with appropriate locations for effective drying. The valves shall be 25mm double flanged gate valves full flow design. A method of anti-vibration shall be provided for mountings of online dryers (moisture removers). This requirement is fully applicable only to transformers with power rating of 80MVA and above plus with a highest voltage of above 132kV.

For transformers with power rating below 80MVA and with highest voltage of 132kV and below, only the valves will be required but not the online dryer itself.

### **3.21.3 Fibre optic temperature sensors**

Transformers shall be provided with fibre optic temperature sensors as indicated in the AB schedules. The vendor must provide with the transformer the fibre optic extensions and the signal conditioning device to present the temperatures as 4-20mA signals to be connected to the data concentrator mentioned above or directly to the Eskom protection panels. These should be terminated in the transformer marshalling kiosk.

### **3.21.4 General**

The condition monitoring station should have a life span matching that of the transformer and must not introduce more frequent maintenance requirements.

All bidders shall provide a proposal for a condition monitoring system for active part, bushings, and on-load tap changers.

## **3.22 Documentation**

Drawings, Photographs, Instruction Books, and Test Reports-As listed below shall be sent to Eskom. All drawings shall include the following information: Eskom, Serial Number, Design Fault Levels, gravitational force design limits, Power Ratings, Voltage Ratio, and Eskom Purchase Order Number.

Five (5) copies of outline, nameplate, base, bushings, schematics and complete wiring diagrams, terminal block arrangement drawings showing physical locations with dimensions are to be submitted for approval. The nameplate, schematic and wiring diagrams shall be submitted one month after the receipt of Purchase Order. The remaining drawings shall be submitted together a minimum of 8 months prior to delivery. The base drawings shall indicate the dimensions, jacking points, load bearing surfaces, and approximate total weight to facilitate the customer's foundation design. *Purchaser* shall return one copy of each drawing with comments or approval. All approved drawings are to be submitted in paper and in a CD. A late drawing penalty shall be assessed according to the schedule A of the specification.

Four (4) Photographs of the core and coil assembly shall be taken at such angles as to provide the maximum of design and construction information for records.

Quality Control Information-after an order has been, a copy of the manufacture quality control manual will be provided upon request to Eskom for their review.

One (1) complete transformer manual shall be delivered with the transformer. The manual shall be easily accessible and protected from moisture / water damage during transport and storage. This manual shall be used for erection and commissioning purposes and shall include the factory test results and diagrams.

A further (4) manuals and one (1) electronic copy on CD shall be delivered not later than 14 days after completion of all commissioning tests. This manual shall include the electrical results from the commissioning testing carried out on site as well as testing done during transport. All oil sample results from tankers and main tank shall also be included. In the CD an original file in the original format for the SFRA test shall be included for the future reference purposes.

All drawings are to comply with the Eskom drawing standard TPC 41-246 .

### **3.23 Adjudication of Tenders**

#### **3.23.1 Failure Rates, Reliability and Manufacturing Experience of *Contractors***

The failure rate, reliability and manufacturing experience of the transformers, reactors and phase-shifters supplied from the transformer factory from which the Employer's transformer(s) will be sourced during the contract duration are to be provided in Schedules A&B. The statistical data of failure rates and manufacturing experience reflects the experience of the factory from which the Employer's transformers will be sourced and not the company group.

The factory failure rate, in service failure rate, manufacturing and testing experience statistical data is used during the tender evaluation.

#### **3.23.2 Population**

The population of transformers to be considered in the calculations of the in failure rates is all the transformers and reactors with a rating above 10 MVA(r) that was manufactured at the factory over the past 10 years, irrespective of who was the customer.

#### **3.23.3 Factory Failure**

A failure in the factory is defined as a situation arising where major opening/dismantling of the transformer is required to correct a failure caused during factory testing. Thus having to drop the oil, un-tank or remove the top yoke in order to repair a failure or defect caused during testing is defined as a factory failure.

#### **3.23.4 Factory Failure Rate**

The factory failure rate (one-year) is defined as the ratio of the number of factory failures to the population of transformers, reactors and phase-shifters manufactured over a one-year period. A minimum of 10 years data must be provided in the tender documentation. The factory failure rate (five-year) is the rolling average of the factory failure rates (one year) taken over a five year period. Failures during testing of special transformers or new developments may be excluded from this statistics. Eskom allows for a maximum of 3% factory failure rate per annum. Eskom reserves the right to audit these figures at any given point. If an approved supplier's performance during the contract period deteriorate and is above this 3% figure, Eskom may terminate placing further orders at any given time.

#### **3.23.5 In-service Failure**

An in-service failure is defined as a forced outage failure plus a scheduled outage failure as defined in IEEE 57.117.1986. Further to the definition in IEEE 57.117.1986 the failure is only regarded as an in-service failure if the transformer had to be removed from its bay for the defect to be repaired.

#### **3.23.6 In-service Failure Rate**

The in-service failure rate (one-year) is defined as the ratio of the number of in-service failures to the population of transformers, reactors and phase-shifters accumulated service time over a one-year period. A minimum of 10 year's data must be provided in the tender documentation. The in-service failure rate (five-year) is the rolling average of the in-service failure rate (one year) taken over a five year period.

#### **3.23.7 On Time Delivery**

The On-Time Delivery Rate is defined as the number of the units that were delivered on or earlier than the agreed contractual date. This shall be calculated on ex-works.

### 3.23.8 On Time Delivery Rate

The On-Time Delivery Rate is defined as the number of the units that were delivered on or earlier than the agreed contractual date over the number of units delivered over the period of 12 months. Eskom requires an on time deliver rate of  $\geq 95\%$ . If an approved supplier's performance during the contract period deteriorate and is below this 95% figure, Eskom may terminate placing further orders.

### 3.24 Quality Assurance

The official Eskom Standard for "Quality Assurance Requirements for the Procurement of Assets, Goods and Services" is TST41-168.

Eskom or the representative reserves the right to inspect the materials, equipment manufacture and witness the tests. The manufacture shall allow access to the Eskom representative without any hindrance or additional charges to the Eskom. The Manufacture shall notify Eskom at least 10 weeks prior to commencement of the tests.

The Manufacturer shall submit a schedule within four weeks of the award of the contract.

This shall show dates for:

- Engineering
- Submit transformer Outline drawing to allow foundation design
- Submit Drawings for approval
- Supply of Instruction Manuals
- Purchasing and Delivery of Components
- Manufacturing and Assembly
- Testing of Transformer
- Shipment to Site

If a unit fails under test, the supplier will officially notify the employer in writing within 24 hrs of the failure, the *Contractor* will set up a meeting with the employer to discuss and agree on a way forward. The *Contractor* will supply a written report on the failure within 30 days of the failure.

### 3.25 Loss Evaluation

All losses will be capitalised using the formula below when adjudicating the tenders.

#### 3.25.1 Guaranteed losses

The manufacture shall guarantee the following losses for each transformer:

- No-Load loss in kilowatts at rated voltage and rated frequency.
- Total losses in kilowatts at rated output, rated voltage and rated frequency
- Auxiliary losses – 50% of the total of the auxiliary supply load to be added to the load losses to give total load losses.
- Load losses shall be evaluated for MVA rating as specified in schedule A of the rating for each transformer.
- Transformer losses determined under tests shall be corrected to 75°C. No-Load loss shall not be corrected.

The transformer cost shall be evaluated as follows:

$$\text{Evaluated Cost} = P + [A * E] + [B * L]$$

**ESKOM COPYRIGHT PROTECTED**

---

Where: P = Transformer tender price  
A = Evaluated Cost of No-load loss per kW  
B = Evaluated Coast of Load loss per kW  
E = No-load loss in kW  
L = Load loss in kW

No load losses A (R/kW)	Load losses B (R/kW)
R63 000	14 000

### 3.25.2 Non Conformance on losses

If the measured no-load losses and/or load losses exceed the IEC tolerances Eskom reserves the right to reject the transformer.

If the no-load losses and/or load losses measured exceed the guaranteed value then the incremental cost of loss evaluation shall apply as a penalty multiplied by the factor 4.

If the measured temperature rises exceed the guaranteed values, the highest deviation in degrees (top oil rise, average winding rise, hot spot rise) will be penalised. For each 1°C exceeding the guaranteed value, 1.5% of the transformer purchase price will be penalised. If the deviation is more than 5°C the transformer will be rejected or countermeasures have to be implemented to mitigate against the deviation.

There will be no credit or payment of premium if actual values are better than guaranteed values.

### 3.26 Training of Purchaser's staff

The *Contractor* shall propose an appropriate and cost effective training program for the operating, maintenance and engineering staff of the *Purchaser*. This shall include the nomination of an appropriate venue and duration of the training period.

If the proposed training involves travelling and accommodation and subsistence away from the *Purchaser's* home country, the *Purchaser* shall be responsible for all the direct travelling and subsistence expenses involved for a maximum number of four (4) of the *Purchaser's* staff.

The *Purchaser* shall have the option at his own expense, to add a further two (2) staff members.

The *Contractor* shall provide a complete and detailed broken down schedule of the training events but is not expected that formal training should last less than 5 consecutive working days nor more than 10 consecutive working days.

The *Contractor* shall advise the *Purchaser* of the minimum pre-requisite level of education required for the employees to successfully participate in the training programme.

Over and above any formal training, the program shall include as a minimum, an on-site component covering:

- on site preparation for transportation
- loading and off-loading procedure and precautions
- Installation procedures and precautions
- functional testing of tap changers, sensors and protective devices
- vacuum treatment, drying filtering and impregnation
- general maintenance and in-service inspections and checks
- all electrical testing of the completed system to ensure that it is ready for service

Special emphasis shall be placed on quality control processes and the maintenance of the oil and insulation system to keep it in the best possible condition to ensure maximum life for the transformer, as well as the underlying theoretical aspects.

These training requirements shall form part of the hand over for each installation.

The *Contractor* shall make available in electronic form training material that is adequate for the *Purchaser* to execute all handling and maintenance necessary in the future. The copy of such material will form part of the manual.

### **3.27 Local Support**

Potential transformer suppliers shall have an established local technical support base. A Supervisor from the *Contractor* shall be available on site within 24 hours of notification of an emergency by the *Purchaser*.

The supplier shall be fully equipped to attend to emergencies and equipment failures within the guarantee period of the transformer.

#### **3.27.1 Local Support's Requirements**

It is required that the local technical support cater for:

- Emergency breakdowns
- Failure investigations
- Maintenance & breakdown spares
- Operational enquiries
- Training

### **3.28 Safety on Transformers**

Safety is very important in Eskom, and this includes when working with transformers. It is important therefore that all transformers designed and manufactured for use in the Eskom network take into consideration the safety needs. This includes but not limited to

- Safety of people working on a transformer, especially on top of the tank. The employees and the contractors should be able to do so with no risk of falling.
- Safety of the people working inside the transformer (e.g. making connections or doing inspections). A worker must be able to safely execute this with no risk of falling as reasonably as possible.
- Safety of people around the transformer when in operation. There must be no possibility of inadvertent contact with live apparatus while on ground level and where this is not achieved, it must be highlighted to the *Purchaser* at the tendering stage.
- Tank designs and components arrangement should be such that as practically reasonable as far as possible, tank rupturing is avoided.

The technology and the materials used in the construction of transformers must support the safety drive of Eskom.

## **4. Authorisation**

<b>Name and surname</b>	<b>Designation</b>
Danie Odendaal	Senior General Manager - Engineering
Prince Moyo	General Manager – Power Delivery Engineering
Dhiraj Bhimma	General Manager – Power Generation Engineering

<b>Name and surname</b>	<b>Designation</b>
Bheki Ntshangase	Senior Manager – HV Plant Engineering SCOT Plant Study Committee
Sidwell Mtetwa	SCOT Transformer and Reactors Care Group
Shamiel Jappie	Power Station Manager – Arnot
Christo Spammer	Power Station Manager – Camden
Anthony Kuzelj	Power Station Manager – Duvha
Gersh Bonga	Power Station Manager – Grootvlei
Maserati Lesolang	Power Station Manager – Hendrina
Christopher Nani	Power Station Manager – Kendal
Jabulane Mavimbela	Power Station Manager – Kriel
Riedewaan Bakardien	Power Station Manager – Koeberg
Rudi van der Wal	Power Station Manager – Komati
Thomas Conradie	Power Station Manager – Lethabo
Tebogo Lekalakala	Power Station Manager – Majuba
Rhulani Mathebula	Power Station Manager – Matimba
Bruce Moyo	Power Station Manager – Matla
Avi Singh	General Manager – Peaking
Ryno Lacock	Power Station Manager – Tutuka
Thomas Tshikalange	Grid Manager – Apollo HVDC CS
Victor Shikoane	Grid Manager – Central
Mphiliseni Mthimkhulu	Grid Manager – Eastern
Lenah Mothata	Grid Manager – Free State
Judith Malinga	Grid Manager – North Eastern
Nozuko April	Grid Manager – North Western
Boitumelo Gcwabaza	Grid Manager – Northern
Danie Du Plessis	Grid Manager – Southern
Kooben Munsamy	Grid Manager - Western
Monde Bala	General Manager – KwaZulu Natal OU
Collin Reddy	General Manager – Eastern Cape OU
Phil Khumalo	General Manager – Free Sate OU
Des Govender	General Manager – Gauteng OU
Agnes Mlambo	General Manager – Limpopo OU
Des Govender	General Manager – Mpumalanga OU
Sibu Mvana	General Manager – Northern Cape OU
Azwi Mamanyuha	General Manager – North West OU
Alwie Lester	General Manager – Western Cape OU

**ESKOM COPYRIGHT PROTECTED**

## 5. Revisions

Date	Rev.	Compiler	Remarks
Feb 2018	2	NS Mtetwa	<p>On paragraph 3.4.8, the requirements for short circuit withstand capability were revised to include thin conductors, and merged with 3.6.6. of the previous revision. 3.6.6 was then deleted.</p> <p>Table 4 was added on paragraph 3.6.</p> <p>Paragraph 3.8.9.2 revised to include protection at the loss of oil in the tap changer conservator.</p> <p>On paragraph 3.9, the tap changer requirements updated to align with IEC revised standard by eliminating the flag cycle requirement. Furthermore, oil type tap changer was kept as an alternative technology.</p> <p>Paragraph 3.9.8.4 revised.</p> <p>Marshalling kiosk requirements revised on 3.11.2</p> <p>Requirements for cooler control expanded on 3.14.7</p> <p>paragraph 3.14.10 added to include self dehydrating breathers.</p> <p>Valves requirements for sections 3.21 revised for the online gas analyser and the online moisture remover.</p> <p>Data concentrator requirements removed on 3.21</p>
June 2014	1	NS Mtetwa	<p>This document was compiled to consolidate the requirements from the previous 3 different divisional specifications and to bring in the new requirements identified through learning since the previous documents.</p>

## 6. Development team (Working Group)

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

Lionel Jordaan	Senior Consultant (Power Generation Engineering – Engineering)
Nkosinathi Buthelezi	Senior Consultant (Power Delivery Engineering – Engineering)
Adesh Singh	Chief Engineer (Power Delivery Engineering – HV Plant)
Lester Geldenhuis	Senior Engineer (Transmission Grids)
Stuart van Zyl	Chief Engineer (Power Delivery Engineering – PTM&C)
Khayakazi Dioka	Corporate Specialist for Transformers and Reactors
Sidwell Mtetwa	Corporate Specialist for Transformers and Reactors

## 7. Acknowledgements

The Work Group (Development Team) acknowledges all the people who reviewed this document and contributed with comments and advises. Further acknowledgements go to all Eskom employees who made sure that the learnings from their various activities form part of this work, the people who compiled the divisional documents, and all the transformer experts who shared their knowledge and experience.