Eskom	Standard	Technology

Title: **STORAGE AND MAINTENANCE OF OIL FILLED TRANSFORMERS AND REACTORS, PLUS BUSHINGS AT VARIOUS SITES**

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Executive Summary

Power transformers and reactors are the most expensive and strategic important components of any power generation, transmission and distribution system. Their reliability is of paramount importance for the availability and profitable operation of such systems. A serious failure of a power transformer can generate not only substantial costs for repair, transport to the factory and financial losses due to power outage, but also consequential damage of other equipment in the substation. Therefore, Eskom has a clear incentive to assess/ inspect the actual condition of Transformer auxiliary components and maintain them during storage, with the aim to minimize the risk of in service failure due to improper storage of the transformer and its components failures in event when the transformer is moved from storage site and destined for in-service operation.

This also assists in identifying various parts against theft during storage. In the event where period of transformer storage is known immediately upon its arrival on site, it is necessary to store the transformer according to known maximum storage period and complying to storage maintenance requirements. The transformer strategic spare owner is therefore responsible for complying with transformer storage instructions and appropriate maintenance required at different intervals as per table 4 and to keep records of inspection by prescribed instructions for audit trail purposes.

1. Introduction

Power transformers and reactors are long lead time assets, i.e. they are not available off-shelf to the exact requirements of a user. In service they form a critical point in the network and in the cases where they are not able to continue in service, it is often desired to have a replacement unit (a spare) readily available. The bushings are a critical component of the transformer or reactor. Their importance of their reliability cannot be further emphasized, they are usually a long lead time item as well. Eskom keeps these items as strategic spares and it is important that they are available in a usable condition when they are required.

The purpose of this standard is to outline storage and maintenance requirements of this equipment in order to make sure that usable spares are available at all times.

2. Supporting clauses

2.1 Scope

This standard is applicable to all Eskom oil filled transformers and reactors that are in storage.

2.1.1 Purpose

To ensure that proper storage and maintenance activities are adhered to in order to keep the transformer in a good serviceable condition.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

The latest revisions of the following documents shall be read in conjunction with this standard. In case of conflict, however, this standard shall take precedence.

[1] 240-56062726: Standard for intrusive work and oil filling, under vacuum of Transformers and reactors on site

[2] 40-90319645: The management of Transmission strategic spare plant and equipment

[3] OEM: Approved inspection and Test Plan

[4] OEM Clean Working Procedures

[5] 240-56062799: Technical Specification for capacitor bushing in power transformers and shunt reactors in all Eskom Divisions

[6] 240-56062720: Oil sample point label standard

[7] TST41-1104: Standard Scope of work and work reports for preventative and condition based maintenance on transformers, reactors and On-Load tap changers in Transmission.

[8] TST41-224: Passive Fire Protection for oil-filled equipment in high voltage yards

[9] 240-94170894: Technical instruction for the management of OIP transformer bushings installed on Eskom transformers for 20 years and above.

[10] 240-122212232: Management of Draw Rod type ABB GOE bushing on Transmission Transformers

The following manufacture's procedures shall be submitted to the employer for evaluation:

- Vacuum and Oil filling under vacuum.
- Erection and Commissioning including Inspection and Test Plans.
- Guarantee conditions
- Period that transformer can remain without oil
- Maintenance procedure.

2.2.1 Normative

[1] OEM Instructions: Original Equipment Manufacturers Operating and Maintenance Instructions as provided by the OEM in the Manual_

[2] IEC60156:1995: Insulating liquids — Determination of the breakdown voltage at power frequency - Test method.

[3] IEC 60422:1989: Supervision and maintenance guide for mineral insulating oils in electrical equipment

[4] IEC 60296: Fluids for electro-technical applications – unused mineral insulating oils for transformers and switchgear

[5] 240-75661431 – Mineral Insulating oils (uninhibited and inhibited) Purchase, management maintenance and testing.

[6] TPC41 -1088 : Minimum Safety Requirements And Risks Assessment When Doing Internal Inspections On Oil Filled High Voltage Equipment.

[7] ESP 32-136, Construction Safety, Health, and Environmental Management.

[8] SANS 555:1985: Mineral insulating oil for transformers and switchgear (uninhibited).

[9] ESKASAAC2: Management of polychlorinated biphenyls (PCB).

[10] TBP41-3661 Life Cycle Management Plan for Power Transformers and Reactors Transmission approved Rotek Scope of Work and Inspection and Test Plan

[11] NRS 079-2:2006. Application guidelines for the management of insulating oil used in the electrical supply industry

[12] ISO 9001:2000: Quality Management Systems

[13] ISO 14000: Environmental Management Systems

[14] EEGE1001: Rotek Engineering — Utilizing Industrial dehumidifiers for intrusive transformer maintenance

[15] EQH — 1008: Rotek Engineering — Work in confined spacers

[16] EC-ST-F-18: Rotek Engineering — Internal inspection of a transformer

[17] ET-OP-F-01: Rotek Engineering — Evacuating transformer and oil filling on site

[18] ORHVS: Operating regulations for high voltage systems

[19] TPC41 — 140: Secondary plant commissioning of transformers and reactors

[20] EC-ST-F-02: Rotek Engineering- Oil filling of conservator tanks fitted with flexible air-cell

2.2.2 Informative

[21] 240-56227424 Rev 1 Standard for commissioning of Power Transformers — Generation

2.3 Definitions

2.3.1 General

For the purpose of this document, the following definitions apply except in the places where it stated.

Definition	Description
Authorised	A person who is trained and has been proven competent to carry out transformer maintenance in terms of this standard.
Long term Storage	Refers to a period of longer than 6 months or no known specific time.

Definition	Description
Short term Storage	Refers to a period of 6 months or less
Breathers	A breather is a device fitted to the transformer filled with a drying agent (like silica gel) to absorb moisture from the air flowing through it
Check list	It is a handy template that one can use to record the condition of each plant. They vary from one to the other depending on the maintenance involved.
Buchholz relay	A protective device, fitted to a transformer or reactor, that is activated by the release of gas in the insulating oil during internal fault conditions
Bushing	Component mounted to the transformer which transfers the internal electrical connection to the outside of the transformer
Conservator tank	Oil expansion tank fitted to a transformer to allow for oil expansion during temperature variations
Cooling system	Sets of fans & pumps used to cool down the transformer insulating oil
Diverter	The diverter is a switch which forms part of an on load tap changer used to do the switching from one tap to the other
Oil leak	Any visible sign of oil weeping or sweating will be regarded as a leak
Oil leak	Any visible sign of oil "weeping" or "sweating" or oil not in the transformer or in a suitable container will be regarded as a leak
Power transformer	Oil filled, grounded level transformer with a minimum primary voltage of 33KV and a minimum of 1 rating MVA (1000KVA). Auxiliary and or station transformers and rectors connected directly to the power transformer are considered as an integral part of the power transformer
Shunt Reactor	Oil filled reactors are almost like a normal transformer but with a gapped core and one winding connecting the line to ground in order to reduce voltage jump at switching on operation.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
OEM	Original Equipment Manufacturer
OIL	Oil Impregnated Paper
RIP	Resin impregnated Paper Bushings

2.5 Roles and responsibilities

Please refer to the latest revision of policy TPL41-426: The management of Transmission Strategic spare plant and equipment.

2.6 Process for monitoring

All actions will be recorded on TAMS and closed out

2.7 Related/supporting documents

OEM manuals and Inspection and Test Plan

3. Requirements

3.1 General

All new or repaired transformers and reactors shall be stored according to the requirements of this standard. These units shall be filled with oil, which meets Eskom's specification.

These sizes of units are shipped without oil in order to contain the transport weight within the limits. While a transformer is without oil, the oil impregnating the solid insulation tends to drain out by gravity and after a certain time the solid insulation becomes semi-dry. In order to preserve the insulation from deteriorating the units should not be stored without oil for more than 6 months after they were drained at the factory or workshop. This is a requirement in order to prevent atmospheric exposure of the solid insulation to moisture and oxygen while it is no longer fully impregnated with oil.

The spare bushings must also be correctly stored to prevent any impurities to render the bushings no longer serviceable.

3.2 Bushings Storage Requirements

Bushing storage will be done depending on the type of bushing. The following table indicates storage requirements for each type of bushing found on Eskom transformers.

Table 1: Bushings storage requirements

Short Term Storage (less than 6months)		
OIP Bushings	**RIP Bushings**	**RIS Bushings**
Bushing can be stored in horizontal position. The bushings must be kept clean and dry. Can be stored both indoors and outdoors.	Store in original crates, with transport desiccant and wrapping/container. Indoor storage only.	Can be stored in original crates at any angle and anywhere (indoor and outdoor).
Long Term Storage (more than 6months)		
Bushing must be stored in vertical position on stands. The bushing must be kept clean and dry.	Must be in crates, with oil side wrapped with an approved shrink-wrap as per 240-95331818.	Can be stored in original crates at any angle and anywhere (indoor and outdoor).

The bushings can be installed on transformers that are stored outdoors and filled with oil, irrespective of the bushing technology.

3.3 Transformers Storage Requirements

The transformer shall be stored in conditions summarized in the table 2 below. It is also important to recognize the further requirements on transformer stored as fully assembled or partially assembled as will be given in the further sections.

Table 2: Transformer insulating medium and periods

Storage method	**Insulating medium**
Short Term	Positive dry air pressure
Long term storage	The active part and tap changers should be immersed under oil as per approved oil filling standard.

3.4 Oil impregnation procedure on units that have exceeded 6 months in storage without oil

Once the storage period has been exceeded by more than six months without oil, for whatever may be the reason, it should be oil filled following the same procedure as for commissioning. The oil shall comply in all respect with the Eskom oil standard applicable at that time of filling.

The transformer should be filled under vacuum, through the bottom valve, up to the correct level above the insulation and the temperature of the oil entering the transformer shall be above 50°C. In order to facilitate the oil penetration of the insulation and absorption of any gas bubbles, a hot oil circulation shall be done at temperatures between 60°C and 70°C. This hot oil circulation shall be at least of two oil passes. The transformer will then be subject to the standing times on Table 3 before the oil can be drained for further activities.

Table 3: Allowable Impregnation time before oil draining from the tank

Rated Voltage in (kV)	Allowable impregnation time in hours before draining the oil
Below 220	12
220 - 400	48
Above 400	120

4. Transformer Storage Methods

4.1 Storage Method 1: Indoor Storage-(Partially assembled)

a) The transformer or reactor shall be filled with oil up to the conservator if the installation does allow the conservator to be erected. Alternatively they me be filled with oil up 100mm below the top cover as long as the active part remains immersed in oil to allow for oil expansion during temperature variations, which are minimal for indoor storage. A permanent transparent pipe may be used to periodically confirm the oil level. All transformers (including tap changers) and reactors shall be filled with new oil under vacuum.

b) The conservator tank, turrets, pipe-work and radiators shall be blanked off with blanking plates and gaskets to prevent moisture ingress, where possible be kept under positive pressure of dry air and equip with a pressure gauge.

c) Cooling fans shall be stored indoors and inside the original crates or equivalent/similar.

d) All temporary connections/ pipe-work shall be flanged in such a way to prevent accidental damage and oil leaks.

e) All temporary pipe work shall be of durable quality suitable for prolonged storage.

f) Tap changer diverters shall be filled with oil and connected to an anti-condensation breather typical for a transformer of an oil content of 1000 litre

g) The unit shall be free of dents in terms on the tank body. Where there are dents, the transformer shall be elevated above final storage position and the base paintwork be maintained and general touch ups done according to an approved paint and corrosion prevention specification.

h) Units can be placed directly on the floor without use of neither the malthoid nor the conveyor belt.

4.2 Storage Method 2: Outdoor Storage-(Fully assembled)

This method of storage is applicable to transformers and reactors on site, and fully assembled on a plinth for outdoor storage. This can be any of the available plinths on site for storage use and should in all respect meet the requirements of the standard *Passive Fire Protection for oil-filled equipment in high voltage yards*.

a) The transformer shall be fully erected/ assembled.

b) All bushings shall be effectively earthed with induction earths (3 kA for 1 sec) – spring loaded clamp on one end and lug with 12 mm hole on other end. The earths shall be connected from the line pin to the bushing base flange

c) Tank shall be effectively earthed to the earth mat of the substation by means of a 50mm x 3mm flat copper.

d) Blanking plates shall be stored in a locked steel cabinet; if impractical (for larger units) it must be stored in the warehouse.

e) All tests shall be performed as per specification.

f) Ac supply shall be connected in such a way that the thermostat is in the circuit to the anti-condensation heater for both the marshalling kiosk and the tap changer motor drive units.

g) The unit shall be free of dents in terms on the tank body. Where there are dents, the transformer shall be elevated above final storage position and the base paintwork be maintained and general touch ups done according to an approved paint and corrosion prevention specification.

h) Units must not sit directly on the floor but malthoid layers or conveyer belts as per the instruction 240-106023234 – usage of conveyer belts as an alternative to malthoid during storage of transformers and must be in correct thickness in the range of 6 to 10 mm.

i) 380V AC 150Amp three phase supply must be available at each storage site. Where possible this supply must be at least 300Amp.

j) Storage area must be fenced off, labelled and locked as per Eskom HV regulations.

k) Cooling fans and oil pumps shall be fitted and powered for the purpose of being run-up and checked for correct operation and excessive vibration/noise during routine inspections.

l) On line dry out equipment shall be continually fitted and connected to the supply to ensure that the moisture is extracted before it can be absorbed in the paper. In cold transformers the moisture migrates towards the paper.

m) The conservator tank shall be fitted with a rubber bag.

n) Testing shall be done as per OEM recommendation of prolonged storage of transformers and reactors

Routine maintenance on transformers and reactors shall be done in accordance with Maintenance standards of transformers in each Division.

For maintenance the following templates should be created:

- Transformer and Reactor Maintenance
- Transformer and Reactor Painting
- Transformer and Reactor Oil Sampling
- Tap Changer Oil Sampling (where applicable)
- Bushing Tan Delta Test (applicable for bushings installed on units)

Inspections on transformers and reactors shall be done in accordance with TST41-638 Standards for substation inspection sheet and per the applicable Work Orders for unit in Generation.

5. Minimum Maintenance requirements during long Term Storage

ACTION	PURPOSE	INTERVAL	RESPONSIBILITY	METHOD
Check silica gel	To prevent moisture ingress	Yearly	Supervisor	2
Check for rust	To prevent the occurrence of blister on painted surface	Yearly	Supervisor	1 & 2
Check for oil leaks, rectify and report	To prevent small leaks becoming serious and to preserve the quality of the product	Yearly	Site supervisor	1 & 2
Auxiliaries and controls	To prevent dust and moisture contamination	Yearly	Site supervisor	2
Ensure the a.c. supply to cubicles and check the operation of the anti-condensation heaters	To keep the anti-condensation heaters in operation continuously	Yearly	Site supervisor	2
Check the firmness of earth connections on bushings	To prevent capacitive charging	Yearly	Site supervisor	2
Operate(run) cooling fans and pumps	To ensure that the starting controls operate and prevent distortion of the motor bearings and shafts To prevent vibrations and failure of blades	2 yearly	Site supervisor	2
Take an oil sample from the bottom main tank and have it analysed for KV, Moisture and age assessment.	To have a history of the condition of the unit when the it is required for service	3 yearly	Site supervisor	1& 2
Record all maintenance activities done.	To keep history for future reference	When maintenance is done.	Site supervisor	All

6. Records

a) Normal maintenance records shall be kept by the Substation and Power Station on the CMMS.

b) All test reports shall be submitted to the transformer system engineer/ Specialist for verification and acceptance

7. Authorization

This document has been seen and accepted by:

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8. Revisions

Date	Rev	Compiler	Remarks
April 2017	1	NV Buthelezi	Incorporates changes to strategic spares methods and new developments. This doc supersedes TST41-626 Incorporate changes to strategic spares as the result of audit findings
Nov 2016	2	NV Buthelezi	Incorporate changes to strategic spares as the result of audit findings

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