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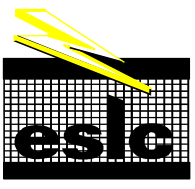
# MAINTENANCE OF ELECTRICITY NETWORKS

## Part 3: Substations

## Section 2: Power transformers, circuit-breakers, isolators and instrument transformers






This specification is issued by
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on behalf of the
User Group given in the foreword

**Table of changes**

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| | | |


Correspondence to be directed to

The NRS Projects Manager
The Standardization Section
Industry Association Resource Centre
Eskom
Private Bag X13
Halfway House 1685

Telephone: (011) 651-6832
Fax : (011) 651-6827
E-mail : nrs@eskom.co.za

Website : http://www.nrs.eskom.co.za

Printed copies obtainable from

SABS Standards Division
Private Bag X191
Pretoria 0001

Telephone: (012) 428-7911
Fax : (012) 344-1568
E-mail : sales@sabs.co.za

Website : http://www.sabs.co.za





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## Foreword

This section of NRS 089-3 was prepared on behalf of the Electricity Suppliers Liaison Committee (ESLC) and approved by it for use by supply authorities.

This section of NRS 089-3 was prepared by a working group which, at the time of publication, comprised the following members:

| | |
|---|---|
| Ntombela D (Chairman) | Eskom Distribution |
| Booysen A | City Power Johannesburg |
| Busch PA | Eskom Corporate |
| Daniels N | Eskom Distribution |
| Dreyer J | Ekurhuleni Metropolitan Municipality |
| Gous A | Eskom Distribution |
| Harris RJ | Nelson Mandela Metropolitan Municipality |
| Hempel C | Nelson Mandela Metropolitan Municipality |
| Hunsley J | eThekwini Municipality |
| Josling J | Tshwane Electricity |
| Kalichuran J | eThekwini Electricity |
| Kruger G | Eskom Distribution |
| Mahlaule FT | City of Tshwane Metropolitan Municipality |
| Marx H | Ekurhuleni Metropolitan |
| Mkongi MS (Project Leader) | Eskom Technology Standardization |
| Nkambule B | City Power Johannesburg |
| Ntlatleng A | City Power Johannesburg |
| Persadh A | Eskom Distribution |
| Rizzotto J | Eskom Distribution |
| Sello SM | Eskom Central Region |
| Terblanche T | Eskom Distribution |
| Wolmarans W | Eskom Generation |

The input to this section of NRS 089-3 of the following organizations is acknowledged:

Ekurhuleni Metropolitan Municipality, City Power Johannesburg, Nelson Mandela Metropolitan Municipality, City of Tshwane, Umhlathuze Metropolitan Municipality, eThekwini Metropolitan Municipality, City of CapeTown, Eskom.

NRS 089-3 consists of the following sections under the general title *Maintenance of electricity networks – Part 3 – Substations:*

*Section 1: General.*

*Section 2: Power transformers, circuit-breakers, isolators and instrument transformers.*

*Section 3: Miniature substations, distribution transformers and electrical enclosures.*

Annexes A, B, C, D, E, F and G are for information only.

## Introduction

This section of NRS 089 specifies minimum requirements for maintenance activities on electrical networks.

This section of NRS 082 specifies a recommended maintenance policy for distribution networks. In this section of NRS 082 maintenance planning is specified as a component of a maintenance policy.

Recognizing that not all electricity distributors are in a position to develop maintenance plans, this section of NRS 089 was developed to provide minimum requirements for maintenance. The Electricity Suppliers Liaison Committee expresses the wish that, in the national interest and in support of government policy to foster local manufacture and stimulate export, all electricity distributors will adopt the recommendations of this section of NRS 089 in so far as their particular conditions will permit. It is intended that the maintenance plans specified in this section of NRS 089 will be reviewed periodically as better information, knowledge and evidence is available in industry.

## Keywords

circuit breakers, instrument transformers, isolators, maintenance, power transformers.

## Contents

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# MAINTENANCE OF ELECTRICITY NETWORKS

## Part 3: Substations

### Section 2: Power transformers, circuit breakers, isolators and instrument transformers

## 1 Scope

This section of NRS 089 sets out the maintenance work to be carried out on power transformers, circuit-breakers, isolators and instrument transformers and defines duties of field staff and specialists.

All specified inspection frequencies in this section of NRS 089 assume the absence of detailed reliability centred maintenance (RCM) studies or similar.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

NRS 000-1, *NRS definitions – Part 1: Complication of NRS and other definitions used in the Electricity Supply Industry.*

NRS 000-3, *NRS definitions – Part 3: High voltage operating regulations.*

NRS 079-1, *Mineral insulating oils (uninhibited) – Part 1: Purchase, management, maintenance and testing.*

NRS 089-3-1, *Maintenance of electricity networks – Part 3: Substations – Section 1:General*.

SANS 555, *Unused and reclaimed mineral insulating oils for transformers and switchgear.*

## 3 Terms, definitions and abbreviations

For the purposes of this document, the terms, definitions and abbreviations given in NRS 000-1 and NRS 089-3-1 apply.

## 4 General requirements

The requirements given in NRS 089-3-1 shall apply.

# 5 Equipment maintenance

The choice of condition monitoring tasks shall be determined by the maintenance manager. The tasks shall include, but are not limited to those given below. See annex A-F for a recommended maintenance schedule for high voltage equipment.

## 5.1 Power transformers

### 5.1.1 Condition monitoring

#### 5.1.1.1 Visual inspection

Visual inspection shall be carried out on a monthly basis; however, environmental conditions might dictate more frequent inspection. Any defects found shall be recorded and reported in accordance with the local supply authority maintenance management standard.

The following actions shall be taken and records thereof shall be kept:

a) check all bushings for chips, cracks or broken sheds. A maximum of 20% of chipped, cracked or broken sheds is permitted on an insulator;

b) check pollution levels on bushings;

c) check for any insulating oil leaks;

d) check oil levels in all conservators, tap changers, diverters and bushings (taking into consideration the effect of ambient temperature). Maximum and minimum levels shall be clearly marked on all gauge glasses;

e) ensure that all gauge glasses are clean and legible;

f) check silica gel, it shall not be more than 30 % pink from the bottom upwards;

g) ensure that all breather oil baths are filled to the correct level and free of water and dust;

h) check all explosion vent diaphragms for cracks, visible oil or other damage. The diaphragms shall not be painted.

i) check whether all surge arresters are station type arresters (preferably mounted on the transformer);

j) check surge arrestors for cracked or broken porcelain, signs of flashover (e.g. soot around seals on porcelain), and broken or punctured vents;

k) ensure that diverters surge relief valves are in the ‘service’ position;

l) check whether the mechanism box door seal is intact;

m) check whether the mechanism heaters are working;

n) record all tap change operations using OLTC counters and OLTC minimum and maximum pointers where fitted. Minimum and maximum pointers shall be reset after the value is recorded;

o) record maximum winding and oil temperatures and also the temperatures indicated at the time of reading. Minimum and maximum pointers shall be reset after the value is recorded. The ambient temperature at the time of recording shall also be noted;

p) check tap change mechanism boxes for cleanliness and for any general or obvious defects;

q) ensure that all off-circuit tap switches are locked in position;

r) check whether seals on all auxiliary connection boxes and temperature gauge housings are in order;

s) listen for any audible discharges;

t) check whether the radiators are warm at the bottom indicating satisfactory operation;

u) check whether radiator cooling fans are clear of obstructions and ensure that all valves are open. (This can be done by "feeling" the temperature of the fins. A colder fin will indicate insufficient oil circulation normally caused by a half-closed valve.);

v) check all cooling fans and oil pumps for correct operation;

w) check whether all tertiary connections are correctly shrouded and insulated;

x) ensure that valves on fins of transformers are in the open position;

y) check whether the operating labels are securely mounted and legible from the operating point;

z) check whether the earth straps are in good condition and effectively connected;

aa) ensure that the oil catchment area is clear of all stones and free of any debris and water; and

bb) check for corrosion and paint of all metal work.

Annex A is an example of the record or checklist for routine inspection of power transformers.

#### 5.1.1.2 Oil sampling

Oil samples shall be taken in accordance with SANS 555 and NRS 079-1, or as otherwise required by the Maintenance Manager. Oil samples shall also be taken after any significant/abnormal system event, which might have stressed the transformer.

For an optimised oil sampling frequency, an oil sampling plan may be derived in accordance with NRS 079-1. Routine oil samples shall be taken to an accredited laboratory for analysis. Portable oil analysis/testing units may be used to test the transformer oil following an abnormal system event.

#### 5.1.1.3 Infrared scanning

Infrared scanning of power transformers shall be carried out regularly as a means of detecting hot spots, cooling and flow problems on transformers, transformer conservator oil level and also transformer temperature problems before they lead to equipment failure.

Infrared scanning shall be carried out when possible, when the equipment is at or above its normal load. The transformers in the substation may be scanned while carrying an additional load in order to identify possible hot connections at an early stage. Annex B is an example of a checklist for condition monitoring and scheduled maintenance or repairs of power transformers.

The minimum scanning frequency shall be as given in table 1:

**Table 1 — Infrared scanning frequency**

| 1 | 2 |
|---|---|
| **Transformer capacity MVA** | **Frequency** |
| > 40 | 6 monthly |
| ≤ 40 | Yearly |

Transformers loaded to near capacity or above might require scanning more frequently. This particularly applies to those transformers loaded abnormally due to emergencies, equipment outages, etc. which if lost on fault could put system integrity at risk.

In situations where plant is loaded well below its rating, RCM/criticality analysis shall determine the infrared running frequency.

#### 5.1.1.4 Evaluation

The person doing the scanning shall evaluate the information available and make a judgement as to the degree of urgency for dealing with any hot spots found.

As a rule of thumb, the agency can be determined in accordance with table 2.

**Table 2 — Determination of urgency**

| 1 | 2 |
|---|---|
| **Temperature above the normal operating temperature of the equipment ($^{o}$C)** | **Degree of urgency** |
| Up to 10 above temp associated item | Deal with when equipment is next available |
| Over up to 30 above temp associated item | Urgent |
| Over 30 | Extremely urgent |

The other transformers in the substation shall be scanned while carrying an additional load in order to identify possible hot connections at an early stage.

Any defects found shall be recorded and reported to the Dispatcher in the case of emergency repair and to the Maintenance Planner for scheduled repair.

### 5.1.2 Corrective maintenance - Items for immediate action

If there are any faults or damage or if faulty items need to be replaced during an inspection and the repairs can be affected with the equipment in service, immediate action shall be taken. The following are examples of such actions:

a) all oil levels that are close to or below the minimum level shall be corrected in all conservators, tap changers, diverters and bushings (taking into consideration the effect of ambient temperature);

b) if silica gel is 30 % pink from the bottom upwards, it shall be replaced;

c) if silica gel is turning pink from the top, reseal the breather/breather pipe mating surface and perform a dielectric strength test on the oil as soon as possible to identify any possible ingress and degradation of the insulation medium;

d) repair or replace the mechanism box door seal;

e) repair or replace faulty mechanism heaters. If a thermostat is fitted, the cut out shall be set at approximately 25 º C.

f) repair or replace damaged seals on all auxiliary connection boxes and temperature gauge housings;

g) clean the breather oil bath and fill to the correct level with transformer insulating oil. Where multi breathers are fitted ensure that a common oil bath is fitted;

h) clear radiator-cooling fins of any obstructions and open all valves;

i) specialist personnel shall replace faulty cooling fans, oil pumps and flow indicators.

j) all on-load tap changers that are not on auto tapping shall be manually tapped up two and

down two taps from the operating tap position three times over and then be left in the original operating tap position. (Only perform this action on transformers that have been serviced within three months of initiating this action);

k) if necessary, refit the operating labels so as to be legible from the operating point.

l) replace earth straps that are not in good condition and reconnect those that are not effectively connected; and

m) clear the oil catchment area of all stones and free it of any debris and water.

## 5.2 Circuit-breakers

### 5.2.1 Condition monitoring

#### 5.2.1.1 Visual inspections

Inspections shall be carried out on all circuit-breakers and oil-immersed isolators to check for abnormal conditions on the equipment.

The condition and cyclo-meter readings of the equipment shall be recorded on approved checklists or feedback templates provided with the work orders.

The checklists or feedback templates shall be handed over to the maintenance planner for equipment history data capturing.

#### 5.2.2.2 Monitoring of insulating oil

Circuit-breaker oil shall be changed in accordance with maintenance requirements as determined by the maintenance manager or as specified in the manufacturer's manual.

Oil shall be handled in accordance with NRS 079-1.

#### 5.2.2.3 Circuit-breaker fault operations

The duty cycle of fault operations shall be monitored to determine when a maintenance intervention is required.

The action limit (10 operations at rated fault current on SF6 circuit breaker and 1 operation for oil circuit-breaker) at which a maintenance intervention is required shall be determined by the following formulas:

$SF_6$ circuit-breakers

$t_s (I_1/I_2)^2 \times n_s$

where

$t_s$ is the action limit for $SF_6$ circuit-breaker;

$I_1$ is the kilo-ampere rated current of the switchgear;

$I_2$ is the busbar fault current level in kilo-ampere; and

$n_s$ is the OEM specified number of trips at maximum kilo-ampere rating but which is taken as being 10 in the absence of an OEM specification.

For oil filled circuit-breakers

$t_o = (I_1/I_2)^2 \times n_o$

where

$t_s$ is the action limit for oil filled circuit breaker;

$I_1$ is the kiloampere rated current of the switchgear;

$I_2$ is the busbar fault current level in kiloampere; and

$n_o$ is the OEM specified number of trips at maximum kiloampere rating but which is taken as being 3 in the absence of an OEM specification.

See annex E for additional information.

### 5.2.3 Corrective maintenance – Items for immediate action

If there are any faults or damage or if faulty items need to be replaced during an inspection and the repairs can be effected with the equipment in service, immediate action shall be taken. The following are examples of such actions:

a) repair or replace mechanism box door seal;

c) refit the operating labels so as to be legible from the operating point;

d) ensure that the earth straps are effectively connected and in good condition;
replace mechanism door handles or hinges: and

e) reset and record of panel alarms.

## 5.3 Isolators

### 5.3.1 Condition monitoring

#### 5.3.1.1 Visual inspections

Inspections shall be carried out on all isolators to check for abnormal conditions on the equipment.

The condition of the equipment shall be recorded on approved checklist or feedback templates provided with the work orders.

The checklists or feedback templates shall be handed over to the maintenance planner for equipment history data capturing.

Excessive bearing grease leaks shall be assessed by specialists and repaired as the severity dictates.

#### 5.3.1.2 Infrared scanning

Infrared scanning shall be carried out in accordance with local supply authority standards.
Any defects found shall be recorded and managed in terms of the local supply authority's maintenance management standards.

### 5.3.2 Corrective maintenance – Items for immediate action

If there are any faults or damage or if faulty items need to be replaced during an inspection and the repairs can be effected with the equipment in service, immediate action shall be taken. The following are examples of such actions:

a) repair or replace mechanism box door seal;

b) repair or replace seals on all auxiliary connection boxes;

c) refit the operating labels so as to be legible from the operating point;

d) ensure that the earth straps are effectively connected and in good condition; and

e) reset and record of panel alarms.

## 5.4 Voltage and current transformers

### 5.4.1 Condition monitoring

#### 5.4.1.1 Visual Inspections

Inspection shall be carried out on all voltage and current transformers to check for abnormal conditions on the equipment. The conditions and meter readings shall be recorded on approval check sheets or feedback templates. The check sheets or feedback templates shall be handed over to the relevant staff for equipment history date capturing.

Records of the following shall be kept:

a) check all porcelain for chips, cracks or broken sheds. A maximum of 20% of chipped, cracked or broken sheds is permitted on an insulator;

b) check pollution levels on porcelains;

c) check for any insulating oil leaks.

d) check oil levels in all CTs, VTs (taking into consideration the effect of ambient temperature). Ensure that oil levels are clearly marked on all gauge glasses;

e) check for discoloration of the silica gel on “Balteua type CTs”, the pink colour signifies a gas leak from the CT;

f) ensure that all gauge glasses are clean and legible;

g) check the seals on all connection boxes;

h) listen for any audible discharges;

i) ensure that the operating labels are securely mounted and legible from the operating point; and

j) ensure that the earth straps are in good condition and effectively connected.

#### 5.4.1.2 Infrared scanning

Infrared scanning shall be carried out in accordance with local standards. Any defects found shall be recorded and managed in terms of the local supply authority’s maintenance management standards.

#### 5.4.1.3 Corrective maintenance – Items for immediate action

If there are any faults or damage or if faulty items need to be replaced during an inspection and the repairs can be effected with the equipment in service, immediate action shall be taken. The following are examples of such actions:

a) repair or replace seals on all connection/terminal boxes’ doors;

b) refit the operating labels so that they are legible from the operating point; and

c) ensure that the earth straps are effectively connected and are in good condition.

## 5.5 Preventive maintenance scheduled actions

All/routine maintenance shall be carried out at the intervals specified in the relevant manufacturer's manual or as dictated by local conditions.

All defects shall be analysed and correlated on a monthly basis in order that maintenance outages can be timeously scheduled. Prior to a scheduled outage condition based monitoring shall be used to ensure that the correct equipment, material and personnel are available on site.

All scheduled work shall be carried out by relevant personnel (see annex C in accordance with the relevant approved maintenance instructions. See annex C for transformer maintenance skills list and appropriate task to be performed

All solvents, lubricants, pastes or greases that are used when performing maintenance shall be as specified in the manufacturers' manuals or in approved maintenance instructions.

### 5.5.1 Transformers maintenance actions

#### 5.5.1.1 Cleaning

When a transformer is taken out of service for maintenance purposes, this opportunity shall be used to clean off any dirt or oil that has collected on the transformer, especially at valves, around gaskets at the Buchholz relay and on all gauge glasses and the bushing porcelains. Steam cleaning or high pressure cleaning might be necessary.

#### 5.5.1.2 Oil leaks

Where oil leaks are present, they shall be repaired by specialist workshop personnel who have been authorized in writing.

The oil level shall be checked and topped up if necessary. Care shall be exercised to ensure that the oil used for topping up complies with the oil standard adopted by the local supply authority.

#### 5.5.1.3 Tap changer/diverter

All work on tap changers other than already laid down in this section of NRS 089-3, shall be carried out by specialist staff only. Tap changer maintenance shall be scheduled in accordance with OEM recommendations or, if unavailable, in accordance with the local supply authority structured process, such as RCM, or a similar engineering evaluation.

The OEM specification and the latest technology shall be checked for the latest practice with regard to tap changer maintenance.

#### 5.5.1.4 Bushings

Bushings shall be tested for tan delta and capacitance and the test cap shall be inspected. This shall be done at the same time as tap changer/diverter maintenance for convenience, (with a maximum interval of five years) and shall be carried out by specialist staff only.

The earthing of the test cap on the bushing shall also be checked. An anti-pollution medium shall be applied to the bushings in accordance with the local supply authority requirements.

#### 5.5.1.5 Cooling system

Faulty oil pumps, flow indicators and cooling fans shall be replaced and the faulty units shall be sent to the workshop for repairs. Replacement of these items shall only be carried out by specialist personnel.

#### 5.5.1.6 Transformer winding temperature device

A transformer winding temperature device is usually a small current transformer placed in a pocket on the transformer. This CT shall be checked for calibration and to ensure that it is covered with oil.

### 5.5.2 Breaker maintenance actions

#### 5.5.2.1 Circuit-breaker trip testing

The circuit-breaker shall be tested to prove its mechanical operation under the following circumstances:

a) if the circuit-breaker has not been opened and closed under normal or fault condition for the period specified in the maintenance plan; or

b) if the period since the previous operation exceeds the period recommended by the manufacturer; or

c) if the trip testing of the circuit-breaker has been recommended by a circuit breaker specialist or by the maintenance manager

Trip testing of the circuit-breakers shall always be performed by activating the controls provided at the point furthest from the equipment, e.g. supervisory controls, the trip test button provided on the control panel or the remote control handle.

#### 5.5.2.2 Circuit-breakers planned maintenance

Overhauls on all circuit breakers shall be carried out in accordance with the manufacturer's specifications, as local conditions dictate.
Maintenance tasks shall be carried out by specialist personnel only and shall be in accordance with approved, relevant maintenance work instructions / Task Manual.

### 5.5.3 Isolators maintenance actions

Overhauls on all isolators shall be carried out in accordance with the manufacturer's specifications, as local conditions dictate or after a period not exceeding ten years from the date of the first commissioning or the last Overhaul.

Maintenance tasks shall be carried out by specialist personnel only and shall be in accordance with approved, relevant maintenance work instructions.

### 5.5.4 Voltage and current transformers maintenance actions

#### 5.5.4.1 Cleaning

When a CT or VT is taken out of service for maintenance purposes, clean off any dirt or oil that has collected on the CT or VT. Steam cleaning or high pressure cleaning might be necessary.

An anti-pollution medium shall be applied in accordance with individual utility maintenance strategies.

#### 5.5.4.2 Oil leaks

If oil leaks are present on a CT or VT, the CT or VT shall be replaced and the faulty unit shall be sent to the workshop for repairs.

### 5.5.5 Reclosers and sectionalizers

#### 5.5.5.1 Oil quenching type

Oil quenching type reclosers and sectionalizers shall be serviced after 80 to 120 operations or yearly whichever comes first. In addition, a monthly visual check shall be carried out and counter readings shall be taken. Only major services that require either a service exchange or an on site service including oil change, contact wear measurement and replacement, other calibration tests and resetting the counter to zero shall be carried out.

#### 5.5.5.2 Vacuum interruption type

Vacuum interruption type reclosers and sectionalizers shall be treated as maintenance free. However a monthly visual and battery voltage check shall be carried out, and counter readings shall be taken. Every 5 to 10 years a major service that includes the replacement of all insulating oil and the measurement of contact wear on the wear indicator shall be carried out.

### 5.5.6 Control technology

Protection maintenance shall be co-ordinated with Control Technology staff to ensure that the panel protection is fully maintained and tested before re-energizing.

## 6 Maintenance documentation

A work order with the applicable job description and approved maintenance instruction shall be issued before any work is carried out. The feedback required for each specific job shall be stipulated on the job description.

The equipment identification information (make, serial number, type etc.) on the work order shall be compared with the equipment nameplate on site at each inspection. Any change in the information shall be noted and returned to the maintenance service provider via the maintenance planner who shall update the information in the maintenance system.

All faults, repairs and replacement effected during inspections and maintenance work shall be recorded on feedback forms or check sheets and returned to the relevant staff who shall capture the information for maintenance planning and for equipment history.

## 7 Skill requirements

The skill level or crafts required and the number of persons required for the maintenance shall be allocated in accordance with the detail specified in the maintenance plan and work instructions / task manual.

# Annex A
(informative)

## Record list for routine inspections of power transformers

Substation: …….. Date: ……

Panel/Bay: …… Make: …….. Serial No: ……

| TASK | ✔ | REMARKS |
|---|---|---|
| 1 Check and record ambient temperature<br>Check and record oil temperature and maximum<br>Check and record winding temperatures and maximums (reset max. indicator) | | |
| 2 Check and record present loading HV<br>Check and record maximum loading HV (reset max. indicator) | | |
| 3 Check and record main tank conservator oil level<br>Check and record Diverter conservator oil level<br>Check and record bushing oil levels<br>Check and record auxiliary equipment oil level/s | | |
| 4 Check and record percentage of silica gel pink<br>Check and record oil pot levels | | |
| 5. Check, test-run and record condition of cooling fans<br>Check, test-run and record condition of oil pumps | | |
| 6 Check and record all on-load tap change operation counters(do not reset) | | |
| 7 List of all defects from inspection checklist | | |

DONE BY (PRINT NAME) _____ SIGNATURE _____

ACCEPTED BY (SUPERVISOR) _____

# Annex B
(informative)

## Checklist for condition monitoring and scheduled maintenance of power transformers

Substation: _____ Date: _____

Panel/Bay: _____ Make: _____ Serial No: _____

| TASK | DONE BY DEPARTMENT | Date/REMARKS |
|---|---|---|
| **CONDITION MONITORING**<br>1 Oil samples taken | | |
| 2 Infrared scanning<br>3. Bushing tests | | |
| **SCHEDULED MAINTENANCE**<br>1 All safety precautions in place | | |
| 2 Clean the transformer | | |
| 3 Repair of hot connections | | |
| 4 Oil leaks repaired | | |
| 5 Tap changer diverter maintenance | | |
| 6 Cooling system maintenance | | |
| 7 Protection maintenance | | |

CHECKED BY (PRINT NAME) _____ SIGNATURE _____

ACCEPTED BY (SUPERVISOR) _____

# Annex C
(informative)

## Transformer maintenance skills list

NOTE The skills listed below shall be appropriate to the task to be performed.

The skill levels are defined as follows:

F First Line - Assistant Official with minimum transformer maintenance training and authorized in writing.

T Trained - Engineering assistant or workshop artisan with formal transformer maintenance training and authorized in writing. (Authorised operator)

S Specialist personnel, manufacturer's personnel or Contractor with in-depth transformer maintenance training and experience and authorised in writing.

NOTE The skill matched to a task is the minimum skill required for the execution of that task.

| TASK | SKILL | | |
|---|---|---|---|
| | F | T | S |
| **1 Maintenance checklist and tasks** | | | |
| 1 A. Oil Level check | | | |
| • Conservator (Main tank) | x | | |
| • Conservator (Tap changer) | x | | |
| • Bushings | x | | |
| • Auxiliary | x | | |
| B. Oil Gauge Glass check | | | |
| • Cracked | x | | |
| • Stained | x | | |
| 2 Breathers check and rectify | | | |
| • If >30% Pink –Replace Gel | x | | |
| • Repair of air leaks (from ground level only) | x | | |
| • Oil pot | x | | |
| 3 Cooling System check | | | |
| • Radiators clear | x | | |
| • Test and run fans | x | x | |
| • Test and run pumps | x | x | |
| • Temperature recording | x | | |
| 4 Oil Leak check | | | |
| • Transformer main tank | x | | |
| • Tap changer tank | x | | |
| • Bushings | x | | |
| • Cooling fins | x | | |
| • Pipe work | x | | |
| • Valves | x | | |
| • Buchholtz | x | | |
| • Gauge glasses | x | | |
| • Conservator tank | x | | |
| • Auxiliary transformer | x | | |

## Annex C
*(continued)*

| TASK | SKILL | | |
|---|---|---|---|
| | F | T | S |
| 5 General | | | |
| 5.1 Bushings check | | | |
| • Clean | x | | |
| • Chipped or cracked | x | | |
| 5.2 Pressure relief device check | | | |
| • Cracked/leaks | x | | |
| 5.3 Anti-condensation heaters check | | | |
| • Marshalling kiosk | x | | |
| • Tap changer mechanism box | x | | |
| • Temperature instrument box | x | | |
| 6 Tap changer | | | |
| • Record number of operations | x | | |
| • Run through +2; -2 taps (OLTC only) | | x | |
| 7 Oil catchment area (transformer bund) | | | |
| • Clear off debris, water and oil | x | | |
| 8 Marshalling kiosk, tap changer mechanism box | | | |
| • Clean | x | | |
| • Door seals intact | x | | |
| **2 Condition monitoring** | | | |
| 1 Oil Samples | | | |
| • Main tank/buchholtz | | x | |
| • Diverter | | x | |
| • Tap changer selector | | x | |
| • Bushings | | | x |
| • Auxiliary transformer | | x | |
| 2 Infrared scanning | | | x |
| 3. Bushing tests | | | x |
| 4 Run through full tap range (O L T C only) | | x | |

## Annex C
*(concluded)*

| TASK | SKILL F | SKILL T | SKILL S |
|---|---|---|---|
| **3 Scheduled maintenance** | | | |
| 1 Repair of hot connections | | x | |
| 2 Repair of oil leaks | | | |
| • Bushings | | | x |
| • Main tank | | | x |
| • Cooling system | | | x |
| • Conservator | | | x |
| • Tap changer | | | x |
| 3 Tap changer maintenance | | | x |
| Run through full tap range | | x | |
| 4 Cooling system | | | |
| • Replacement of oil pumps | | | x |
| 5 Protection | | | |
| • Buchholz test - mechanical | | | x |
| - signal | | | x |
| • Junction box - wiring | | | x |
| • C T Terminal box - cracks | | | x |
| - No arcing | | | x |
| • Temperature indicators | | | |
| oil in thermal pockets | | | x |
| alarm tested | | | x |
| trip tested | | | x |
| calibrated | | | x |
| | | | x |
| • Tap changer protection/control | | | x |
| • Pressure relief devices | | | x |
| • Oil level indicators | | | x |
| • Marshalling kiosk | | | x |
| • Transformer protection panel | | | x |
| • Remote control checked | | | x |
| • Indications checked | | | x |

# Annex D
(informative)

## Recommended maintenance for high-voltage circuit-breakers

## High-voltage circuit-breakers

| Sub Type | Predetermined (Time) | Condition Based (Time) | Overhaul (Time) | Overhaul (Condition) |
|---|---|---|---|---|
| Air Blast | 1 Monthly | 3 Yearly Minor<br>1 Yearly Trip Test | 9 Yearly Major | As OEM recommends |
| Bulk Oil | 1 Monthly | 1 Yearly Minor | 3 Yearly Major | (I1/I2)n Counts Major |
| SF6 | 1 Monthly | No Minor Service (Routine Inspection Suffices) | 12 Yearly Major | ((I1/I2)^2)n Counts Major |
| | | 1 Yearly Trip Test | | |
| Minimum/ Small Oil | 1 Monthly | 1 Yearly Minor | 3 Yearly Major | (I1/I2)n Counts Major |
| Vacuum | 1 Monthly | 3 Yearly Minor | 9 Major Yearly | As OEM recommends |
| | | 1 Yearly Trip Test | | |

The duty cycle of fault operations can be monitored to determine when a maintenance intervention is required.

The action limit at which a maintenance intervention is required may be determined by the following formulas in the absence of specification, specified by the Original Equipment Manufacturer (OEM):

$SF_6$ circuit-breakers = $(I_1/I_2)^2 \times n$

Oil-filled circuit-breakers = $(I_1/I_2) \times n$

Where:
$I_1$ = kA rated current of the switchgear
$I_2$ = Busbar fault current level in kA.

For SF6 circuit breakers
n = the OEM specification for no. of trips at maximum kA rating. In the absence of OEM specification n=10

For oil circuit breakers
n = the OEM specification for no. of trips at maximum kA rating. In the absence of OEM specification n=1

# Annex E
(informative)

## Recommended maintenance for different types of isolators

### Isolators

Pre-determined inspections and Infrared scans are recommended.
Frequency is determined by local conditions or Manufacturer recommendations
Minor maintenance annually where the isolator is operated and lubricated if needed.
Major overhaul be completed every three years in adverse environments, or else at least every 10 years.

### WODs and SODs

These are essentially isolators with an energy storage device to allow automatic opening. Maintenance is to be via an annual trip test or on report of defects. The trip test must incorporate lubrication also. The frequency may be increased where considered necessary, based on inputs from Maintenance Executors, or as determined by the Maintenance Manager.

# Annex F
(informative)

## Intervals for inspections

All specified frequencies in this document assume the absence of detailed R.C.M. studies or similar.

| Equipment | Frequency | |
|---|---|---|
| | **1 year** | **10 years** |
| Auto Reclose Switches | Test R.E.F. batteries and replace if necessary<br>(Quarterly) | |
| Air Break Switches<br>(Two Yearly,<br>Line to be de-energised**)** | Insulator condition.<br>Contact leads.<br>Loose connections.<br>Mechanism stability.<br>Rust on hardware.<br>Operating handle mechanism for damage or lack of lubrication.<br>Condition of padlock, i.e. ease of operation and/or damage. | |
| Auto-Reclose Switches | Insulators.<br>Jumper condition and/or clearance.<br>Paintwork.<br>Oil leaks. | |
| Sectionalizers | Insulators.<br>Jumper condition and/or clearance.<br>Paintwork.<br>Oil leaks. | |
| Transformers | Insulators.<br>Jumper condition and/or clearance.<br>Paintwork.<br>Oil leaks. | |
| Transformers | All connections are tight.<br>Insulators for damage.<br>Pole mountings.<br>Rust on tank and hardware.<br>LV Circuit Breaker for safe operation.<br>Earth bonding is complete.<br>Oil leaks. | |

# Annex G
(informative)

## Impact Assessment Form

| Impact assessment | | | |
|---|---|---|---|
| **Document title:** | **POWER TRANSFORMERS, CIRCUIT BREAKERS AND ISOLATORS SUBSTATION MAINTENANCE VTS CTs** | | |
| **Document no:** | **NRS 089-3-2:2008** | **Revision no:** | **0** |

| Activity | Detail |
|---|---|
| **1. What training is required to implement this document? (e.g. awareness training, practical / on job, module.)** | |
| **2. Who will require training? (State designations.)** | |
| **3. What prerequisites are needed for students?** | |
| **4. What equipment will be required for training? (Computers etc.)** | |
| **5. What special tools will be required for training?** | |
| **6. What special requirements are needed for the trainer?** | |
| **7. Time period for training to be completed?** | |
| **8. What special tools / equipment will be needed to be purchased by the organisation to effectively implement?** | |
| **9. Does the document affect the budget?** | |
| **10. Time period for implementation of requirements after training is completed?** | |
| **11. Does the Buyers Guide or Buyers List need updating?** | |
| **12. What Buyer's Guides have been created?** | |
| **13. Was Training & Development department consulted w.r.t training requirements?** | |
| **14. Were the critical tasks in the document identified?** | |
| **15. Is any training material/information available on the subject in this document?** | |
| **16. Was the document approval process adhered to?** | |

| | |
|---|---|
| Total implementation period | |
| Total training cost | |
| Total cost of tools / equipment | |
| Total cost involved | |

**Comments:**

| Assessment Compiled by: | | Recommended by (Functional Responsibility): | |
|---|---|---|---|
| Name: | | Name: | |
| Designation: | | Designation: | |
| Dept: | | Dept: | |
| Date: | | Date: | |

## Bibliography

EKARAAG4: Rev. 6, *Operating regulations for high voltage systems (ORHVS*).

ESKPBAAD6: Rev 6, *Environmental management policy.*

SCSASAAX4, Rev 2, *Standard for the Maintenance of Circuit Breakers and Oil Immersed Isolators*.

SCSASAAW1: Rev. 0, *Infra-red scanning of HV current carrying equipment*.

SCSASACH3: Rev 0, *Condition Monitoring.*

SCSADABK6: Rev 0, *Maintenance Planning Directive.*

SCSPVACU1: Rev 0, *Pre-Task Planning and feedback process*.

SCSASAAY4: Rev 0, *Standard for the requirements and maintenance of equipment earthing at distribution substation.*

SCSASAAY2: Rev 2, *Standard for the Maintenance of Isolators*.