

Substation Maintenance Instruction

Power, auto and regulating transformers

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Substation Maintenance Instruction

ASSET STANDARDS & DESIGN

Document No	:	SMI 155
Amendment No	:	7
Approved By	:	GMAS
Approval Date	:	31/03/16
Review Date	:	31/03/19

SMI 155 POWER, AUTO AND REGULATING TRANSFORMERS

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1.0 PURPOSE

To set out in detail the maintenance requirements for power, auto and regulating transformers.

2.0 SCOPE

This instruction is to be read in conjunction with Substation Maintenance Instruction SMI 100 - Minimum requirements for maintenance of transmission and zone substation equipment, for transmission and zone substation equipment, and Substation Maintenance Instruction SMI 101 - Minimum requirements for maintenance of distribution equipment, for distribution equipment.

This instruction specifies the maintenance and test requirements for power, auto and regulating transformers. It also details mid-life refurbishment requirements for power transformers.

3.0 REFERENCES

Internal

- Company Policy 9.9.1 – Network Asset Maintenance
- Company Procedure GSY 1066 - Worksite Hazard and Risk Assessment
- Network Management Plan December 2013 Review
- Earthing Design Instruction EDI 516 – Major substation earthing design, construct and commissioning
- Substation Maintenance Instruction SMI 100 - Minimum requirements for maintenance of transmission and zone substation equipment
- Substation Maintenance Instruction SMI 101 - Minimum requirements for maintenance of distribution equipment
- Substation Maintenance Instruction SMI 103 - Insulation oil testing
- Substation Maintenance Instruction SMI 118 - Transmission and zone substation maintenance data entry and defect prioritisation
- Substation Maintenance Instruction SMI 119 - Transmission and zone substation data entry, asset structure and details
- Substation Maintenance Instruction SMI 121 - Storage and handling of insulating oil
- Substation Maintenance Instruction SMI 156 – Breathers

External

- *ENA National Electricity Network Safety Code (Doc 01-2008)*
- *Electricity Supply Act 1995 (as amended)*
- *Work Health and Safety Act 2011*
- *Work Health and Safety Regulation 2011*
- *AS/NZS 60137:2008 - Insulated bushings for alternating voltages above 1000 V(IEC 60137, Ed. 5.0 (2003) MOD)*
- *AS/NZS 60076.3:2008 - Power transformers Part 3: Insulation levels, dielectric tests and external clearances in air (IEC 60076-3, Ed. 2 (2000) MOD)*
- *IEC 61620:1998 - Insulating liquids –Determination of the dielectric dissipation factor by measurement of the conductance and capacitance – Test method*

4.0 DEFINITIONS AND ABBREVIATIONS

DDF	dielectric dissipation factor
DP	degree of polymerisation of the paper insulation
EDI	Earthing Design Instruction

Ellipse	Endeavour Energy asset database
Furan	compounds generated from the oxidation of paper
IFT	interfacial tension
IR	insulation resistance
PI	polarisation index
SCADA	Supervisory Control and Data Acquisition
SMI	Substation Maintenance Instruction
NPV	net percent value
WAN	wide area network

5.0 ACTIONS

5.1 General

Distinct types or brands of transformer may not contain some of the components listed for routine maintenance, in which case the allocated maintenance for that particular component is to be disregarded.

All materials used and all work methods employed must be in accordance with the manufacturer's recommendations.

Signature tests are to be carried out before and after major overhaul maintenance and both sets of results (before and after) recorded in the Endeavour Energy transformer database located in **G:\EE Maintenance**, under the appropriate substation folder.

5.2 Routine maintenance schedules

Routine maintenance
1.0 INSPECTION
GENERAL
Inspect the equipment and report any defects.
TEMPERATURE INDICATOR and RESISTIVE TEMPERATURE DETECTOR (RTD)
Check that sensible values are being read.
TEST FANS AND PUMPS
Operate pumps and fans to verify correct operation
HV TERMINATIONS
Inspect for signs of corrosion, burning, overheating or other defects.
TANK: Common - separate (main and tap changer)
Check oil level in conservators.
Inspect for oil leaks.
Inspect for rust, corrosion, poor paintwork condition or other defects.
INSULATORS/BUSHINGS: High voltage - low voltage - neutral
Inspect for leaks, cracks, treeing, tracking, visible effects of corona or other defects.
BREATHER
Carry out breather inspection in accordance with SMI 156.

STEELWORK/HARDWARE								
Inspect for rust, corrosion, loose or missing bolts, poor paintwork condition or related defects.								
2.0 TRANSFORMER SIGNATURE TESTS (result reporting format is shown in Section 5.4).								
TEMPERATURE AND HUMIDITY								
Test and record ambient temperature, oil temperature (deg. C) and relative humidity prior to commencement of test.								
Routine maintenance								
INSULATION RESISTANCE AND POLARIZATION INDEX								
Carry out the following tests at 2.5kV DC using suitable test equipment. HV - LV (and TV bridged and) earthed. LV - HV (and TV bridged and) earthed. TV - LV and HV bridged and earthed if applicable. Only two (2) tests will be required for a two (2) winding transformers. Record and report 1min, 10min insulation resistances and polarisation index (measured values). PI values of less than two (2) must be reported immediately. <table><tr><td>PI < 1.0</td><td>indicates dangerous condition and immediate corrective action is required</td></tr><tr><td>1 < PI < 1.25</td><td>indicates poor condition</td></tr><tr><td>1.25 < PI < 2</td><td>indicates fair condition</td></tr><tr><td>PI > 2</td><td>indicates good condition</td></tr></table> The minimum value of IR at one (1) minute in MΩ will be: 0.8 x transformer primary voltage in volts ----- square root (transformer KVA) The tested IR value below this minimum value may indicate probable insulation breakdown and immediate corrective action is required. Comparisons must be made to previous test history to establish a trend. Substantial variations in the plotted IR values must be reported and further tests may be required for investigating the cause. After the test has been completed, all terminals must be grounded for at least 10 minutes to allow any residual charge to decay to a negligible value.	PI < 1.0	indicates dangerous condition and immediate corrective action is required	1 < PI < 1.25	indicates poor condition	1.25 < PI < 2	indicates fair condition	PI > 2	indicates good condition
PI < 1.0	indicates dangerous condition and immediate corrective action is required							
1 < PI < 1.25	indicates poor condition							
1.25 < PI < 2	indicates fair condition							
PI > 2	indicates good condition							
DDF AND WINDING CAPACITANCE :								
The DDF between the windings and ground must be measured in GST (5) L-guard mode. The inter-winding DDF must be measured in UST (3) test mode. Carry out the following tests at 2.5kV AC using a Biddle capacitance and dissipation test set or similar: H – Ground L – Ground H – L and where applicable, T – Ground T – H T – L Record and report DDF and capacitance values. Winding DDF values of >7 mW/Var must be reported. Comparisons must be made to previous test history to establish a trend. Substantial								

variations in the plotted DDF values must be reported and investigated.
BUSHING TEST
Bushings with DDF tap points must be tested between the high voltage and the bushing DDF tap point in accordance with AS/NZS 60137:2008, clause 9.1. Comparisons must be made to previous test history to establish a trend. Substantial variations in the plotted DDF values must be reported and investigated.
3.0 MAJOR OVERHAUL
3.1 AS FOUND CHECKS
TANK: Common - separate (main and tap changer)
Test tank oil in accordance with SMI 103 – Insulation oil testing.
THERMOMETER: Oil temperature - winding temperature
Record the maximum temperature, minimum temperature and ambient temperature.
3.2 OVERHAUL
INSULATORS/BUSHINGS: High voltage - low voltage - neutral
Clean with recommended solvent.
OIL SURGE RELAY
Inspect for oil leaks.
GROUND LEVEL GAS RECEIVER
Inspect for oil leaks.
Check if gas is present in ground level gas receiver - if gas is present carry out gas testing in accordance with SMI 103 – Insulation oil testing.
OIL PRESSURE RELIEF VALVE
Inspect for oil leaks.
EXPLOSION VENT
Examine condition of diaphragm.
BREATHER
Carry out breather maintenance in accordance with SMI 156 - Breathers.
Routine maintenance
CUBICLE:
- Heater
Check operation.
- Thermostat
Check thermostat setting.
- Anti-vibration dampers
Check condition.
- Cubicle
Inspect for chipped paintwork and rusted steel.
Repaint if necessary.
- Gaskets
Check condition.
WIRING: Oil surge relay - oil pressure relief valve - heater - cooler control cubicle

Check connections.
OPERATION: Oil surge relay - oil pressure relief valve - winding temperature indicator - oil temperature indicator
Check tripping.
Check alarm operation.
- Winding temperature indicator
Carry out CT secondary checks.
GASKETS
Check condition.
COOLING EQUIPMENT: Radiators
Inspect for rust, corrosion, poor paintwork condition or other defects.
Inspect for oil leaks.
- Fans
Check condition of fan guards and mounting bolts.
Check terminal box connections.
Check manual operation.
Check automatic operation.
Check blade rotation is correct.
Check fan failure alarm.
- Cooler control cubicle
Check heater operation.
Check thermostat operation.
Check doors, door seals and gaskets for possible moisture ingress into cubicle.
- Oil circulating pump
Check terminal box connections.
Check gasket condition.
- Operational checks
Check oil flow switch operation.
Check manual operation.
Check automatic operation.
Check oil pump failure alarm.
BUSBAR FLEXIBLES
Check condition.
Check tightness.
3.3 FINAL CHECKS
Check all oil levels.
3.4 FINAL TESTS
Carry out signature tests as specified in Section 2.0 – Transformer Signature Tests and record results.

5.3 Testing of essential spare transformers

Oil quality test

Oil samples to be taken and sent for analysis (analysis to include moisture, furans, acidity, breakdown voltage, colour, IFT, DDF and conductivity to IEC 61620). These samples must be assessed in accordance with SMI 103 – Insulation oil testing.

After sampling, oil levels to be checked and topped up as required, using new oil that is stored and tested in accordance with SMI 121 – Storage and handling of insulating oil.

Insulation resistance tests

Carry out the following tests at 2.5kV DC using suitable test equipment.

HV - LV (and TV bridged and) earthed.

LV - HV (and TV bridged and) earthed.

TV - LV and HV bridged and earthed if applicable.

Only two (2) tests will be required for a two (2) winding transformers. Record and report 1min, 10min insulation resistances and polarisation index (measured values).

PI values of less than 2 must be reported immediately.

PI < 1.0 indicates dangerous condition and immediate corrective action is required

1 < PI < 1.25 indicates poor condition

1.25 < PI < 2 indicates fair condition

PI > 2 indicates good condition

The minimum value of IR at one (1) minute in MΩ will be:

0.8 x transformer primary voltage in volts

square root (transformer KVA)

The tested IR value below this minimum value would indicate probable insulation breakdown and immediate corrective action is required.

Comparisons must be made to previous test history to establish a trend. Substantial variations in the plotted IR values must be reported and further tests may be required for investigating the cause.

After the test has been completed, all terminals must be grounded for at least 10 minutes to allow any residual charge to decay to a negligible value.

5.4 Report format

POWER TRANSFORMER TEST RESULTS				
ASSET DATA				
Asset ID no:		Serial number:		
Location/substation:				
TX voltage ratio:		Device/TX no:		
Test date:		Ambient temperature (deg. C):		
Oil temperature (deg. C):		Relative humidity (%):		
INSULATION RESISTANCE AND POLARISATION INDEX TEST RESULTS				
Test equipment:		Test voltage (kV):		
Insulation under test ☐		HV/LV, E and TV	LV/HV, E and TV	TV/HV, LV and E
1 min. insulation resistance (MΩ)				
10 min. insulation resistance (MΩ)				
Polarisation index				
DDF TEST RESULTS				
Test equipment:		Test voltage (kV):		
DDF test between windings: UST (3)	Insulation under test	H/L	L/T	H/T
	Capacitance (pF)			
	DDF (mW/VAR)			
DDF test winding to earth: GST L-Guard (5)	Insulation under test	H/G	L/G	T/G
	Capacitance (pF)			
	DDF (mW/VAR)			
DDF test bushing	Insulation under test	HV terminal/ DDF tap point	LV terminal/ DDF tap point	
	Capacitance (pF)			
	DDF (mW/VAR)			

All test results are to be recorded electronically within the transformer asset database located on G drive at **G:\EE Maintenance** under the relevant substation folder.

6.0 AUTHORITIES AND RESPONSIBILITIES

General Manager Asset Management has the authority and responsibility for approving this instruction.

Manager Asset Standards & Design has the authority and responsibility for making recommendations to the **General Manager Asset Management** in respect to this instruction.

Network Maintenance Manager has the authority and responsibility for keeping the content of this instruction up to date.

Regional Transmission Managers have the authority and responsibility for:

- maintaining transmission and zone substation transformers in accordance with this instruction;
- engaging Endeavour Energy employees and/or contractors who have appropriate qualifications and are competent to carry out the work; and
- providing appropriate equipment and training.

All Endeavour Energy employees and/or contractors have the authority and responsibility for:

- meeting the requirements of this instruction, and SMI 100 (for transmission and zone substation equipment), when carrying out maintenance on transformers;
- working in accordance with local and statutory requirements;
- upholding a high level of public safety;
- working in accordance to Endeavour Energy's Electrical Safety Rules;
- updating Endeavour Energy's asset database; and
- communicating abnormalities found in the transformer to the Regional Transmission Manager and the Network Maintenance Manager.

7.0 DOCUMENT CONTROL

Documentation Content Coordinator : Network Maintenance Manager

Documentation Distribution Coordinator : **Branch** Process Coordinator