NS 230

Testing of Distribution Substations

SEPTEMBER 2011

SUMMARY

Network Standard NS 230 applies to the testing of distribution substations throughout all parts of Augrid's supply area. This standard is applicable to pole, kiosk and chamber substations.

ISSUE

Ausgrid staff: This document is for issue to all staff involved with the testing and commissioning of distribution substations.

Where this standard is issued as a controlled document replacing an earlier edition; remove and destroy the superseded document.

Accredited Service Providers: This document is issued on an uncontrolled basis. Users are responsible for ensuring that the document they are using is current and includes any amendments issued since the date on the document. Ausgrid will not accept any liability for work carried out to a superseded standard. Ausgrid may not accept work carried out which is not in accordance with current standard requirements.

Ausgrid maintains a copy of this and other Network Standards together with updates and amendments on www.ausgrid.com.au.

Ausgrid also offers a subscription service which provides for updates and amendments to standards on payment of an annual fee.

DISCLAIMER

As Ausgrid's standards are subject to ongoing review, the information contained in this document may be amended by Ausgrid at any time.

It is possible that conflict may exist between standard documents. In this event, the most recent standard is to prevail.

This document has been developed using information available from field and other sources and is suitable for most situations encountered in Ausgrid. Particular conditions, projects or localities may require special or different practices. It is the responsibility of the local manager, supervisor, assured quality contractor and the individuals involved to ensure that a safe system of work is employed and that statutory requirements are met.

Ausgrid disclaims any and all liability to any person or persons for any procedure, process or any other thing done or not done, as a result of this Network Standard.

INTERPRETATION

In the event that any user of this Standard considers that any of its provisions are uncertain, ambiguous or otherwise in need of interpretation, the user should request Ausgrid to clarify the provision. Ausgrid's interpretation shall then apply as though it was included in the Standard, and is final and binding. No correspondence will be entered into with any person disputing the meaning of the provision published in the Standard or the accuracy of Ausgrid's interpretation.

Issuing Authority	Distribution Automation Substation Engineering	DO&R
Content Approver	Executive Manager - Logistics and Distribution Engineering	DO&R
Content Owner	Manager – Distribution Automation Substation Engineering	DO&R

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September 2011

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FOREWORD

Ausgrid is responsible for the management and operation of Ausgrid's electricity supply network. The network is a major infrastructure investment, and is required to operate reliably and effectively.

The site testing requirements specified in this Network Standard are intended to satisfy electrical performance requirements, and to meet all statutory obligations.

This Network Standard may be amended or updated at any time to reflect improvements in design, technology advances etc. The personnel conducting the testing shall ensure the latest version of this Network Standard is used for the testing of the Distribution Substation to which it applies.

SCOPE

This Network Standard is intended for the testing of new pole, kiosk and chamber distribution substations.

For existing substations, authorised Ausgrid staff may decide which tests are appropriate during the augmentation. Tests selected from this Network Standard, for augmentations, shall depend on the specific substation changes completed during the works. Alternative test voltage levels and limits may be applied where appropriate, to previously in-service equipment.

Testing methods within this Network Standard supersede those in the following standards:

- NS 114 – Electrical Design and Construction Standards for Chamber Type Substations
- NS 117 – Design and Construction Standards for Kiosk Type Substations
- NS 122 – Pole Mounted Substation Construction.

DEFINITIONS

HV	High voltage is normally more than 1,000 volts alternating current (AC) or 1500 volts direct current (DC)..
LV	Low voltage is normally more than 50 volts alternating current (AC) or 120 volts ripple free direct current (DC) but is not more than 1,000 volts AC or 1500 volts DC..
DM&C	Distribution Monitoring & Control equipment used for remote monitoring and control of substations

REFERENCES

- NS 114 – Electrical Design and Construction Standards for Chamber Type Substations
- NS 116 – Design Standards for Distribution Earthing
- NS 117 – Design and Construction Standards for Kiosk Type Substations
- NS 122 – Pole Mounted Substation Construction
- NS 161 – Specification for Testing of Underground Cables
- Ausgrid's Electricity Safety Rules
- AS 60076.1 – Power Transformers – General

1 GENERAL

Checks, measurements and tests shall be conducted as per this Network Standard. Compliance shall be demonstrated throughout the procurement, construction and inspection phases of the substation project as appropriate.

The following tests, unless defined as 'Optional', are the minimum required for most new substations. Test results shall be recorded in the Test Report and made available to the relevant Ausgrid Officer prior to the inspection of the substation. See attached Transformer Commissioning/Breakdown Report (Form A153) available in numbered duplicate bound book format from Ausgrid Print Office.

The completed Test Report must be retained in the relevant Region or Area for future reference.

Testing shall be carried out during the equipping phase or on completion as appropriate and before the commissioning of the substation. Ausgrid reserves the right to witness and/or repeat any test procedure that is specified in this document.

All test equipment and instrumentation used for testing shall have been calibrated by a NATA Registered Calibration Organisation and have a current test sticker affixed. This will ensure the test equipment used is traceable.

Results of all tests are to be included in the Test Report and shall include:

- test date
- test completed
- measured values
- result expressed as pass/fail
- instrument/equipment number and calibration date.

In the event of equipment within a distribution substation being identified as defective within the warranty period, whether during testing/commissioning or operation, the Distribution Automation & Substation Engineering (DASE) section within DO&R shall be informed promptly on phone 02 93946066. For ASP equipped substation projects contact should be made through the relevant Ausgrid Officer for that project.

Contact must be made within 1 working day of the defect being identified.

Personnel shall arrange appropriate barriers and standby person(s) in accordance with their SWMS and Ausgrid's Electrical Safety Rules, prior to commencement of these tests.

Warning Electric Shock Hazard Application of test voltages to equipment will result in high voltages appearing on various equipment terminals, suitable precautions are to be taken to ensure personnel do not come into contact or near approach to live parts and test connections during testing. Closing and securing unattended kiosk doors, appropriate safety barriers/ screens and/or an observer shall be utilised to ensure adequate clearances to persons are maintained.

Warning Electric Shock Hazard Application of test voltages to equipment will result in high voltages appearing on various equipment terminals, suitable precautions are to be taken to ensure personnel do not come into contact or near approach to live parts and test connections during testing. Closing and securing unattended kiosk doors, appropriate safety barriers/ screens and/or an observer shall be utilised to ensure adequate clearances to persons are maintained.

2 TRANSFORMER & EQUIPMENT TESTING

The following tests shall be conducted on the transformer/s and associated equipment at site:

- HV and LV continuity test, refer 2.1
- insulation resistance tests on the total installation, refer 2.2 (transformers, HV & LV switchgear and power cables)
- induced HV test refer 2.3 and requirements below
- Transformer oil tests (if required refer 2.4)

The Induced HV test (Winding test) on Distribution Transformers must be conducted on all transformers at site prior to commissioning, with the following exceptions which apply under the circumstances stated:

1. or Pole Transformers to be commissioned locally, winding tests can be conducted at a depot provided that no significant cause of concern is identified over the transport and handling to site. This is the preferred option, or

2. for Pole Transformers and kiosks/padmounts where it is deemed by installation staff as impractical to conduct the testing then remote energisation of the substation from a location elsewhere on the network shall be employed as per current Operating practices.

Where Ausgrid has not supplied the transformer it must comply with Ausgrid's current specification. A copy of the transformer specification and routine test results

are to be forwarded to the relevant Ausgrid Officer, who will forward the results to Logistics & Distribution Engineering for approval. The routine test results shall include all tests as required by AS-60076 Power Transformers – Part 1 – General.

Upon approval, Logistics & Distribution Engineering shall issue an Ausgrid Transformer Asset Number (eg Txxxxxx), via the relevant Ausgrid Officer.

Prior to any testing, all Distribution Monitoring & Control (DM&C) wiring must be disconnected from the LV test and supply points.

Depending on the LV SAIF board's year of construction, the DM&C connections to be disconnected are found on the:

- Top of "Voltage Test Point Fuses" and "GPO Socket Fuse". (See DWG 202327 – Ref. 7a)

Or on earlier models -

- Voltage test point terminals labelled "Voltage Test Block" and the GPO supply terminals labelled "GPO Socket". These are found next to the CT terminal strip. (See DWG 202327 – Ref. 7c)

2.1 HV and LV Winding Continuity Tests

HV Windings

Test the continuity of the HV Windings. Conduct the test with a 1000V insulation resistance tester in continuity mode. Other suitable and calibrated ohmmeters with appropriate voltage and current outputs are acceptable. Due to the large inductances involved, it is necessary to wait until the insulation resistance tester current stabilises before accurate resistance values are recorded.

As a general rule, substantial differences between the measured resistances on delta-connected HV windings may indicate a faulty tapping switch, open/short-circuited windings or loose/faulty connections.

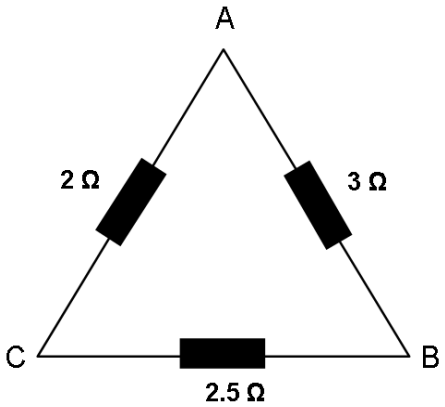

Figure 1 – Delta Connected HV Windings with example Resistances

It should be noted that one open-circuited HV delta-connected winding will not result in an infinitely high resistance on measurement.

Measuring between A and B terminals in Figure 1, the resistance when all windings are healthy will be 1.8Ω (2Ω + 2.5Ω in parallel with 3Ω).

If the winding was open-circuited between A and B terminals, the measured resistance would sum to 4.5Ω (2.5Ω + 2Ω). The two other measurements, B-C and C-A, will have respective resistances of 2.5Ω and 2Ω because the open-circuited winding prevents paralleling. Therefore, substantial differences between winding resistances need to be investigated.

LV Windings

Test the continuity of the LV Windings. Conduct test with a 1000V insulation resistance tester in continuity mode. Other suitable and calibrated ohmmeters with appropriate voltage and current output are acceptable.

For a 3-phase transformer test : a-n, b-n, c-n and n-earth.

For a single phase transformer referring to nameplate diagram, conduct the test:

- a1/a2 to a3/a4 with the winding bridges installed
- a1 to a3 and a2 to a4 with the winding bridges removed.

Due to the very low resistance of LV windings, results using a standard 1000V insulation resistance tester cannot be relied on to identify shorted windings. Only the presence of abnormally high resistance/open-circuited windings can generally be determined.

2.2 Insulation Resistance Test

Tests shall be conducted while adhering to the minimum approach distance to any energised HV mains. Using a 1000V insulation resistance tester, test and record the insulation resistance of:

- the total HV circuit, measured to earth. This test includes the HV switchgear/fuses. The transformer is to be on Tap position 1 to ensure the entire winding is tested.
- the combined LV circuits, measured to earth. This test includes the connections to the supply side of the LV switchgear/fuses. **The transformer neutral bushing is to be disconnected from earth during the test. All LV surge diverter earth connections are to be disconnected during the test.**
- the HV to LV phases**. The LV neutral shall be disconnected from earth. All LV surge diverter earth connections are to be disconnected during the test.**

For any installation, the insulation resistance measured shall not be less than:

- HV – Earth 200 M Ω *
- LV – Earth 100 M Ω
- HV – LV 200 M Ω *

* A reading of 100 M Ω + is acceptable if this is the maximum full scale reading on the insulation testing instrument.

Due to the inductive characteristics of transformers, the insulation resistance reading shall not be taken until the test current stabilises.

2.3 Induced HV (Winding) Test

Transformer testing by the manufacturer, at the manufacturer's premises, does not negate the requirement to perform this test. Subject to the exceptions set out under Section 2.

This test shall be performed before all site connections are made. For kiosk type substations this removes the possibility of damage to, or loss of grease from the HV connections separable connectors (elbows), when plugging them in and out.

The HV bushing insert connection for test purposes can be made by inserting a metallic type rod of 7.92+0.04mm (5/16”) overall maximum diameter with a tapered end to extend out a connection point for the earth test lead. Testing is to be conducted without any insulation over the exposed bushings.

LV test connections for chamber and pole substations can be made directly to the low voltage terminals. For kiosk substations the LV test connections can be made to the bottom terminals of the test auxiliary fuse holders located at the top of the SAIF LV board.

Due to the presence of High Voltage during the test, adequate safety requirements shall be met. Safe working practices shall be consistent with Ausgrid’s Electrical Safety Rules.

The induced HV test aims to prove there are no high-impedance earth faults on the transformer’s HV windings. Faults are characterised by excessive dielectric discharge. This discharge may be caused by damaged or contaminated winding insulation.

2.3.1 Induced HV (Winding) Test for Three Phase Transformers

The test involves energising individual windings on the LV (star) side using a single phase test set. This energises the corresponding HV winding. Attaching an earth to one energised HV terminal will expose the other terminal of the energised HV winding to 11kV to earth.

The practice of increasing the winding/terminal insulation to an over-voltage of 1.73 (√3) times the normal terminal operating voltage stresses the transformer’s insulation to earth. The inter-turn insulation of the energised HV Winding is also subjected to the induced voltage and therefore tested.

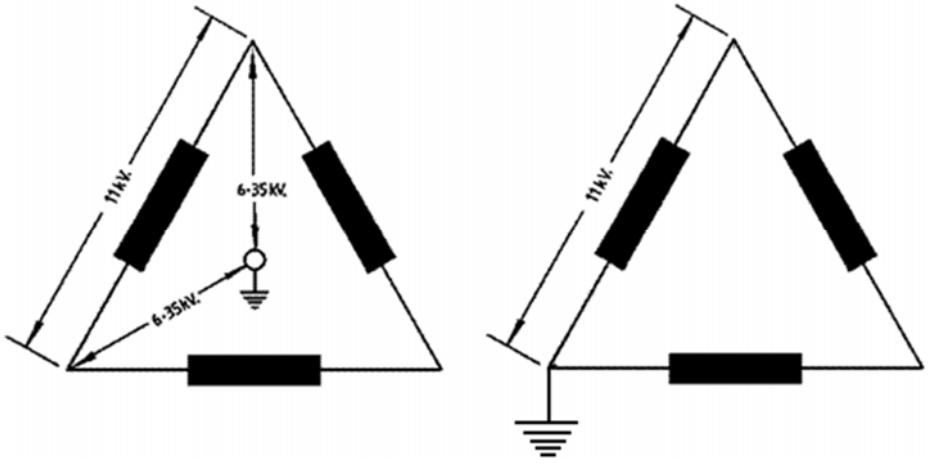

Figure 2 – Standard Delta vs. Delta winding Earthed

Earthing all HV terminals individually and energising different windings from the LV terminals, consists of 9 separate tests. There are an additional 3 tests with the HV terminals isolated. This testing method exposes any high resistance winding faults to different voltages. By monitoring the winding test set current for substantial changes, faults can be identified. If the in service earth connections to the transformer tank cannot be used then a separate conductor needs to be connected between the substation earth and the transformer tank before commencing the test.

All tests shall be conducted with the transformer on Tap position ‘1’. The entire HV winding will then be tested. This will also induce the maximum possible voltage on

the tested phase. In order to maintain safe clearances and to prevent damage to the transformer, the Tap switch must not be changed whilst testing is in progress.

Note: The transformer isolator on the LV board is to be in the "open/disconnected" position and the RMI tee off switch is also to be in the "open" position.

Current and voltage measurement should be made using a tong ammeter and digital multimeter respectively. The instruments can be connected to the test set at the positions provided.

Connection layout for the Induced HV Test on a 3 phase transformer:

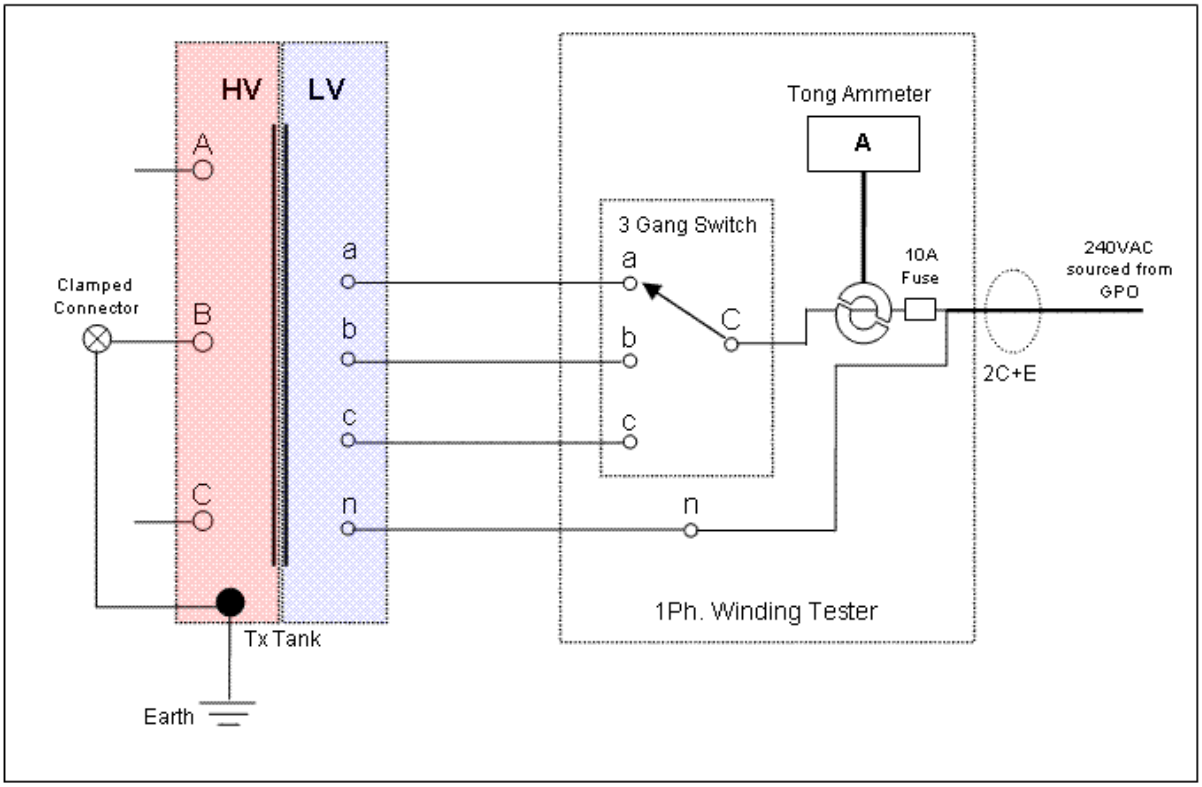

Figure 3 – Example – 1 of 9 tests with a HV terminal earthed; 'A' winding energised & 'B' terminal earthed

With the tap switch in position 1, energise the LV windings 'a'-'n', 'b'-'n' and 'c'-'n' individually. With each LV winding energised, measure the no-load current and volts with:

- HV isolated (all HV phases open circuit)
- A phase earthed
- B phase earthed
- C phase earthed

Ensure the 240VAC Winding Test Set voltage is isolated prior to changing connections.

The duration of each test should be one minute, with or without cabling attached.

Theoretically, results should indicate the current measured is the same when energising 'a' and 'c' phases. There should be a small difference in the current measured for 'b' phase injection.

Practically, the maximum permissible deviation in the current measurement is:

- ‘a’ and ‘c’ phase current variation should be a maximum of 10% of each other
- ‘b’ phase current should not be less than 60% of whichever is the lower of the ‘a’ and ‘c’ phase currents.

A winding problem could be indicated by an audible discharge from within the transformer, or the LV injection current measured is inconsistent.

If an audible discharge is heard or the LV current is inconsistent, the Distribution Automation & Substation Engineering (DASE) section within DO&R shall be informed. The transformer will generally be rejected and replaced by another.

2.3.2 Induced HV (Winding) Test for Single Phase and SWER Transformers

In a single phase 11kV or 22kV transformer, attaching an earth to one HV terminal will expose the other terminal of the HV winding to 11kV to earth or 22kV to earth respectively.

Earthing both HV terminals individually and energising a1-a2 LV terminals consists of 2 separate tests. There is one additional test with HV terminals isolated prior to those tests.

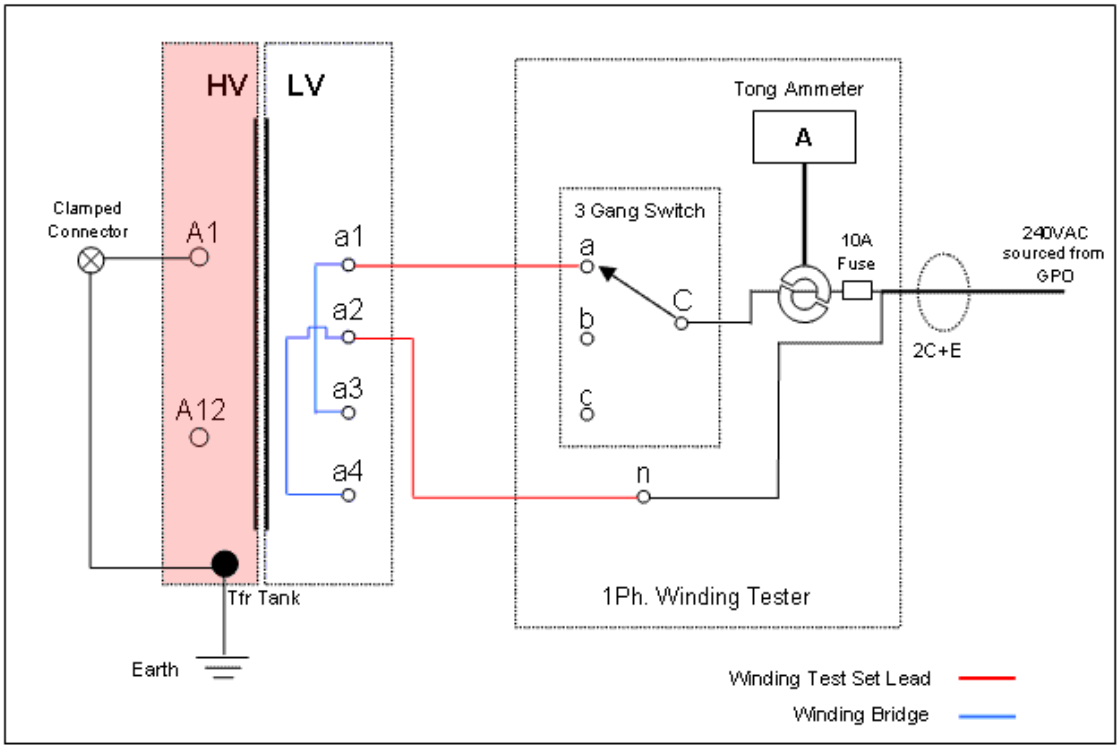

Figure 4 – Connection Layout-Single phase transformer- 1 of 3 tests with a HV terminal earthed

With the tap switch in position 1, energise the LV winding a1 and a2 terminals while a1-a3 and a2-a4 winding bridges connected. With terminals energised, measure the no-load current and volts with:

- HV isolated
- A1 terminal earthed
- A12 terminal earthed

Ensure the 240VAC Winding Test Set voltage is isolated prior to changing connections.

The duration of each test should be one minute, with or without cabling attached.

Theoretically, results should indicate the current measured is the same both for A1 and A12 terminals. Practically, the maximum permissible deviation in the current measurement is a maximum of 10% of each other.

A winding problem could be indicated by an audible discharge from within the transformer, or the LV injection current measured is inconsistent.

If an audible discharge is heard or the LV current is inconsistent, the Distribution Automation & Substation Engineering (DASE) section within DO&R shall be informed. The transformer will generally be rejected and replaced by another.

In a SWER transformer, attaching an earth to the ER terminal will expose the other terminal of the HV winding to 12.7kV to earth.

Earthing A1(ER) terminal and energising from a1-a2 LV terminals consist of only 1 test.

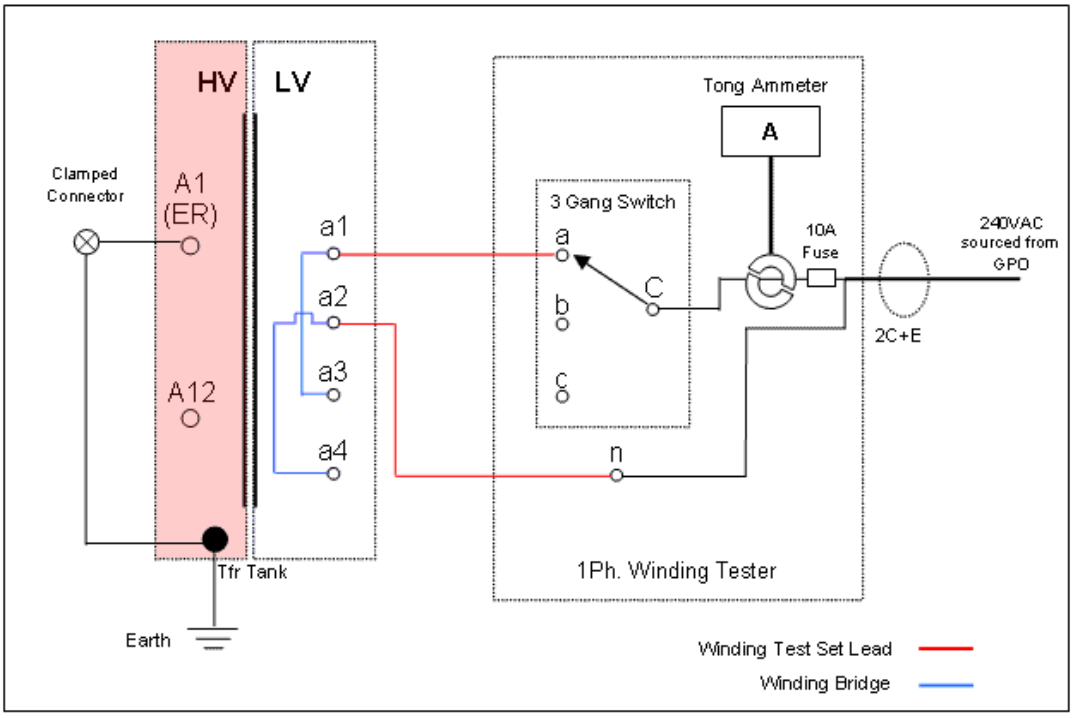

Figure 5 – Connection Layout –SWER transformer- ER terminal earthed

With the tap switch in position 1, energise the LV winding a1 and a2 terminals while a1-a3 and a2-a4 winding bridges connected. With terminals energised, measure the no-load current and volts with:

- A1 terminal (ER bushing) earthed

The duration of the test should be one minute, with or without cabling attached.

A winding problem could be indicated by an audible discharge from within the transformer, or the LV injection current measured is inconsistent.

If an audible discharge is heard or the LV current is inconsistent, the Distribution Automation & Substation Engineering (DASE) section within DO&R shall be informed. The transformer will generally be rejected and replaced by another.

2.4 Transformer Oil Tests (Optional)

Transformers supplied by Ausgrid do not require additional transformer oil tests. Transformers not supplied by Ausgrid shall comply with Ausgrid technical

specifications for distribution transformers and shall be of the sealed oil conservation system.

Additionally oil analysis of samples taken from non Ausgrid supplied transformer shall be tested by a NATA approved testing organisation in accordance with Ausgrid requirements. These requirements can be provided upon request.

2.5 Earthing Tests

The following tests are to be performed on all distribution substations, in addition to the tests detailed in NS116 – Design Standards for Distribution Earthing.

2.5.1 HV and LV Earth Continuity Test

Earth continuity is to be measured using a calibrated 1,000V insulation resistance tester on the continuity range. Other suitable ohmmeters with appropriate voltage and current outputs may be used. The earth continuity reading shall be less than 0.5Ω.

Test the earth resistance between the:

- main transformer tank earth to the substation earth bar
- LV neutral bushing to the substation earth bar.

2.5.2 HV to LV Earth Insulation Test (Segregated Earthing Installations only)

Using a 1,000V insulation resistance tester on the 1000V insulation test range, measure the insulation resistance between the HV and LV earth system.

This is to be done at the substation earth bar. This earth bond must be disconnected, where fitted, at the test point. The HV and LV earth electrode tails shall also be disconnected at the test points.

The insulation resistance reading shall not be less than 1.0 MΩ.

2.6 Voltage Withstand Test (Optional)

Ausgrid may request applied voltage withstand testing on the following equipment:

- HV racking type or site assembled multi cubicle HV switchgear
- Non Ausgrid supplied distribution transformers (this is a separate test from the Induced HV (Winding) Test required under Clause 2.3) where adequate evidence cannot be supplied of this be performed at the manufacturing works.

2.7 Connection Tightness Check

All HV & LV terminations are to be checked to ensure they have been adequately tightened. The LV board and RMI connections are to be tightened as per the manufacturer's manual required torque settings. Additionally, all site assembled LV busbar bolted joints including neutral and earth connections are to be checked for tightness. On verification of adequate tightening, each bolt head shall be marked with a marker type pen to indicate completion, a simple bold line across the bolt head will suffice. This will allow potential visual verification by the relevant Ausgrid Officer during inspection. The process of tightness checking should ideally be done during assembly works; and must be performed by an independent technician to that whom assembled the connection.

TRANSFORMER COMMISSIONING / BREAKDOWN REPORT

SUPERVISOR _____ ENG. _____ EA _____ DC _____ FILE

P.T. SUB No. _____ NAME _____ ZONE _____

STRIKE OUT ALL ITEMS THAT DO NOT APPLY

1. TRANSFORMER PARTICULARS.

NAME PLATE		H.V. CONNECTIONS	L.V. CONNECTIONS
Pos. No. in Sub _____	Make _____	Permanent / Temporary	Permanent / Temporary
S.C.C. No. _____	kVA _____	S.C.L.C. / 3. C.L.C.	S.C.L.C. / 4. C.L.C.
Ser. No. _____	Nominal Ratio _____ / _____ V.	S.C.P.V.C. / Polythene /	S.C. P.V.C. /
Cont. No. _____	Imp.% _____	Open Wiring - Solid / Stranded	Open Insulated / In Conduit.
Group Ref _____	Temp rise _____ °C	Endbox / Trunking	Endbox
Diagram of Connections. To be drawn on back on this sheet. (See B.S.I. 4033 re checking of connections and preparing diagram prior to handling over transformer to P.E. for balance checks or PE./O.E. for "Temporary phase out").		Glands	Glands
		Insulators - Terminal / Leadthrough	Insulators - Terminal / Leadthrough.
		Conductor Size _____	Conductor Size - Active _____ Neutral _____

2. PHASE ROTATION.

(Using Indicator or Lamps) Clockwise / Anticlockwise

3. VOLTAGE AND LOAD CHECK. On transformer. Tapping No. _____ _____ V. / _____ V

Transformer Voltage (No Load)		Transformer Voltage (No Load) Date _____ at _____ am/pm		
Date _____ at _____ a.m.		Volts		Amps
a-n _____	a-b _____	a-n _____	a-b _____	a phase _____
b-n _____	b-c _____	b-n _____	b-c _____	b phase _____
c-n _____	c-a _____	c-n _____	c-a _____	c phase _____
				Neutral _____

4. LOAD SHARING CHECK (MULTIPLE TRANSFORMER STATIONS)

Station M.D.I. reading _____ A. K. = _____ Time placed on load _____ am/pm

(RED HAND)

No. 1 Trans. amp.	a _____	b _____	c _____
No. 2 Trans. amp.	a _____	b _____	c _____
No. 3 Trans. amp.	a _____	b _____	c _____
No. 4 Trans. amp.	a _____	b _____	c _____

Use two instruments if available.
If load is fluctuating, estimate average value and note here.
Fluctuating / Steady

5. PROTECTION OPERATION

H.V. Fuse - Overload - Leakage - Differential - Gas Pressure.

6. EXTERNAL INSPECTION

Diaphragm broken / checked / fitted / Protective Cover Removed / Oil level checked, topped up
Breather checked / Spillage Prevention REmoved (Glass Wool Felt or Cap).
Oil thrown. Tank distorted. Smoke. Any oil leak? _____
Other damage _____

7. INTERNAL INSPECTION

Smell. Colour of oil _____
Evidence of failure _____

8. MEGGER TEST (Disconnect neutral)

Insulation Tests	MΩ	Continuity Tests	Ω		
H.V. Winding - E	_____	H.V.	A-B _____	L.V.	a-n _____
L.V. Winding - E	_____		B-C _____		b-n _____
H.V. - L.V.	_____		C-A _____		c-n _____

If L.V. - earth is less than 5MΩ and H.V. - earth is less than 20MΩ or continuity checks not balanced, isolate cables or tail and recheck. Insert figures on back of sheet. PASS / FAIL.

9. WINDING TEST

N.B. Treat Transformer as alive. Use Single Phase Supply and record the current on the three L.V. Phases with the H.V Terminals Isolated and then Earthed in turn. As far as practicable take readings at a set voltage.

H.V. WINDING	A. PHASE AMPS	B. PHASE AMPS	C. PHASE AMPS	VOLTAGE APPLIED
ISOLATED				
A. PHASE EARTHED				
B. PHASE EARTHED				
C. PHASE EARTHED				

10. GENERAL

(a) H.V. and L.V. switchgear labelled and stencilled where required _____
(b) Permanent labels have been fitted / ordered _____
(c) Are open type connections effectively shielded? H.V. / L.V. _____
(d) State if internal connections or polarity are known to be non-standard, or if external position of neutral is other than standard _____
(e) Is painting necessary? _____
(f) Transformer terminals marked on tank _____
(g) Transformer position marked on tank _____
(h) IS THE L.V. NEUTRAL CONNECTED OT THE EARTH BUS? _____

11. REMARKS:

If transformer is FAULTY, Technician Fitter is to complete Defective Apparatus Report (Area 101)

_____

_____

_____

_____

_____

_____

Commissioning Date _____ _____ Technician Date _____

A.153

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