

**1. SCOPE**

This document details PowerSystems requirements for electrical testing of HV Equipment up to and including 33kV.


**2. ISSUE RECORD**

This is a **Reference** document. The current version of **Controlled** and **Reference** documents is held on the Energy Networks Intranet Document Library.

**It is your responsibility to ensure you work to the current version.**

Issue Date	Issue No.	Author	Amendment Details
November 02	1	Alastair Graham	Initial Issue
September 2013	2	John Russell	Document Reviewed

**3. ISSUE AUTHORITY**

Author	Owner	Issue Authority
John Russell Lead Engineer	David Neilson Substation Manager	Jane Wilkie Head of Asset Management   Date: .....10/09/2013.....

**4. REVIEW**

This is a **Reference** document which has a 10 year retention period after which a reminder will be issued to review and extend retention or archive.

**5. DISTRIBUTION**

This document is not part of a Manual but it is published to the Energy Networks Internet site.

---

**6. CONTENTS**

<b>1. SCOPE.....</b>	<b>1</b>
<b>2. ISSUE RECORD.....</b>	<b>1</b>
<b>3. ISSUE AUTHORITY .....</b>	<b>1</b>
<b>4. REVIEW .....</b>	<b>1</b>
<b>5. DISTRIBUTION.....</b>	<b>1</b>
<b>6. CONTENTS .....</b>	<b>2</b>
<b>7. REFERENCES.....</b>	<b>3</b>
<b>8. RELATED DOCUMENTS .....</b>	<b>4</b>
<b>9. POLICY .....</b>	<b>5</b>
<b>9.1 Electrical Tests Required Prior to Connection to the System .....</b>	<b>5</b>
<b>9.2 Electrical Tests Required Prior to Energisation.....</b>	<b>8</b>
<b>10. GENERAL REQUIREMENTS .....</b>	<b>9</b>
<b>10.1 Safety Precautions for Pressure Testing.....</b>	<b>9</b>
<b>10.2 Special Precautions with Vacuum Switchgear .....</b>	<b>9</b>
<b>10.3 Procedure in Cases Where Pressure Testing is Not Possible .....</b>	<b>9</b>
<b>11. TESTING METHODS AND TEST VOLTAGES .....</b>	<b>10</b>
<b>11.1 Switchgear .....</b>	<b>10</b>
<b>11.2 Cables.....</b>	<b>11</b>
<b>11.2.1 Test Voltages .....</b>	<b>11</b>
<b>11.2.2 Cable Oversheath Tests for 33kV xlpe Cables .....</b>	<b>13</b>
<b>11.3 Power Transformers .....</b>	<b>14</b>
<b>11.3.1 Pole Mounted and Secondary Ground Mounted Transformers.....</b>	<b>14</b>
<b>11.3.2 Primary Transformers .....</b>	<b>15</b>
<b>11.4 Voltage Transformers .....</b>	<b>16</b>
<b>11.4.1 Un Earthed Primary Winding.....</b>	<b>16</b>
<b>11.4.2 Earthed Primary Winding.....</b>	<b>17</b>
<b>12. TESTING OF COMBINED EQUIPMENT .....</b>	<b>18</b>
<b>13. APPENDIX 1: DERIVATION OF TEST VOLTAGES .....</b>	<b>19</b>
<b>14. APPENDIX 2: FLOW CHART .....</b>	<b>19</b>

## 7. REFERENCES

**For the purpose of this Specification the following definitions shall apply:**

Company:	Refers to SP Distribution plc, SP Transmission plc and SP Manweb plc.
PowerSystems:	SP PowerSystems Ltd, operator of network assets on behalf of the Company.
SP Transmission plc	The Transmission Licence Holder for the transmission service area formally known as ScottishPower.
SP Distribution plc	The Distribution Licence Holder for the distribution service area formally known as ScottishPower
SP Distribution plc	The Distribution Licence Holder for the distribution service area formally known as ScottishPower
AC Pressure Test:	AC Power Frequency overvoltage test to ascertain suitability of plant for energisation.
DC Pressure Test:	DC overvoltage test to ascertain suitability of plant for energisation.
Equipment:	Switchgear, transformers, cables, overhead lines, surge arresters, voltage transformers, current transformers, unit substations.
Energisation:	The application of Voltage to an item(s) of Equipment from the system.
High Voltage:	An AC voltage exceeding 1000 volts measured between the phase conductors.
Insulation Resistance Test:	Impedance test to ascertain condition of insulation prior to energisation.
Approved:	Equipment which is Approved in accordance with PowerSystems documents for use or installation on the Company network.
New:	Approved Equipment which has not previously been connected to the system and which has been routine tested in a Manufacturing Facility with a Quality Management System in accordance with the relevant standard prior to delivery.
Combined Equipment:	Equipment connected with other Equipment
Previously In Service:	Equipment which, has previously been connected to the system and is deemed suitable for re-use in accordance with PowerSystems document, ASSET-01-010, PowerSystems Plant Re-Use policy, and has been electrically tested in accordance with the requirements detailed in this document.
Site Assembled Connections	Connections made/modified on site or insulation which has in some way been affected subsequent to factory testing or testing undertaken for Previously In Service Equipment. This does not include cable connections.

## 8. RELATED DOCUMENTS

It is important that users of the documents listed below ensure that they are in possession of the latest issues of the documents together with any amendments.

### Statutory Legislation

ESR 88                      Electricity Supply Regulations, 1988 (as amended)

### PowerSystems

ScottishPower Safety Rules, Electrical and Mechanical 4<sup>th</sup> Edition.

OHL-04-005,              Distribution Construction Manual - Overhead Line, Construction (DCM  
3.4.1)                      Practises

ASSET-01-010              PowerSystems Plant Re-Use policy

## 9. POLICY

Previous Testing Policy's were based on the 1937 Electricity Supply Regulations which obliged Distribution Network Operator's, to undertake Electrical Tests prior to connection of Equipment to the system. The Electricity Supply Regulations 1988, as amended, do not require Distribution Network Operator's to Pressure Test Equipment prior to installation onto the system. However ESR88, regulation 17 states "All supplier's works shall be sufficient for, and the circumstances in, which they are used and so constructed, installed, protected (both electrically and mechanically), used, and maintained as to prevent danger or interruption of supply so far as is reasonably practicable".

The PowerSystems policy for electrical testing of Company Equipment, outlined below, has been developed giving due consideration to the risks and the practical benefits. It is important not to overstress Equipment by inappropriate repetition of type or routine tests under inadequate site conditions. However, it is necessary to confirm that no damage has occurred during transportation and erection of the Equipment. The assessment undertaken by PowerSystems has shown that repeating manufacturers routine tests on New Equipment does not significantly detect manufacturing defects, but does potentially increase the risk to PowerSystems personnel on site. Therefore repeating manufacturers routine tests shall not be undertaken. For Previously In Service Equipment, appropriate tests shall be undertaken prior to installation at site in accordance with this document.

### 9.1 Electrical Tests Required Prior to Connection to the System

**When New Equipment is to be connected to the system for the first time or where Previously In Service Equipment which has been refurbished and is to be re-used, then prior to connection to the system, the Equipment shall be electrically tested in accordance with Tables 1 – 6, outlined.**

Where Equipment is being transferred from an energised in service position, to be **immediately** connected and energised to the system at another site, without refurbishment work having taken place, then there is no requirement to undertake prior to site AC pressure tests as detailed in tables 1 –6. Where required by Tables 1-6, AC pressure testing at site shall still apply.

**Table 1**

<b>Switchgear:</b>	<b>New:</b>	<b>Previously In Service:</b>
11kV, RMU's, switches and extensible secondary switchgear	No AC pressure test	AC pressure test prior to site, in accordance with tests 1-4, section 10.1 Table 8 for Previously In Service Equipment.
Primary and 33kV extensible switchgear. Outdoor 33kV circuit breakers.	AC pressure test Site Assembled Connections at site, in accordance with tests 1-3, section 10.1 Table 8 for New Equipment. <sup>(1)</sup>	AC pressure test prior to site, in accordance with tests 1-4, section 10.1 Table 8 for Previously In Service Equipment. AC pressure test Site Assembled Connections at site, in accordance with tests 1-3, section 10.1 Table 8 for Previously In Service Equipment.
Air-break switch disconnectors and Pole mounted expulsion fuses	No AC pressure test	No AC pressure test
PMAR's and pole mounted enclosed metal switches	No AC pressure test	AC pressure test prior to site, in accordance with tests 1-4, section 10.1 Table 8 for Previously In Service Equipment.
33kV RMU's	AC pressure test Site Assembled Connections at site, in accordance with tests 1-3, section 10.1 Table 8 for New Equipment.	AC pressure test prior to site, in accordance with tests 1-4, section 10.1 Table 8 for Previously In Service Equipment. AC pressure test Site Assembled Connections at site, in accordance with tests 1-3, section 10.1 Table 8 for Previously In Service Equipment.

Note (1)      Where a New panel is being added to a Previously In Service, in situ extensible switchboard, the busbars shall be tested in accordance with the Previously In Service Test Values, Table 8.

**Table 2**

<b>Cables</b>	<b>New</b>
Cable section with or without joint/termination <sup>(2)</sup>	No pressure test. 5kV insulation resistance test on cable oversheath for 33kV xlpe cables, in accordance with section 10.2.2.

Note(2): It may be prudent in certain circumstances to pressure test the cable section prior to connection to the system where it is considered appropriate to do so.

**Table 3**

<b>Transformers and Voltage Regulators:</b>	<b>New</b>	<b>Previously In Service</b>
Pole Mounted	No AC pressure test. Insulation Resistance Test (megger) on site, in accordance with section 10.3.1, installed on pole.	No AC pressure test. Insulation Resistance Test (megger) on site, in accordance with section 10.3.1, installed on pole
Ground Mounted Secondary	No AC pressure test.	No AC pressure test. Insulation Resistance Test (megger) on site, in accordance with section 10.3.1.
Primary	No AC pressure test. Insulation Resistance Test (megger) on site, in accordance with section 10.3.2.	No AC pressure test. Insulation Resistance Test (megger) on site, in accordance with section 10.3.2.

**Table 4**

<b>Voltage Transformers and Metering Units</b>	<b>New</b>	<b>Previously In Service</b>
Un-Earthed Primary Winding	500V Insulation Resistance Test (megger) the secondary (LV) winding at site, in accordance with section 10.4.1, table 7.	AC Pressure Test prior to site, in accordance with section 10.4.1, table 8. 500V Insulation Resistance Test (megger) the secondary (LV) winding at site, in accordance with section 10.4.1, table 7.
Earthed Primary Winding	500V Insulation Resistance Test (megger) the secondary (LV) winding at site, in accordance with section 10.4.2, table 9.	500V Insulation Resistance Test (megger) the secondary (LV) winding at site, in accordance with section 10.4.2, table 9.

**Table 5**

<b>Surge Arresters</b>	<b>New</b>	<b>Previously In Service</b>
	No pressure test.	5kV Insulation Resistance Test (megger) on site.

**Table 6**

<b>Unit Substations &amp; Pad Mounts</b>	<b>New</b>	<b>Previously In Service</b>
Unit Substation	No pressure test.	AC pressure test prior to site, in accordance with section 10.1

## 9.2 Electrical Tests Required Prior to Energisation

Prior to Combined Equipment being energised at system voltage, electrical tests shall be performed in accordance with Table 7.

**Table 7**

<b>Combined Equipment</b>		
Cable + Switchgear excluding Transformer <sup>(3), (4), (5)</sup>		Phase – Phase and Phase – Earth, DC pressure test combined installation in accordance with section 11.
Cable + Switchgear including Transformer <sup>(3), (4), (5)</sup>		Phase- Earth, DC pressure test combined installation in accordance with section 11.
Cable + Transformer		Phase- Earth, DC pressure test combined installation in accordance with section 11.
Cable + Cable	11kV fault repairs and small deviations, typically less than 30m	5kV Insulation Resistance Test (megger).
	All other 11kV cable –cable installations	Phase – Phase and Phase – Earth (where appropriate), DC pressure test combined installation in accordance with section 11.
	33kV cable – cable installations	Phase – Earth, DC pressure test combined installation in accordance with section 11.
Overhead Line + Pole Mounted Equipment		5kV Insulation Resistance Test (megger), installed on pole. Visual Inspection in accordance with PowerSystems document OHL-04-005.

- Notes
- (3) Surge Arresters may be left connected during DC Pressure Testing
  - (4) Precautions shall be taken to disconnect VT's prior to DC Pressure Testing.
  - (5) 33kV outdoor circuit breaker no additional DC test required.



## 10. GENERAL REQUIREMENTS

Electrical tests shall be carried out by suitably Authorised or trained Persons using PowerSystems Approved Equipment. The testing shall be conducted in accordance with the requirements of the current ScottishPower Safety Rules, Electrical & Mechanical, where applicable.

The pressure test voltage shall be increased gradually to the specified value and maintained for the specified time.

### 10.1 Safety Precautions for Pressure Testing

Special precautions shall apply for high voltage testing to ensure safety:

- In locations permanently set aside for pressure testing, the control point shall be such that the operator has full view of the apparatus under test to ensure that no one is in the danger zone. Security arrangements in the danger zone shall incorporate a reliable system of indications and also where applicable interlocks that de-energise the zone if anyone attempts to enter it.
- Where testing is to be done on site, then this shall be done in accordance with the Scottish Power Safety Rules, PSSI 9.
- For reasons of both safety and accuracy, it is essential that the Equipment under test be earthed both before and after the application of the test potential.

### 10.2 Special Precautions with Vacuum Switchgear

Vacuum switchgear, may generate x-rays when the open contact gap is stressed at high voltage, however under normal system voltage and pressure test values detailed within this document, there are no harmful emissions. As an additional safeguard to personnel, the Equipment must be tested with the vacuum interrupters contained in the manufacturers' normal housing and all personnel be positioned not less than 2 metres away from the unit under test.

### 10.3 Procedure in Cases Where Pressure Testing is Not Possible

**In exceptional circumstances where on-site testing is not possible but is required by this document, then prior to any Equipment being Energised, written authority shall be obtained from the Customer Operations Manager or his nominated representative.**

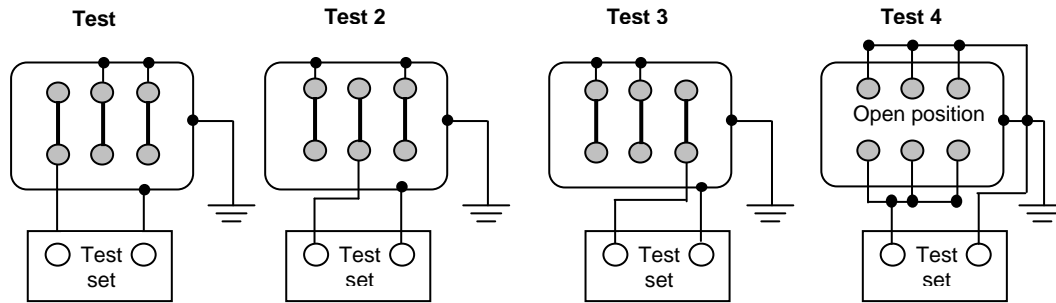
**In some cases where this document requires prior to site tests, it may be permissible to undertake these tests at site. This shall be at the discretion of the Customer Operations Manager or his nominated representative.**

**11. TESTING METHODS AND TEST VOLTAGES**

PowerSystems testing policy requires a combination of both AC and DC Pressure Testing and Insulation Resistance Testing, as detailed within section 8. Irrespective of whether AC or DC testing is carried out the insulation will retain a high voltage charge upon completion of the test. For safety reasons this shall be safely discharged through an impedance to earth.

**11.1 Switchgear**

Where required by section 8.1, Pressure test voltages shall be AC at power frequency in accordance with Table 1 and the appropriate values detailed in Table 8. The test connections shall be as shown in Figure 1. In tests 1,2 and 3 the tests voltage shall be carried out on the conductors of all sections of the switchgear by closing the switch device in order to test the complete assembly. Where circumstances preclude this, the test shall be applied to each discrete portion, as necessary.



**Figure 1. Test Connections for Pressure Testing Switchgear**

Voltage transformers shall be isolated during the pressure testing of the switchgear by being withdrawn or on non withdrawable units, by removing the HV connection. Current transformers secondaries shall not normally be short circuited nor shall relays, instruments and other auxiliary apparatus be disconnected.

**Table 8. Test Voltages for Switchgear**

Rated Voltage (kV)	AC test voltage (kV rms)	
	New Equipment	Previously In Service
3.3	-	4.0
6.6	-	8.0
11	22.4	12.0
22	40.0	25.0
33	56.0	36.0
Test Duration - 1 minute		

*The above test values are for discrete switchgear apparatus (ie before being connected to the system). The values shall not be employed for switchgear that forms part of the system. After the switchgear is connected to the system the combined Equipment shall be DC pressure tested in accordance with section 8.2 and test values detailed in section 11, Table 10.*

## 11.2 Cables

It is not normally required to pressure test cables prior to connection to the system, however it may be prudent in certain circumstances to pressure test the New cable section prior to connection to the system where it is considered appropriate to do so.

Where deemed necessary by Table 2, DC test voltages shall be used for pressure testing cables. The respective test voltages and test connections are indicated in the following sections.

### 11.2.1 Test Voltages

Where deemed necessary by Table 2, the test voltages for complete cable circuits shall be in accordance with the values given in Table 9. The test connections are shown in Figures 2, 3 and 4

The current observed during a DC pressure test will initially include the charging current. After full voltage is reached the charging current will decay and the remaining leakage current is used to indicate the condition of the cable. The leakage current of a healthy cable should be less than 0.2mA although it may be greater depending on the length of cable and termination arrangement.

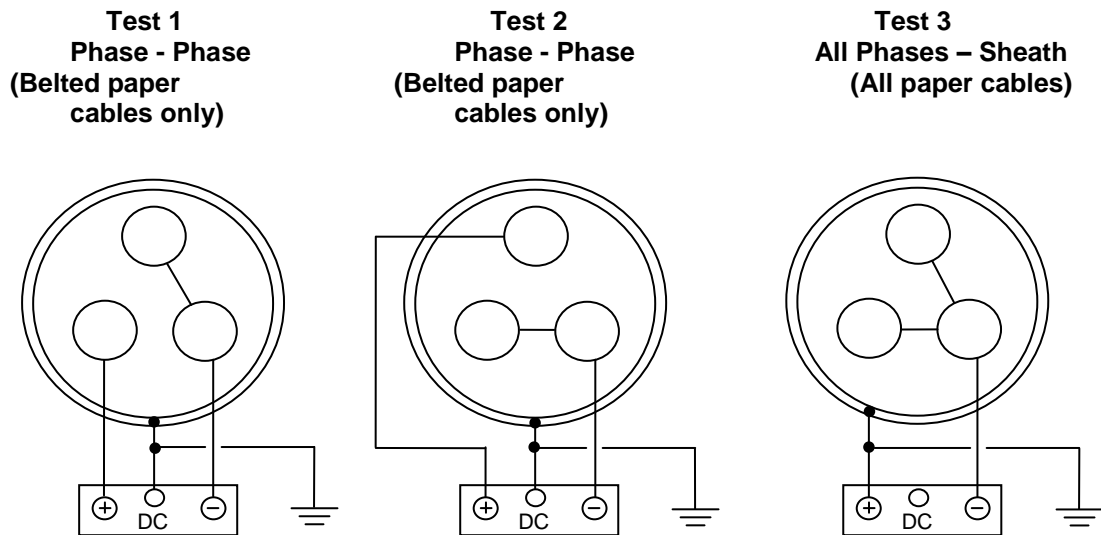
**Table 9. Test Voltages cables**

		DC test voltage (kV)	
		New cables Only	
Voltage (kV)	Cable Type	Phase - Phase	Phase - Earth
3.3	Belted Paper	5	3
6.6	Belted Paper	10	6
	Screened XLPE	[6]	6
11	Belted paper	17	10
	Screened Paper	[6]	10
	Screened XLPE		10
22	Screened Paper		20
	Screened XLPE		20
33	Screened Paper		30
	Screened XLPE		30
		Test duration – 5 minutes	

Note:[6]Not applicable - phase to phase tests are not carried out for screened cables

Where the circuit to be tested includes both belted and screened cable types, the test connections appropriate to screened cables shall be used and only the appropriate phase to earth tests shall be carried out.

The cable under test must be discharged to earth after each pressure test and the conductors must all be connected to earth whilst the test lead connections are being modified.



**Figure 2. Test Connections for Pressure Testing Complete Paper Insulated Cable Circuits**

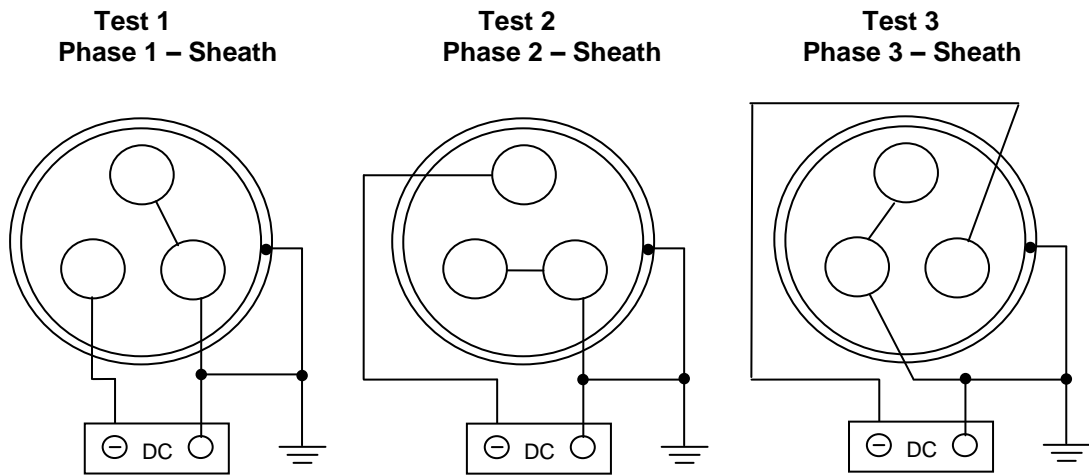


Figure 3. Test Connections for Pressure Testing three core Polymeric Cable Circuits

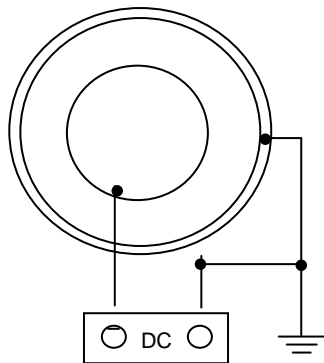


Figure 4. Test connections for Pressure testing single core polymeric cables

#### 11.2.2 Cable Oversheath Tests for 33kV xlpe Cables

The overshaths of 33kV xlpe insulated cables shall be tested and proved to be intact after laying and backfilling but before jointing/connection.

*A 5kV insulation resistance test shall be applied for 1 minute between the copper screen wires and an earth electrode. Cables for use in ducted installations shall have a conductive outer layer and the insulation resistance test shall be applied between this layer and the screen wires.*

### 11.3 Power Transformers

Where required by section 8, transformers shall be Insulation Resistance tested. A distinction is made between primary and secondary transformer types with the respective test connections indicated in the following sections.

#### 11.3.1 Pole Mounted and Secondary Ground Mounted Transformers

Where required by section 8.1, Table 3, Pole mounted and secondary ground mounted transformers shall be tested after erection and prior to energisation.

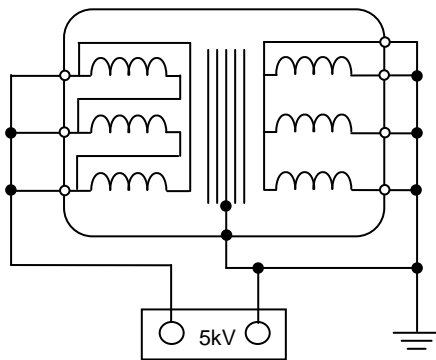
The test shall comprise two parts, 1) the HV winding tested to the LV and earth, and 2) the LV winding tested to HV and earth.

Test 1) shall be made by application of a voltage of **5kV to the HV winding** applied for 1 minute. Test 2) shall be made by the application of a voltage of **1kV applied to the LV winding** for 1 minute. The test voltage may be derived from a suitably Approved constant voltage insulation test set.

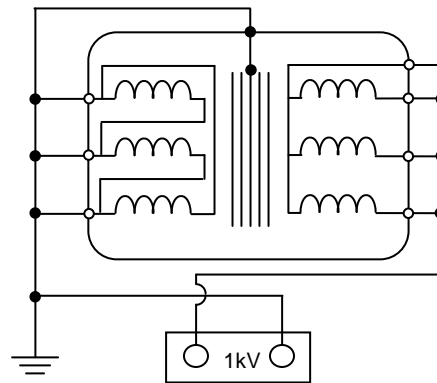
The transformer shall be considered suitable for connection to the system if the insulation of both windings is greater than 200 MΩ. (This value may be affected by moisture on exterior bushings)

The test connections to be used are detailed in Figure 5.

**Test 1 - HV Winding Test**



**Test 2 - LV Winding Test**



**Figure 5. Test Connections for Insulation Resistance Testing Pole Mounted and Secondary Ground Mounted Power Transformers**

### 11.3.2 Primary Transformers

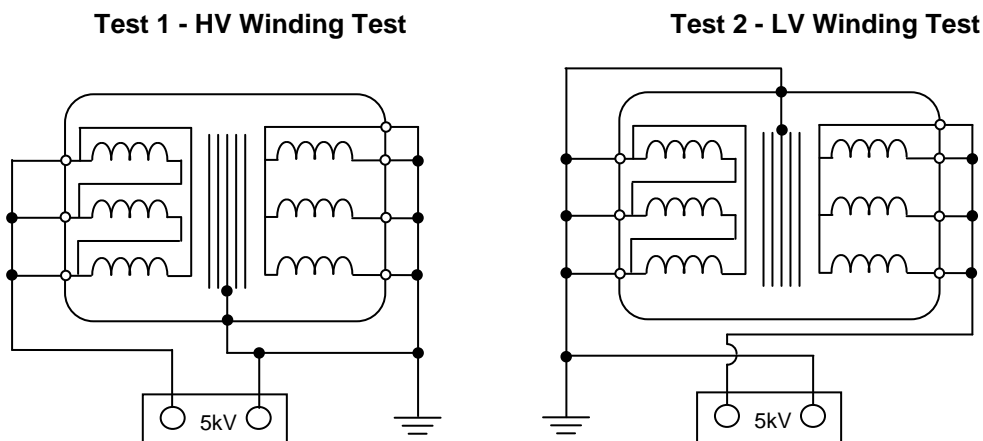
In addition to the pre-commissioning checks required for new primary transformers, each transformer shall be subjected to an on site insulation resistance test prior to commissioning.

The test shall comprise two parts, 1) the HV winding tested to the LV and earth, and 2) the LV winding tested to HV and earth.

The tests shall be made by application of a voltage of 5kV to the winding under test, applied for 1 minute. The test voltage may be derived from a suitably Approved constant voltage insulation test set.

The transformer shall be considered suitable for connection to the system if the insulation of both windings is greater than 200 MΩ. (This value may be affected by moisture on exterior bushings)

The test connections to be used are detailed in Figure 6.

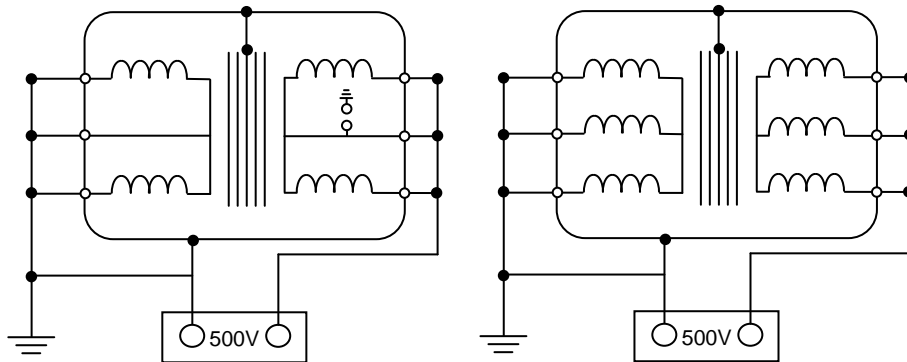


**Figure 6. Test Connections for Insulation Resistance Testing of Primary Transformers**

## 11.4 Voltage Transformers

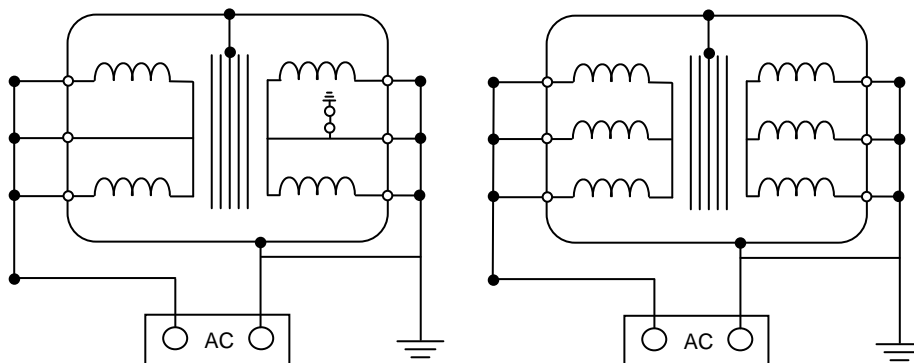
*Voltage transformers shall be tested in accordance with section 8.1 table 4, prior to energisation.*

### 11.4.1 Un Earthed Primary Winding



**Fig 7. Insulation Resistance LV Winding Test**

Where the yellow phase is earthed, the earth link shall be removed prior to testing. The test voltage of 500V shall be applied for 1 minute between earth and all terminals of the secondary winding connected together. All other terminals shall be earthed. **On completion of the test the yellow phase earth link shall be replaced, where appropriate.**

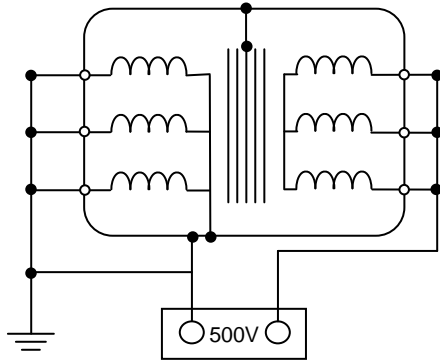


**Fig 8. AC Pressure Test**

*AC Pressure Test, in accordance with section 10.1, Table 8 for Previously In Service switchgear. The test voltage shall be applied for 1 minute between earth and all the terminals of the primary winding. The test connections shown should not be used for VT's with earthed primary windings, as the test voltage may result in breakdown of the star point insulation.*



#### 11.4.2 Earthed Primary Winding



**Fig 9. Insulation Resistance LV Winding Test**

The test voltage of 500V shall be applied for 1 minute between earth and all terminals of the secondary winding connected together. All other terminals shall be earthed. **The primary earth should not be removed for testing.**

**12. TESTING OF COMBINED EQUIPMENT**

*Electrical tests on Combined Equipment where required by section 8.2, shall be undertaken prior to energisation at the test voltages detailed in table 10.*

**Table 10. Test Voltages for Combined Equipment**

Rated Voltage(kV)	DC test voltage (kV)	
	Phase - Phase	Phase - Earth
3.3	5.0	3.0
6.6	10.0	6.0
11	17.0	10.0
22	34.0	20.0
33	51.0	30.0
Test Duration - 5 minutes		

The design specification for all existing switching devices are such that there is a substantial margin of safety across the isolating gap when it is stressed on either side by simultaneous application of system and test voltages for combined plant given in Table 10.

**13. APPENDIX 1: DERIVATION OF TEST VOLTAGES**

This appendix has been included to detail how the values for AC and DC Pressure Test voltages were derived.

Rated Voltage of Equipment	System Voltage: Phase - Phase	System Voltage Phase - Earth	New AC Pressure Test, IEC 298	Reduced Value AC Pressure Test	DC Pressure Test Phase Earth (Combined)	DC Pressure Test Phase Phase Voltage (Combined)
(7)			(8)	(9)	(10)	(11)
	3300	1905		3630	2964	5134
12000	6600	3811		7260	5928	10267
12000	11000	6351	22400	12100	9880	17112
36000	22000	12702	40000	24200	19759	34224
36000	33000	19053	56000	36300	29639	51336

Notes:

- (7) For 6.6kV the rated voltage of New Equipment is 12kV, For 22kV the rated voltage of New Equipment is 36kV.
- (8) New AC Pressure Test, IEC 694: For switchgear, Appendix DD of IEC 298. This is 80% of values detailed in table 1a of IEC694.
- (9) Reduced Value AC Pressure Test, for Previously In Service Switchgear. System voltage \* 1.1.
- (10) DC Pressure Test, Phase – Earth. System voltage \* sqrt(2) \* 1.1) / sqrt (3)
- (11) DC Pressure Test, Phase – Phase. System voltage \* sqrt(2)

**14. APPENDIX 2: FLOW CHART**

See Document SUB-02-613 (Appendix 2), published separately.