INTERPLANT STANDARD - STEEL INDUSTRY		
IPSS	**CODE OF PRACTICE FOR TESTING & COMMISSIONING OF TRANSFORMERS AND RELATED SWITCHGEARS**	**IPSS:1-04-035-08**
	Corresponding IS does not exist	

0. FOREWORD

0.1 This Inter Plant Standard has been prepared by the Standards Committee on Switchgear and Controlgear, IPSS 1:4 with the active participation of the representatives of the steel plants & reputed consulting organizations and was adopted in March 2008.

1. SCOPE

1.1 The code of practice on testing and commissioning of transformers and related switchgear covers guidance on testing and commissioning of power and distribution transformers. It is intended as a guide to testing and commissioning engineers, contractors and others engaged in the testing and commissioning of power and distribution transformers and related switchgears.

1.2 Special purpose transformers such as gas cooled, synthetic liquid insulated, dry type, mining transformers, converter transformers and instrument transformers are excluded from the scope of this code. In such cases, manufacturers instructions shall be strictly followed. A list of such special purpose transformers is given in **Appendix-A.**

1.3 In the preparation of this code, considerable assistance has been derived from the following :

a) IS 2026:1981 (Part I to IV), Specification for Power Transformers

b) IS 10028:1981, Code of Practice for Selection, Installation and Maintenance of Transformers

c) Electrical Engineer's Reference Book - by M G Say

d) Erection, Maintenance & Operation Manual for Power Transformers issued by NGEF Ltd

e) Manual on Transformers (Revised - 1987)

Section J Test Manual For Transformers

Section K Erection, Maintenance and Commissioning Manual - Issued by the Central Board of Irrigation & Power

f) Installation, Operation & Maintenance Instructions for Transformers - issued by Siemens.

2. TESTING

2.1 General - The normal practice for testing Power and Distribution Transformers is to carry out a comprehensive set of tests at the manufacturer's works - the number and nature of which depend on whether the transformer is the first of a new design or otherwise; and a few relatively sample tests after installation at site to prove that the transformer is ready for service. The two classes of works tests are referred to as "Type" and "Routine" respectively. The first transformer of a particular design is subjected to both "type" and "routine" tests, while `routine tests' only are applied to later units.

2.2 General Requirements for Type, Routine and Special Tests:

2.2.1 Tests shall be made at any ambient air temperature below 50^{o}C and with cooling water (if required) at any temperature not exceeding 30^{o}C.

2.2.2 Tests shall be made at the manufacturer's works, unless otherwise agreed between the manufacturer and the purchaser.

2.2.3 All external components and fitting that are likely to affect the performance of the transformer during the test, shall be in place.

2.2.4 Tapped windings shall be connected on their principal tapping, unless the relevant test clause requires otherwise or unless the manufacturer and the purchaser agree otherwise.

2.2.5 The test basis for all characteristics, other than insulation, is the rated condition unless the test clause states otherwise.

2.2.6 Where it is required, test results shall be corrected to a reference temperature of 75^{o}C.

2.2.7 Tests are not required to be performed on bought-out equipments like oil coolers, oil actuated relays etc at the works of the transformer manufacturer. Furnishing test certificates from the OEM works, shall be deemed to be satisfactory evidence. Inspection of tests at the sub-contractor's works will be arranged by the supplier wherever required.

2.3 Type Tests

2.3.1 *The following shall constitute the type tests* :

a) Measurement of winding resistance ;

b) Measurement of voltage ratio and check of voltage vector relationship;

c) Measurement of impedance voltage/short-circuit impedance (principal tapping) and load loss;

d) Measurement of no-load loss and current;

e) Measurement of insulation resistance;

f) Dielectric tests; (Tan delta tests)

g) Temperature - rise; and

h) Tests on on-load tap changers, wherever appropriate.

2.3.2 *Additional Type Tests* - Following additional type tests shall also be conducted on 420 kV class Power Transformers.

2.3.2.1 Transformer Tank

a) *Vacuum Tests* - One transformer tank of each size shall be subjected to full vaccum and tested at an internal pressure of 3.33 kN/m^2 (25 torr) for one hour. The permanent deflection of flat plates after the vacuum has been released, shall not exceed the value specified below and the performance of the transformers shall not be affected in any way.

Horizontal length of flat plate (mm)	**Permanent deflection** (mm)
Upto and including 750	5.0
751 to 1250	6.5
1251 to 1750	8.0
1751 to 2000	9.5
2001 to 2250	11.0
2251 to 2500	12.5
2501 to 3000	16.0
Above 3000	19.0

b) *Pressure Test* - One transformer tank of each size together with its radiators, conservator vessel and other fittings shall be subjected to a pressure corresponding to twice the normal head of oil or to normal pressure plus 35 kN/m^2 whichever is lower. The applied pressure shall be measured at the base of the tank and maintained for one hour. The permanent deflection of flat plates after the excess pressure has been released, shall not exceed the values specified in a) above.

2.3.2.2 Relief Device - The pressure relief device of each size shall be subjected to increasing oil pressure. It shall operate before reaching the test pressure specified in the test at b). The operating pressure shall be recorded. The device shall seat - off after the excess pressure has been relieved.

2.4 Routine Tests

2.4.1 *The following shall constitute the routine tests* :

a) Measurement of winding resistance;

b) Measurement of voltage ratio and check of voltage vector relationship;

c) Measurement of impedance voltage/short-circuit impedance (principal tapping) and load loss;

d) Measurement of no-load loss and current;

e) Measurement of insulation resistance;

f) Dielectric tests; and

g) Tests on on-load tap-changers, wherever appropriate.

2.4.2 Additional Routine Tests - Following additional routine tests shall also be conducted on 420 kV class Power transformers:

2.4.2.1 Magnetic Circuit Test - After assembly, each core shall be tested for 1 minute at 2000 V ac between all bolts, side plates and structural steel work. Immediately prior to despatch of the transformer from the manufacturer's works, the magnetic circuit shall be pressure tested for 1 minute at 2000 V ac between the core and earth.

2.4.2.2 Oil Leakage Test on Transformer Tank - All tanks and oil-filled compartments shall be tested for oil tightness by completely filling with air/oil of a viscosity not greater than that of insulating oil conforming to IS 335:1993 New insulating oils (*fourth revision*) at the ambient temperature and applying a pressure equal to the normal pressure plus 35 kN/m^2 (5 lb/sq inch) measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil and 1 hour for air, during which time no leakage shall occur.

2.5 Special Tests

2.5.1 The following tests shall be carried out by mutual agreement between the purchaser and the supplier :

a) Measurement of zero-sequence impedance of three-phase transformers;

b) Short-Circuit test;

c) Measurement of accoustic noise level;

d) Measurement of the harmonics of the no-load current;

e) Measurement of the power taken by the fans and oil pumps; and

f) Partial discharge measurement of condenser bushings.

2.5.2 If special tests other than those listed in clause no. 2.5 are required, the test method shall be subject to agreement between the manufacturer and the purchaser.

2.6 Rules For Some Special Classes of Transformers

2.6.1 In transformers, where uniformly insulated windings having different Um values are connected together within the transformer (usually auto transformers), the test voltage for separate - source power - frequency withstand test shall be determined by the winding with the highest Um value.

NOTE : Um = Highest voltage for equipment

2.6.2 For transformers with a high voltage winding having Um>300 kV, lightning impulse tests are routine tests for all windings.

2.6.3 In transformers, which have one or more non-uniformly insulated windings, the test voltage for:

a) The induced over-voltage withstand test, and for

b) The switching impulse test, if used;

are determined by the winding with the highest Um value, and the windings with lower Um values may not receive their appropriate test voltages. This discrepancy should normally be accepted.

2.6.4 During switching impulse tests, the voltages developed across different windings are approximately proportional to the turns ratios. If rated switching impulse withstand voltages are assigned to several windings, the problem shall be solved as specified in clause 2.6.3. A tapped winding of lower Um without

assigned switching impulse withstand voltage shall be connected on its principal tapping during the switching impulse test.

2.6.5 Series windings in booster regulating transformers, phase shifting transformers, etc., where the rated voltage of the winding is only a small fraction of the voltage of the system, shall have a value of Um corresponding to the system voltage.

2.7 Tests on Oil

2.7.1 Following tests shall be conducted on oil samples drawn from transformer tank and OLTC chamber:

i) Break down voltage
ii) Tan delta
iii) Water content
iv) Acidity

2.7.2 Dielectric Strength Test of Oil - In order to obtain a representative sample of the oil, extreme care should be taken and absolute cleanliness observed when extracting the sample. Proceed as follows :

a) Use only wide-necked glass bottles, of atleast 1 litre capacity, with glass stoppers (not corks), for collecting the sample.

b) Before use, the bottles should be thoroughly cleaned with pure benzene, or a detergent, and perfectly dried.

c) The sample is to be drawn from the bottom drain valve after the transformer is left undisturbed for sufficient time.

d) In order to remove any moisture or dirt adhering to the valve passage, allow about 4 to 5 litres of oil to drain off into a clean dry vessel before extracting the sample into the bottle.

e) The sample should then be tested for its dielectric strength as per IS 335:1993.

The above procedure also applies, in essence, to askarels.

3. PREPARING FOR COMMISSIONING (GENERAL CHECKS)

3.1 Prior to putting the transformer into service, attention should be paid to the following points :

1) Check and correct the level of oil in the conservator, bushings, diverter switch tank etc.

2) Check that the colour of the silica-gel in the breather is blue.

3) Check the various protective devices and their signaling and tripping contacts for foolproof operation.

4) Check all flanges, joints and fittings for oil leaks and retighten the flange bolts etc, if necessary.

5) Make sure that all the butterfly valves of the radiators (whenever provided) are open.

6) Open all the plugs/venting screws on radiators, bushings, Buchholz relay and tank cover until oil appears and then close them, making sure that no air remains inside the transformer tank.

7) Check that the transformer is properly earthed.

8) Check that the tapping switch is on the desired position.

9) Check and adjust arcing horn gaps on bushings.

10) Check that the thermometer pockets are filled with oil.

11) Check the heaters provided in cubicles, conservator etc.

12) In the case of water cooled transformers, the pressure gauge readings on both water and oil sides to confirm that the water pressure is less than the oil pressure. The quantity of oil and water flow should not be less than specified.

4. TEST BEFORE SWITCHING ON (PRE-COMMISSIONING TESTS)

4.1 These vary considerably with the size and importance of the installation.

4.2 For a small or medium-sized distribution transformer, the minimum requirements would be visual examination for transport damage and an insulation test with a portable instrument. Preferably there should be a check of the ratio (by applying a medium voltage to the HV terminals and measuring the induced voltage at the LV terminals), and on the oil level and condition to confirm that ingress of moisture has not occured. Measurements of ratio and of polarity are essential if a transformer is to be connected into a circuit where it will operate in parallel with other transformers.

4.3 On large units, which are normally despatched either without oil or only partially filled, checks must be made on the filling procedure and of the condition of the oil prior to filling, in addition to ensuring that the insulation has not become wet during transport.

4.4 Auxiliary equipment such as on-load tap-changing gear and any protective relays and current transformers associated with the main transformer must also be checked for correct operation.

4.5 In general, a repetition of high-voltage tests carried out at the works is not considered to be necessary. Where the transformer is subjected to re-testing at site at high-voltage, the test-voltage level is normally restricted to 75% of the applied voltage during tests at the works.

4.6 The tests to be carried out at site before commissioning the transformer will depend upon :

- The voltage and kVA rating of the transformer,
- Facilities available at site, and
- Conditions of contract.

Appendix - B gives typical tests to be carried out.

5. ENERGIZING

5.1 If all the above tests/checks are found satisfactory, allow a settling time of at least 24 hours for oil and release air from all points. Now the transformer can be energized after setting the protective relays to the minimum extent possible. Wherever possible, the voltage should be built up in steps. Any abnormality during commissioning such as vibration of radiator parts, hum etc should be observed. After a few hours of energization at no-load, the transformer shall be switched off. The Buchholtz relay should be checked for collection of air/gas. Abnormalities noticed should be corrected. All protective relays should be reset to normal values. Transformer can now be re-energized and loaded gradually.

5.2 After commissioning, the following details should be furnished to the manufacturer :

i) Details of transformer including its serial number.

ii) Date of commissioning, with test results.

iii) Substation/Generating station where commissioned.

iv) Protection given to the transformer such as lightning arrestor, differential protection, circuit breaker on HV/LV side etc.

v) Loading details.

6. CONTROL PANEL FOR `ON LOAD TAP CHANGINGS' AND PARALLEL OPERATION OF TRANSFORMERS

6.1 General - If a transformer is to be connected to run in parallel with an existing transformer, then the following conditions must be fulfilled :

i) Identical voltage ratio on all tappings

ii) Percentage impedance within $\pm$10% tolerance

iii) Rated output of transformers should not differ by more than 1:3

iv) Polarity must be same

v) Frequency must be same

vi) Vector symbols and group numbers

Transformers with Vector symbols of the same group number can be operated in parallel. The phase sequence should be well observed. Transformers having the group numbers 3 and 4 can be considered properly connected for parallel operation when the terminals are connected in the following manner :

		H V side	**L V side**
Transformers having group number	3	ABC	abc
	4 or	ACB CBA	acb cba
	or	BAC	bac

Connections in Group A shall not be paralleled with those in Group B.

Group A - star/star, delta/delta, and delta/zig-zag

Group B - delta/star, star/delta, and star/zig-zag

6.2 **Control Panel For `On Load Tap Changings'** - One number control panel is required for each of the transformers to be operated in parallel. The transformers can also be operated individually.

The incoming supply of 415 V, 3 phase, 50 Hz is taken to one of the control panels and the supply to the other panel is taken from this panel.

6.3 Equipment Details

6.3.1 Control Switches - There are three selector switches:

a) Parallel/Individual selector switch (b15)

For operation of the transformers either individually or in parallel.

b) Local/Remote Selector Switch (b10)

When the transformers are operated individually, then on-load tap changing can be carried out either locally or from remote. When the transformers are operated in parallel, only remote operation is possible.

c) Master/Follower Selector Switch (b20)

This selector switch is used to make one of the transformers Master and the other Follower. A lock with key is provided for each of the selector switch (b20), such that the key can be taken out only in Follower position. When operating in parallel, only one number key is to be used, i.e. only one number key is accessible to the operator. Therefore, it is not possible to make both the transformers Master.

6.3.2 Time relays - Two Time Relays; one (d5) for OLTC gear operation discrepancy supervision with a time adjustment range 0-10 seconds and the other(d9) for parallel - out of stop with 0-10 seconds are provided. Time relay d5 is set at 6 seconds and d9 is also set at 6 seconds. (The motor drive takes about 5 seconds for each tap changing).

Two indicating relays (d6 and d10) for visual indication of the OLTC gear operation discrepancy and taps-out of step indication respectively are provided. One of the contacts of the indication relays are used with contacts d11 and d12 for energizing the Alarm Horn. The indicating relay can be reset thus resetting the Alarm Horn. The tap changer in progress is indicated by an indicating lamp (h10).

6.4 Operation - The following sequence of operation to be followed strictly while carrying out the tap changing operation or parallel operation of two transformers. Keep the selector switch b15 in individual position, selector switch b10 in local position and selector switch b20 in the Follower position.

6.5 Parallel Operation

6.5.1 Suppose Transformer - 1 is to be operated as `Master' and the Transformer - 2 to be operated as `Follower'. Let us say, control panel corresponding to Transformer-1 is Panel-1 and the control Panel Corresponding to Transformer-2 is Panel-2.

6.5.2 Now, give the supply to the control panels. On giving supply to the control panels, see whether the tap positions of the two transformers are at the same tap. If not, bring them to same tap by operating the transformers individually. Now keep the control switches b10 in both the panels in remote position, control switch b20 in panel-1 in Master position and in Panel-2 in Follower position. Control switches b15 in both the panels in parallel position.

Pressing the push-button (b4 or b3) of Panel-1, the Motor Drive is made to operate, simultaneously the Motor Drive of the Transformer-2 also starts operating. The time relays d5 of Panel-1 and Panel-2 are energized through the N.O. contacts of contactors d4 of Panel-1 and Panel-2 which are energized as soon as the motor drive gets the supply. Indicating lamps h10 glow from the time of motor starting to the time of motor stopping indicating the Tap-changer in progress.

6.5.3 At the end of one tap change operation, the supply to motor is automatically cut-off thus stopping the Motor Drive. For the further tap changing operation the procedure is repeated. If one tap changing operation takes more than 6 seconds due to some discrepancy in the OLTC gear, at the end of 6 seconds, the corresponding Time Relay d5 operates, thus instantly cutting off the supply to motor through its contact d5, which trips the air circuit-breaker controlling the motor. Simultaneously, the corresponding indicating relay d6 operates giving visual indication. An Alarm horn is also energized giving audible alarm. The Alarm horn can be stopped by resetting the indicating relay. The sequence of operation is same even if the Transformer-2 is made Master and Transformer-1 the Follower.

6.5.4 During the Parallel operation, if due to some discrepancy the two transformers become out of step, the contactor d7 of the Follower Panel-2 de-energizes, thus de-energizing the contactor d8. The N.C. contact of d8 energizes the Time Relay d9. After the lapse of seconds, the contacts of Time Relay operate thus cutting off the supply to control circuit of the motor drive by opening the NC contact d9. Thus preventing further tap changing operation.

6.6 Individual Operation

6.6.1 The Master/Follower switch in both the panels is kept in Follower position, Local/Remote Selector switch in Remote position and the Individual/Parallel in Individual position.

6.6.2 By pressing the push-button, the Motor Drive of the OLTC gear can be operated. In this case, when the Motor Drive of Transformer-1 operates, the Motor Drive of Transformer-2 does not follow automatically. But it has to be operated separately.

6.6.3 Provision is also made to :

1) Trip the corresponding circuit Breaker controlling the transformer when there is discrepancy in the OLTC gear operation, and

2) Trip both the circuit breakers controlling the two transformers in parallel, when the taps are out of step.

6.6.4 A separate switch for the supply is to be used. This is not included in the control panel. This switch should be closed at the correct time.

6.7 General Equipment Details

b10 :
b15 : Selector switches
b20 :

d5 :
d9 : Time Relays

d6 :
d10 : Indicating Relays

d11 :
d12 : Contactors for control circuit

h10 : Indicating Lamp
d7 :
d8 : Contactors

b3 :
b4 : Push buttons

7. PRE-COMMISSIONING TESTS ON RELATED SWITCHGEAR

7.1 Test on OLTC and RTCC Panels

7.1.1 The following Routine tests shall be conducted on each OLTC and RTCC panels, along with the transformer at works:

Routine Tests

The following shall constitute the routine tests:

a) Manual operation for 10 complete cycles

b) Electrical operation in Remote/Local/Auto modes

c) Checking of interlocks

d) Checking for functioning of proper voltage regulation as per setting

e) Auxiliary circuits insulation tests

f) Power frequency withstand voltage test to earth

g) Power frequency withstand voltage test between any two adjacent contacts of Tap changer.

Type Tests

The following shall constitute the type tests :

a) Mechanical test

b) Auxiliary circuits insulation tests

c) Test for temperature - rise of contacts

d) Switching tests

e) Short-circuit current test

f) Transition impedance test

g) Mechanical life test

h) Dielectric test

7.1.2 Test certificate for Type tests as mentioned above shall be furnished for identical OLTC.

Site Tests

a) All routine tests as indicated above excluding power frequency withstand test on OLTC.

b) Checking of OLTC operation in Manual/Electrical/Auto modes with HV supply connected to the transformer.

c) Verification of proper functioning of Remote Tap changer indication.

d) Checking of functioning of Line Drop compensator.

7.2 Circuit Breaker

a) Insulation resistance test on each pole by HV Megger

b) Insulation resistance test on control circuit

c) ac high voltage test

d) Measurement of contact resistance for all the three phases

e) Checking the auxiliary circuits associated with circuit-breaker

f) Functional check of breaker operation electrically at 70% and 100% of rated dc supply voltage

g) Checking of Interlocks provided in Control Circuits and tripping through simulated protective relay contacts

h) Primary injection test

i) Secondary injection test for relays

7.3 Disconnecting Switch

a) Insulation Resistance test on each pole by HV Megger

b) Insulation Resistance test on Control Circuit

c) Measurement of contact resistance for all the Three Phases

d) Checking the auxiliary circuits associated with Disconnect Switch

e) Functional check of Disconnecting Switch operations electrically at 70% and 100% of rated dc supply voltage

f) Manual checking of operations (close-open) by handle for both main and earthing switches

7.4 Current Transformer

a) Insulation Resistance test on each winding by Megger to earth and between windings

b) Checking of all ratios on all cores by Primary injection set

c) Polarity check on each winding

d) Continuity test

e) Check for connection to correct taps

7.5 Potential Transformer

a) Checking of voltage ratios on all windings

b) Polarity checking on each winding

c) Insulation resistance test on each winding by Megger to earth and between windings

d) Check for connection to correct taps

e) Oil level check

7.6 Lightning Arrestor

a) Check for connections to ground and line

b) Continuity check (in case of Metal Oxide Silicon type only)

c) Operation check of discharge counter

7.7 Grounding

a) Continuity of grounding connection

b) Testing of Earth Resistivity of Individual Electrode

c) Testing of Earth resistivity of the combined earthing system

7.8 Switchboards/Distribution Board/Battery Charger/Control Panels

a) Measurement of Insulation Resistance of Bus-bar system

b) Measurement of I.R. of Control Circuit

c) Functional check of circuit components

d) Calibration test of Relays and Meters

e) Secondary injection test for relays

7.9 Battery

a) Polarity check of the battery system and check for outgoing Leads connections

b) Measurement and recording of specific gravity and voltage at each cell

c) Capacity test

7.10 Cables

a) Contractor shall thoroughly test and megger all cables, wires and equipment to prove the same are free from ground and short circuit.

b) If any ground or short-circuit is found, the fault shall be rectified or the cable and/or equipment replaced.

c) All power cables after installation and prior to connections shall be subjected to High Potential tests. Also the insulation resistance values shall

be measured both before and after Hipot test for comparison. The leakage current shall also be measured during the Hipot test at site and recorded in test report.

7.11 All tests shall be recorded in test report and shall be submitted to Engineer-in-charge.

8. EQUIPMENTS REQUIRED FOR PRE-COMMISSIONING TESTS AND TESTS FOR MAINTENANCE

Sl. No.	Test	IS Ref.	Equipment Required
1.	IR value of Transformer	IS 2026	Megger
2.	Resitance of Transformer windings	- do -	Resistance Bridge
3.	Ratio of Transformer windings	- do -	Ratiometer
4.	Electric strength of Transformer oil	IS 6729 IEC std. 60	Electric Strength Testing Equipment
5.	Resistivity of Transformer oil	IS 6103 IEC std. 247	1) Resistivity cell 2) Megohm - meter 3) Hot Chamber
6.	Tan delta of Transformer oil	IS 6262	1) Schering Bridge 2) Resistivity cell 3) Hot Chamber
7.	Moisture Content of Transformer oil	IS 2362	Karl Fisher Apparatus
8.	Acidity test of Transformer oil	IS 335	Accessories for acidity test of Transformer oil
9.	Gas Analysis	-	Micro Gas Analyser
10.	IR value of bushing	-	Megger
11.	Capacitance and tan delta of bushing	-	Schering Bridge

9. REFERENCE

9.1 Specifications, Fittings and Accessories

1. IS 648 : 1994 : Non-oriented electrical steel sheets for magnetic circuits (*fourth revision*).

2. IS 649 : 1997 : Methods of testing steel sheets for magnetic circuits of power electrical apparatus (*second revision*).

3. IS 1180 : 1989 : Outdoor type three-phase distribution transformer up to and including 100 kVA, 11 kV.

4. IS 1271 : 1985 : Thermal evaluation and classification of insulating materials for electrical machinery and apparatus in relation to their stability in service.

5. IS 1885 : 1977 : Electrotechnical vocabulary Part 38 - Power Transformers & Reactors (*second revision*).

6. IS 2026 : 1977/1981 : Specification for power transformers.

   Part 1 : 1977 : General

   Part 2 : 1977 : Temperature - rise

   Part 3 : 1981 : Insulation levels and dielectric tests.

   Part 4 : 1977 : Terminal marking, tappings & connections

7. IS 2099 : 1986 : Bushings for alternating voltages above 1000 V (*second revision*).

9.2 Selection Installation, Operation and Maintenance

1. IS 1255 : 1983 : Code of Practice for installation and maintenance of power cables upto and including 33 kV rating.

2. IS 1866 : 2000 : Code of practice for maintenance and supervision of mineral insulating oil in equipment (*third revision*).

3. IS 3043 : 1987 : Code of practice for earthing.

4. IS 3716 : 1978 : Application guide for insulation coordination

5. IS 5528 : 1985 : Guide for short-circuit calculations.

6. IS 8478 : 1977 : Application guide for on-load tap changers.

7. IS 8690 : 1977 : Application guide for measuring devices for high-voltage testing.

8. IS 9434 : 1992 : Guide for sampling and analysis of free and dissolved gases and oil from oil-filled electrical equipment (*first revision*).

9. IS 9615 : 1980 : Guide on general aspects of electro-magnetic interference suppression.

10. IS 10028 : 1981/1985 : Code of practice for selection, installation and maintenance of transformers.

11. IS 10118 : 1982 : Code of practice for selection, installation and maintenance of switchgear and controlgear.

12. IS 10561 : 1983 : Application guide for power transformers.

13. IS 11697 : 1986 : Guide for the determination of lightning impulse electric strength of insulating liquids.

9.3 Transformer Oil and Oil Testing

1. IS 335 : 1993 : New insulating oils for transformers (*fourth revision*).

2. IS 1866 : 2000 : Code of practice for maintenance and supervision of mineral insulating oil in equipment (*third revision*).

3. IS 2362 : 1993 : Determination of water content by the Karl Fisher method (*second revision*).

4. IS 6103 : 1971 : Method of test for specific resistance (resistivity) of electrical insulating liquids.

5. IS 6104 : 1971 : Method of test for interfacial tension of oil against water by the ring method.

6. IS 6262 : 1971 : Method of test power factor and dielectric constant of electrical insulating liquids.

7. IS 6792 : 1992 : Method for determination of electric strength of insulating oils (*first revision*).

8. IS 6855 : 2000 : Method of sampling for liquid dielectrics (*first revision*).

9. IS 11697 : 1986 : Guide for the determination of lightning impulse electric strength of insulating liquids.

9.4 Insulation Co-ordination and High Voltage Testing

1. IS 1876 : 1961 : Method for voltage measurement by means of sphere gaps.

2. IS 2071 : 1974 : Methods of high voltage testing

   Part 1 : General Definitions and test requirements.

   Part 2 : Test procedures

   Part 3 : Measuring devices (*Revised*)

3. IS 2165 : 1977/1983 : Specification for insulation co-ordination.

4. IS 3716 : 1978 : Application Guide for insulation co-ordination.

5. IS 6209 : 1982 : Methods for partial discharge measurements.

6. IS 8690 : 1977 : Application Guide for measuring devices for high voltage testing (*revised*)

7. IS 11349 : 1985 : Oscilloscopes and peak voltmeters for impulse tests.

APPENDIX-A

(See clause 1.2)

a) Single phase transformers rated at less than 1 kVA and polyphase transformers rated at less than 5 kVA;

b) Outdoor type three phase distribution transformers upto and including 100 kVA, 11 kV [*covered under IS 1180 (Pt 1) : 1989 and (Pt 2) : 1989*];

c) Instrument transformers (*covered by IS 2705 : 1992 and IS 3156 : 1992*);

d) Transformers for static converters;

e) Starting transformers;

f) Testing transformers;

g) Traction transformers mounted on rolling stock;

h) Welding transformers [*covered under IS 1851:1997 & IS 4804 (Pt 1):1968*];

i) Mining transformers (*covered by IS 2772 : 1982*);

j) Earthing transformers (*covered by IS 3151 : 1982*);

k) X-ray transformers;

l) Reactors (*covered by IS 5553 : 1989/90*);

m) Furnace type transformers ;

n) Dry type power transformers (*covered under IS 11171 : 1985*)

APPENDIX - B

(See Clause 4.6)

TYPICAL TESTS CARRIED OUT BEFORE COMMISSIONING

[as per IS 10028 (Part II) : 1981]

Sl. No.	Tests	Details
1.	General inspection	a) Control and relay panels, etc. b) Junction boxes and marshalling kiosks
2.	Secondary injection	On all transformer protection relays
3.	Primary injection (also to be repeated at the end of all other commissioning tests)	a) Tests on operation and stability of earthfault relays on high voltage side b) Tests on line directional elements of high voltage line relays c) Tests on high speed neutral ammeter d) Tests on over-current relays on low voltage side e) Test on operation and stability of earth-fault relays on low voltage side f) Tests on operation of standby earth-fault relay on low voltage side g) Tests on over-current relay on high voltage side (*when current transformers are not in transformer bushings*) h) Voltage compensation
4.	Ratio tests	a) With 415 V applied on high voltage side, measure the voltage between all phases on the low voltage side for every tap position. b) To check phasing, measure volts : A to a, b and c B to a, b and c C to a, b and c Where A, B and C are the terminals of three phases on high voltage side and a,b and c are the corresponding terminals on low voltage side.

APPENDIX – B (Contd…)

Sl. No.	**Tests**	**Details**
4. contd	Ratio tests	c) Magnetic balance test.
5.	Tripping tests	a) High Voltage b) Low voltage c) Inter-tripping tests d) Winding temperature trips
6.	Calibrate earthing resistance	
7.	Buchholtz relays	a) Tests for angle, air injection, etc. b) Check that there is no air in protector before commissioning c) When energizing transformer, close in on Trip etc. b) Check for stability when oil pumps are started : 1. at ambient temp. 2. at a winding temp. of 80^{o}C or above.
8.	Alarm circuits	a) Buchholtz relay b) Oil and winding temperature thermometer c) Cooling gear failure
9.	Fans and pumps	a) Check that the oil valves are open in cooling circuit b) Check the rotation of pumps, automatic starting overload devices, etc. c) Check stability of Buchholtz relay [see 7 (d) above]
10.	Tap changing tests to check mechanism, indi-cation, buzzer, lamp, etc.	
11.	Phasing tests	a) At 415V [see 4 (b) above] b) Between transformers in a bank c) To prove internal and external connection for parallel operation. d) On auxiliary supplies and voltage transformer.

APPENDIX – B (Contd…)

12.	Insulation tests	a) On high and low voltage windings. b) On current and voltage transformers, circuit etc.
13.	Site test for oil	a) Check oil level b) Dielectric test c) Volume resistivity d) Acidity e) tan delta f) Water content
14.	Voltage compensation test (if compensating current transformers are fitted.	a) Primary injection [see 3 (h) above] b) Load test [see 20 (g) below] c) If necessary, switch in with relays connected to correctly compensated voltages from the other transformers.
15.	See that neutral earthing switches are closed before making alive.	
16.	Check transformers on in equal taps before switching in	a) For transformers in a bank b) For transformers in parallel
17.	Set down relays before closing in – advise control	
18.	If necessary, arrange temporary protection for soaking and switching in, for example unrestricted earth fault, if soaking from low voltage side with 113V and 213 V open.	
19.	Set up relays after soaking and before going on load-advise control	

APPENDIX – B (Contd…)

20.	Load tests	a) Voltmeter, ammeters, etc on both high and low voltage sides. b) Overcurrent c) No spill in high voltage starpoint d) No creeping of contacts on both high and low voltage earthfault relays e) Voltages on relays f) Directional elements - low voltage, directional overcurrent and the earthfault relays (if fitted). g) Voltage compensation.
21.	Tap changing test on load over full range of taps.	
22.	Advise control of any new equipment commissioned	
23.	If possible for transformers rated above 1000 kVA, when being energised for the first time, the voltage should be built up gradually.	
24.	Low voltage excitation current.	
25.	Single phase, magnetic balance test.	

TABLE 1

(As per IS: 2026 (part III) - 1981)

REQUIREMENTS AND TESTS FOR DIFFERENT CATEGORIES OF WINDINGS

SL NO	CATEGORY OF WINDING	WITHSTAND VOLTAGES CONSTITUTING INSULATION LEVEL	TESTS AND TESTS TYPE
1.	Um < 300kV Uniform insulation	a) Power frequency b) Lightning impulse (optional for dry type transformers) c) Lightning impulse for neutral, if specified	a) Separate source ac (routine) b) Lightning impulse (type) on line terminals c) Modified impulse test on neutral (special) d) Induced over-voltage (routine)
2.	Um < 300Kv Non-Uniform insulation	a) Power frequency for line terminal b) Lightning impulse for line terminal c) Power frequency for neutral d) Lightning impulse for neutral, if specified	a) Separate source ac (routine) (corresponding to insulation level of neutral) b) Lightning impulse on line terminal (type) c) Modified impulse test on neutral (special) d) Induced over-voltage (routine)
3.	Um $\geq$300kV Non-Uniform insulation specified according to Method 1	a) Power frequency for line terminals b) Lightning impulse for line terminals c) Power frequency for neutral d) Lightning impulse for neutral, if specified	a) Separate source ac (routine) (corresponding to insulation level of neutral) b) Lightning impulse on line terminals (routine) c) Modified impulse test on neutral (special) d) Induced over-voltage (routine)

TABLE 1 (Contd…)

4.	Um $\geq$ 300kV Non-Uniform insulation specified according to Method 2	a) Lightning impulse for line terminals b) Switching impulse for line terminals c) Power frequency for neutral d) Lightning impulse for neutral, if specified	a) Separate source ac (routine) corresponding to insulation level of neutral b) Lightning impulse on line terminals (routine) c) Modified impulse test on neutral (special) d) Switching impulse on line terminals (routine) e) Induced over-voltage (routine) (with partial discharge indication)

(Um = Hightest voltage for equipment)

TABLE -2

(As per IS 2026 (part III) : 1981)

RATED WITHSTAND VOLTAGES FOR TRANSFORMER WINDINGS WITH HIGHEST VOLTAGE FOR EQUIPMENT Um ≤ 300 kV

HIGHEST VOLTAGE FOR EQUIPMENT Um (kV rms)	RATED SHORT DURATION POWER FREQUENCY WITHSTAND VOLTAGE (kV rms)	RATED LIGHTNING IMPULSE WITHSTAND VOLTAGE (kV peak)	
		List 1	List 2
1.1	3	-	-
3.6	10	20	40
7.2	20	40	60
12.0	28	60	75
17.5	38	75	95
24.0	50	95	125
36.0	70	145	170
52.0	95	250	
72.5	140	325	
123.0	185 230	450 550	
145.0	230 275	550 650	
170.0	230 275 325	550 650 750	
245.0	325 360 395	750 850 950	

NOTE 1 : The underlined value is the preferred value in IS 12360:1988, Voltage bands for electrical installations including preferred voltages and frequency.

NOTE 2 : Guidance for the choice between alternative rated withstand voltage combinations may be obtained from IS 2165.