INTERPLANT STANDARD - STEEL INDUSTRY		
IPSS	**GUIDE FOR SELECTION OF OIL FILLED POWER / DISTRIBUTION TRANSFORMER FOR STEEL PLANT DUTY** (*FIRST REVISION*)	**IPSS:1-04-012-11**
	Based on IS 2026:1977, 1180:1989 10028:1985, 6600:1972	Formerly: IPSS:1-04-012-99

0. **FOREWORD**

0.1 This Inter Plant Standard has been prepared by the Standards Committee on Switch Gears and Control Gears, IPSS 1:4 with the active participation of the representatives of the steel plants/units, reputed consulting organizations and established manufacturers of Power/Distribution Transformers; and was adopted in November 2011.

0.2 With a view to overcome the problems faced by the steel plants in operation, maintenance and repair of oil filled transformers of Indian make, "Specification for Oil Filled Distribution Transformers for Steel Industry" was prepared defining the duty and service conditions, constructional features and protection aspects. During meeting of the Standards Committee at Bokaro in February 1995, it was decided that this should not be a procurement specification and the title should be changed to "Guide for Selection of Oil Filled Power/Distribution Transformers for Steel Plant Duty". Accordingly, the comments from representatives of steel plants, other associated organizations and manufacturers as well as salient points emerging out of the discussion are incorporated.

0.3 The Standard is generally based on the following ISs:

i) IS 2026 (Part1):1977 `Power Transformers :Part 1 General (*first revision) (amendment 3)*

ii) IS 1180 (Part 1) :1989 `Outdoor type three phase distribution transformers upto and including 100 kVA 11 kV:Part 1 Non-sealed type (*third revision) (amendment 1)*

iii) IS 1180 (Part 2) :1989 `Outdoor type three phase distribution transformers upto and including 100 kVA 11 kV:Part 2 sealed type (*first revision)*

iv) IS 10028 (Part 1):1985 `Code of practice for selection, installation and maintenance of transformers :Part 1 Selection

v) IS 10028 (Part 2):1981 `Code of practice for selection, installation and maintenance of transformers :Part 2 Installation (superseding IS 1886)

vi) IS 10028 (Part 3):1981 `Code of practice for selection, installation and maintenance of transformers :Part 3 Maintenance (superseding IS 1886) (Amendment 1).

vii) IS 6600:1972.`Guide for loading of oil immersed transformers'.

0.4 In the preparation of this Standard, considerable assistance has been derived from CBIP's manual on transformers, BHEL's company standard on transformer oil and MPSEB's experience on the use of thermo syphon filters.

1. SCOPE

1.1 This Inter Plant Standard gives guidance for selection, service conditions and certain constructional and protectional aspects of distribution/power transformers, which form the bulk of steel plant transformers. Types of cooling namely ONAN, ONAF/OFAF/OFW may be provided as per the requirement of the purchaser.

2. SELECTION OF TRANSFORMER RATING

2.1 In order to reduce varieties for the purpose of standardization, the rating of the transformer shall be selected from the following standard ratings. These are for ONAN :

(**KINDLY RE-CHECK THE TABLE GIVEN BELOW AS PER DECISIONS TAKEN IN THE MEETING**)

Voltage Ratio	kVA Ratings for ONAN Conditions
3.3, 6, 11kV/433 V	100, 250, 400, 630, 1000, 1250, 1600, 2000, 2500
11000 V/3300 V	630, 1000, 1600, 4000, 10000
11000 V/6600 V	2000, 3150, 4000, 5000, 6300, 8000, 10000
33/6.9 kV	10000, 12500, 16000, 20000, 25000, 31500
33/11.5 kV	10000, 12500, 16000, 20000, 25000, 31500
132/11.5 kV	10000, 12500, 20000, 40000, 50000, 63000
132/34.5 kV	40000, 50000, 63000, 80000
220 (230)/11.5kV	50000, 63000, 80000, 100000, 125000
220 (230)/34.5 kV	50000, 63000, 80000, 100000, 125000

220/132 kV	100000, 125000, 160000
132/11/6.9 kV}	50000, 63000, 80000
132/11/11.5 kV}	

NOTE : (1) The secondary voltage shall be decided by the plant.
(2) 132 kV or 110 kV may be decided by the respective plant.

2.2 The rated kVA indicated above corresponds to continuous duty; nevertheless oil-immersed transformers complying with this standard may be overloaded in accordance with IS 6600:1972.

The rated kVA assigned shall take into account service conditions corresponding to those specified later in Cl.No. 3.1.

2.3 Transformers shall withstand without damage the thermal and dynamic effects of external short circuit under the conditions specified in Cl. 8.1 of IS 2026 (Part 1):1977 `Power Transformers: Part 1 General (*first revision*) (*amendments 3*) (*re-affirmed 1991*)' which recognizes following three categories for the rated kVA of three phase transformers:

Category 1	upto 3150 kVA
Category 2	3151 to 40000 kVA
Category 3	above 40000 kVA

The symmetrical short-circuit current (rms value) shall be calculated using the short-circuit impedence of the transformer and the system impedence for transformers of category 1 to 3 in accordance with Cl. 8.1.1.2 and Cl. 9.1.2 of IS 2026 (Part 1):1977. The duration of the current (I) to be used for the calculation of the thermal ability to withstand short circuit shall be 2 seconds, unless otherwise specified by the purchaser. On specific requirement, this may be considered as 5 seconds with mutual agreement between supplier and purchaser.

The peak value of the short circuit current shall be calculated in accordance with Cl. 16.11.2 of IS 2026 (Part 1):1977.

Typical values for the short-circuit impedence of transformers are given in Table 3 of IS 2026 (Part 1):1977.

3. DUTY AND SERVICE CONDITIONS

3.1 **Site Conditions -** The following shall constitute the normal service conditions for the purpose of this standard:

a) *Ambient Temperature* - Reference ambient temperature shall be 50^{o}C for indoor application with an ambient of 55^{o}C for outdoor duty..

b) *Humidity* - The maximum relative humidity shall be 100%. However both maximum ambient temperature and maximum relative humidity may not occur simultaneously.

c) *Altitude* - The altitude shall not exceed 1000 m.

d) *Ambient Air* - The ambient air may contain fair amount of conductive dust, oily fumes, corrosive fumes etc.

3.2 Cyclic Duty Conditions

The rated kVAs indicated in Cl.No. 2.1 corresponds to continuous operation with normal expectation of life. In practice, uninterrupted continuous operation at full rated kVA is unusual. Allowable cyclic daily loads can be worked out, taking into account seasonal variations of ambient temperature in accordance with Table 1 to 6 of IS 6600:1972. However, following limitations have been assumed:

a) For normal cyclic duty, the current does not exceed 1.5 times the rated value.

b) In no case a hot-spot temperature in the windings of 105 deg C is exceeded.

c) The permissible maximum alsolute temperatures at rated output and principal tap shall be:

i) Oil (by thermometer method) – 85 deg C
ii) Winding (by resistance method) – 95 deg C

(Distribution transofrmers may feed impact loads where the rate of rise of current may be of the order of 0.5 In to 1.2 In in 0.01 sec. and these can occur repeatedly throughout its life time.)

3.3 Service Condition

Distribution transformers in some steel plant applications feed un-grounded 11 kV/6.9 kV power system, having a vast network of cables. Earth fault in 11 kV/6.9 kV system over-stresses the insulation of the transformer winding. Arcing with ground causes voltage oscillations of higher magnitudes and thus further overstressing the transformer windings.

3.4 Transformer shall be designed to be operated within frequency variation of +3% to -5%.

3.5 Transformers of all ratings shall be suitable for outdoor duty.

3.6 Protection current transformer (whether phase or neutral) shall not be mounted in the transformer tank.

3.7 Cable box shall be air insulated type. No compound filled cable box is acceptable. Arrangement for termination shall be such that cables are not required to be terminated to the bushing stud directly. Cable box shall be standardized separately supported detachable type so that transformer can be taken out for maintenance without removing the cables.

4. MATERIALS & CONSTRUCTION OF TRANSFORMERS

i) The transformer and accessories shall be designed to facilitate operation, inspection, maintenance and repairs. All apparatus shall also be designed to ensure satisfactory operation under such sudden variations of load and ambient conditions as stipulated in Cl. No. 3 of this specification.

ii) The design shall incorporate every reasonable precaution and provision for the safety of all those concerned in the operation and maintenance of the equipment keeping in view the requirements of Indian Electricity Rules.

iii) All materials used shall be of the best quality and of the class most suitable for working under the conditions specified. The following acts only as a guide for material selection and constructional aspects:

4.1 Winding

i) All star connected windings for system of 66 kV and above shall have graded insulation as defined in IS 2026:1977. All windings for system voltages lower than 66 kV shall be fully insulated. All neutral points shall be insulated for the voltages specified in IS 2026:1977. All windings shall be of copper. No aluminium winding is acceptable.

ii) Power transformers shall be designed to withstand the impulse and power frequency test voltages as specified in IS 2026:1977.

iii) The insulation of transformer windings and connection shall be free from insulating composition liable to soften, ooze out, shrink or collapse and be non-catalytic and chemically inactive in transformer oil during service.

iv) The coil clamping arrangement and the finished dimensions of any oil ducts shall be such as will not impede the free circulation of oil through the ducts.

v) Rectangular conductors of work hardened copper with high proof stress shall be used for transformer of rating 50 MVA and above with more radial and axial support to withstand high value of electromagnetic forces during fault.

vi) The conductors shall be transposed at sufficient intervals in order to minimize eddy currents and equalize the distribution of currents and temperatures along the windings.

vii) The windings and connections of all transformers shall be braced to withstand shocks which may occur during transport, or due to switching short-circuit and other transient conditions during service.

4.2 **Tank**

i) The transformer tank and cover shall be fabricated from good commercial grade low carbon steel suitable for welding and of adequate thickness. The tanks of transformers shall be complete with all accessories and shall be designed so as to allow the complete transformer with the tank filled with oil, to be lifted by crane or jacks, transported by road/rail without overstraining any joint and without causing subsequent leakage of oil.

ii) The main tank body excluding tap changing compartments, radiators and covers shall be capable of withstanding vacuums as per the following table:

Highest system voltage kV	**MVA Rating**	**Vacuum Gauge Pressure kN/m^2**	**mm of Hg**
Upto 72 kV	Upto 1.6	34.7	250
	Above 1.6 & upto 20	68.0	500
	Above 20	100.64	760
Above 72 kV	For all MVA ratings	100.64	760

iii) Active part (core and winding) of the transformer shall not be bolted/fastened with tank cover. Tank cover shall be designed to be removed separately. Transformers above 40 MVA shall preferably have bell shaped tank for maintenance purpose.

4.3 Oil

i) The transformers shall normally be supplied along with the first filling of oil and 10 per cent excess quantity of oil.

ii) The oil shall be as specified in IS 335:1993 `New Insulating oils (fourth revision)(amendment 1)' and shall be free from moisture and shall have uniform quality throughout.

iii) Transformer oil shall be vacuum filtered separately at $50^{o}C$ to $70^{o}C$ using a suitable filtration machine. Oil treatment shall be terminated when the following parameters are attained:

kV rating of transformer	Recommended Permissible Limit	
	Electric Strength (BDV) in kV (min)	Moisture Content ppm (max)
Upto 132 kV	60	20
220 V	65	15

iv) Electric strength and moisture content shall be determined by following the test procedure of IS 335:1993.

v) The design and all materials and processes used in the construction of the transformer shall be such as to reduce to a minimum risk of the development of acidity in the oil.

vi) Air seal bag (constant oil pressure system) shall be provided in the conservator for all 132 kV class and above transformers and for other voltage grade transformers with rating of 25 MVA and above.

4.4 **Tap Changers** - Distribution transformers shall be provided with off-load tap changers for a range of $\pm$ 5% in steps of 2.5%.

Power Transformers shall be provided with on-load tap changers for a range of +5% & -15% in steps of 1.25%

The diverter switches for the on-load tap changers shall be housed in separate compartment.

Separate Buchholz relay shall be provided for the diverter switch chamber.

5. TESTS

5.1 Measurement of Winding Resistance

The resistance of each winding at principal, maximum and minimum tap shall be measured by Wheatstone or Kelvin Bridge or digital meter depending on the value of the resistance. Typical schematic diagrams are given in Fig. 1 and 2 of Section J of CBIP manual on transformer.

5.2 Measurement of Ratio, Polarity and Phase Relationship

The turns ratio on each tapping between pairs of windings shall be measured by a direct reading ratio meter. The accuracy of the ratio meter shall be 0.1 per cent and the ratio meter shall have provision to adjust phase angle due to leakage flux.

Polarity and phase relationship can be measured with most of the direct reading ratio meter where a reversing switch for polarity change is provided.

5.3 Measurement of Impedance Voltage/Short-circuit impedance (Principal Tapping) and Load Loss

The current in all lines shall be measured and the average shall be taken as the test current. The voltage between lines shall be measured and the average of the readings shall be taken as the tested voltage.

Load loss shall be measured at the principal tap only along with impedance voltage measurement. Two watt-meter or three watt-meter method of measurement shall be used. The measured loss shall be corrected to rated current by multiplying with the square of the ratio of rated current to test current.

5.4 Measurement of No-load Loss and No-load Current

The test shall be in accordance with IS 2026 (Part 1):1977. Frequency should be recorded during the test and if it is higher/lower than 50 Hz, the excitation voltage may be increased/decreased in same proportion. The losses and current thus recorded should be considered as measured at rated voltage and frequency.

5.5 Measurement of Insulation resistance

The insulation resistance of each winding in turn to all the other windings, core, frame and tank connected together and to earth shall be measured by standard megger or electronic digital mega-ohm meter.

5.6 **Dielectric Tests**

The tests and voltage levels shall be in accordance with IS 2026 (Part 3):1981 `Power transformers: Part 3 Insulation level and dielectric tests (second revision) (amendment 1)' and as specified in order.

5.7 **Temperature Rise Test**

The test shall be in accordance with IS 2026 (Part 2I):1977 `Temperature-rise (amendment 2) .

5.8 **Tests on On-load Tap-changers**

The test shall be in accordance with IS 2026 (Part I):1977.

5.9 **Measurement of Zero sequence impedance(s) of three phase transformer**

The test shall be in accordance with IS 2026 (Part I):1977.

5.10 **Short Circuit Test**

The test shall be in accordance with IS 2026 (Part I):1977.

5.11 **Measurement of the Harmonics of the No-load Current**

The test shall be in accordance with IS 2026 (Part I):1977.

5.12 **Measurement of Acoustic Noise Levels**

Acceptable acoustic noise level shall be 5 dB above NEMA standard publication TR-1 as per CBIP manual (Section A) and Test Manual (Section J) for transformers.

5.13 Dissolved gas analysis report for filled oil in transformer of 132 kV class and above shall be furnished.

6. MISCELLANEOUS POINTS

6.1 Winding temperature and oil temperature probes shall be enclosed in robust flexible metallic conduits to prevent damage.

6.2 Only gun metal valves shall be provided on all transformer of rating 50 MVA and above.

6.3 Pressure release device in place of explosion vents shall be provided for transformers of ratings 2 MVA and above.