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Indian Standard

CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF TRANSFORMERS

PART 1 SELECTION

0. FOREWORD

0.1 This Indian Standard (Part 1) was adopted by the Indian Standards Institution on 21 May 1985, after the draft finalized by the Transformers Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The code of practice on installation and maintenance of transformers was originally published in 1961 as IS : 1886, intended as a guide to installation engineers, contractors and others engaged in the installation and maintenance of power and distribution transformers. It was revised subsequently in 1967, with additional details regarding internal inspection of transformers. Apart from the information concerning transformers themselves, the code covered ancillary work, such as ventilation, cabling and isolation of transformers.

0.3 The persent version of the code has been brought out to include additional details, such as the criteria of selection of transformers and to update the information in other respects. This code has been published in the following three parts:

Part 1 Selection

Part 2 Installation

Part 3 Maintenance

0.4 Attention is drawn to IS : 10561-1983* which may also be referred to for additional guidance for determination and selection of transformer characteristics. Attention is also drawn to the Report of the Committee for Standardization of the Parameters and Specifications of Major Items of 400 kV Substation Equipment and Transmission Line Materials, issued by the Central Electricity Authority in 1984.

*Application guide for power transformers.

0.5 In preparation of this standard, assistance has been derived from 'Specification for power and distribution transformers' issued by the Central Board of Irrigation and Power, New Delhi.

1. SCOPE

1.1 This standard (Part 1) covers guidelines for selection of distribution and power transformers covered by IS : 1180 (Parts 1 and 2)* and IS : 2026 (Parts 1 to 4)† respectively for voltage ratings up to and including 400 kV (highest system voltage $U_m = 420$ kV).

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 1885 (Part 38)-1977‡ shall apply.

3. GENERAL

3.1 The transformers covered in this standard are classified into the following groups:

a) Distribution transformers (up to and including 1 600 kVA),

b) Power transformers (above 1 600 kVA),

c) Generator transformers, and

d) Unit auxiliary and station transformers.

NOTE — The terms used here are not in line with IS : 2026 (Part 1)-1977§ where generator transformers, unit auxiliary and station transformers are covered in the general category of power transformer. This distinction has been made in this code of practice as the selection criteria is different for different groups.

*Specification for outdoor type three-phase distribution transformers up to and including 100 kVA 11 kV:

Part 1 Non-sealed type (*second revision*).

Part 2 Sealed type.

†Specification for power transformers:

Part 1 General (*first revision*).

Part 2 Temperature-rise (*first revision*).

Part 3 Insulation levels and dielectric tests (*second revision*).

Part 4 Terminal markings, tappings and connections (*first revision*).

‡Electrotechnical vocabulary : Part 38 Transformers (*first revision*).

§Specification for power transformers : Part 1 General (*first revision*).

3.2 The following should be considered as the main governing features of each group of transformers for the purposes of selection:

a) Ratings,

b) Taps,

c) Connection symbol,

d) Impedance,

e) Termination arrangement,

f) Cooling, and

g) Fittings and accessories.

4. CRITERIA FOR SELECTION OF DISTRIBUTION TRANSFORMERS [UP TO AND INCLUDING 1 600 kVA]

4.1 Ratings — The kVA ratings should comply with IS : 2026 (Part 1)-1977*. The no-load secondary voltage should be 433 volts for transformers to be used in 415 V system. Voltage should be normally in accordance with IS : 585-1962† except for special reasons when other values may be used. For transformers requiring to be operated in parallel, the voltage ratio should be selected in accordance with guidelines given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981‡.

4.2 Taps — The transformers of these ratings are normally provided with off-circuit taps on HV side except in special cases when on-load tap changers are specified. The standard range for off-circuit taps which are provided on HV side should be $\pm$ 2·5 percent and $\pm$ 5·0 percent. In case of on-load tap changers, the taps may be in steps of 1·25 percent with 16 steps. The positive and negative taps shall be specified to suit the system conditions in which the transformer is to be operated.

4.3 Connection Symbol — The two winding transformers should be preferably connected in delta/star in accordance with IS : 2026 (Part 4)-1977§. The exact connection symbol (Dyn 11 or Dyn 1) is to be specified depending upon requirements of parallel operation with other transformers in accordance with guidelines given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981‡ and **4** of IS : 10561-1983‖.

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*Specification for power transformers: Part 1 General (*first revision*).

†Specification for voltages and frequency for ac transmission and distribution systems (*revised*).

‡Code of practice for selection, installation and maintenance of transformers: Part 2 Installation.

§Specification for power transformers : Part 4 Terminal markings, tappings and connections (*first revision*).

‖Application guide for power transformers.

4.4 Impedance — Consideration shall be given in the selection of impedance for the standard available rating of the switchgear on the secondary side and associated voltage drops. However, the impedance values shall, as far as possible, conform to those specified in Table 3 of IS : 2026 (Part 1)-1977*. For transformers requiring to be operated in parallel, the percentage impedance should be selected in accordance with guidelines given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981†.

4.5 Termination Arrangement — The HV and LV terminals may be bare outdoor bushings, cable boxes or bus trunking depending upon the method of installation. Wherever compound filled cable boxes are used, it is preferable to specify disconnecting chamber between transformer terminals and cable box to facilitate disconnection of transformer terminals without disturbing the cable connections (*see also* IS : 9147-1979‡). In case of extruded insulation cables with connections in air, a separate disconnecting chamber is not necessary.

NOTE — A separate specification for cable end boxes for oil-immersed transformers suitable for extruded insulated cables is under preparation.

4.6 Cooling — The transformers covered in this group are generally ONAN, AN or ANAN cooled. Standard service conditions are given in **3** of IS : 2026 (Part 1)-1977*. For service conditions different from these, selection of temperature-rise limits should be in accordance with IS : 2026 (Part 2)-1977§ or IS : 11171-1985‖ as applicable.

4.7 Fittings and Accessories

4.7.1 *For Oil Filled Transformers* — The fittings and accessories should be as specified in Appendix C of IS : 2026 (Part 1)-1977*. Explosion vent should be specified for all 11 kV transformers above 400 kVA rating and all 33 kV transformers. When radiators are required to be detached for transportation, isolating valves should be specified. Alarm and trip contacts for oil temperature indicator, winding temperature indicator and gas actuated relay may be specified when monitoring and control devices are available for the transformer application.

4.7.2 *For Dry Type Transformers* — Fittings under serial No. 6, 12 and 15 of **C-1** and serial No. 1, 6 and 7 of **C-2** of IS : 2026 (Part 1)-1977* are not required for dry type transformers.

*Specification for power transformers: Part 1 General (*first revision*).

†Code of practice for selection, installation and maintenance of transformers : Part 2 Installation.

‡Specification for cable sealing boxes for oil-immersed transformers suitable for paper-insulated lead-sheathed cables for highest system voltages from 12 kV up to and including 36 kV.

§Specification for power transformers: Part 2 Temperature-rise (*first revision*).

‖Specification for dry type power transformers.

5. CRITERIA FOR SELECTION OF POWER TRANSFORMERS (ABOVE 1 600 kVA)

5.1 Ratings — The secondary no-load voltage should be specified 5 percent more than the nominal voltage to compensate the transformer regulation partly. For transformers requiring to be operated in parallel, the voltage ratio should be selected in accordance with guidelines given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981*.

5.2 Taps — On-load tap changers on HV side should be specified, wherever system conditions warrant. For interconnecting auto-transformers with on-load tap changer, system conditions may warrant tapping on low voltage side. In case of OLTC, the total number of taps should be 16 in steps of 1·25 percent. The distribution on positive and negative taps shall be decided to suit the system conditions. Off-circuit taps, when specified, should be in the range of $\pm$ 2·5 percent and $\pm$ 5 percent provided on the HV side.

5.3 Connection Symbol — The preferred connections for two winding transformers up to 66 kV high voltage (HV) side rating are delta/star (Dyn) and star/star (YNyn). For higher voltages, connections star/star (YNyn) or star/delta (YNd) may be preferred. The selection of connection group should be made taking into consideration the requirements of parallel operation with other transformers as given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981*. For transformers of ratings up to 50 MVA, three limb (Yyo) construction, no stabilizing winding is required unless the tertiary winding is required for auxiliary loads. In case of unloaded tertiary winding, one terminal should be brought out for testing purposes.

5.4 Impedance — The transformer impedance is decided taking into consideration the secondary fault levels and the voltage dip. The typical impedance values are given in Table 3 of IS : 2026 (Part 1)-1977†. For transformers requiring to be operated in parallel, the percentage impedance should be selected in accordance with guidelines given in **12.0.1** and **12.0.1.1** of IS : 10028 (Part 2)-1981*.

5.5 Termination Arrangement — Primary and secondary terminals may be bare bushings, cable boxes or bus trunking depending upon the method of installation. Wherever compound filled cable boxes are used, it is preferable to specify disconnecting chamber between transformer terminals and cable box to facilitate disconnection of transformer

*Code of practice for selection, installation and maintenance of transformers: Part 2 Installation.

†Specification for power transformers: Part 1 General (*first revision*).

terminals without dismantling the cable connections (*see also* IS : 9147-1979*). In case of extruded insulation cable connections in air, a separate disconnecting chamber is not necessary.

NOTE — A separate specification for cable end boxes for oil-immersed transformers suitable for extruded insulated cables is under preparation.

For transformers up to 33 kV, porcelain bushings and for transformers of 66 kV and above, oil-filled condenser type bushings should be specified. For installation in polluted atmospheres, the bushings should be specified with extra creepage distances as given in IS : 2099-1973†.

5.6 Cooling — The type of cooling may be ONAN, ONAN/ONAF, ONAN/ONAF/OFAF or OFWF. Standard service conditions are given in 3 of IS : 2026 (Part 1)-1977‡. For service conditions different from these, selection of temperature-rise limits should be in accordance with IS : 2026 (Part 2)-1977§. The following cooling arrangements are recommended:

	Rating MVA	*Voltage Class* kV	*Cooling Type*		*Equipment*
a)	Up to 10	Up to 66	ONAN		
b)	12·5 to 40	Up to 132	ONAN (60 percent)	ONAF	
c)	50 to 100	Up to 220	ONAN (50 percent)	ONAF (62·5 percent)	One 100 percent bank with two 100 percent pumps (one running and one standby)
			OFAN (62·5 percent)	OFAF	One standby fan or two 50 percent banks with two 100 percent pumps. (one running and one standby)

*Specification for cable sealing boxes for oil-immersed transformers suitable for paper-insulated lead-sheathed cables for highest system voltages from 12 kV up to and including 36 kV.

†Specification for bushings for alternating voltages above 1 000 V (*first revision*).

‡Specification for power transformers : Part 1 General (*first revision*).

§Specification for power transformers: Part 2 Temperature-rise (*first revision*).

Rating MVA	*Voltage Class* kV	*Cooling Type*		*Equipment*
				Two standby fans, one in each 50 percent bank
d) Above 100	Up to 400	ONAN (50 percent)	ONAF (62·5 percent)	Same as for (c)
		OFAN (62·5 percent)	OFAF	
		or		
		OFAF/ODAF		Three 50 percent OFAF coolers
		or		
		OFWF/ODWF		Two 100 percent OFWF coolers

NOTE — The manufacturer should be asked to confirm the available rating under complete failure of 50 percent cooling.

5.7 Fittings and Accessories — The fittings and accessories should be as specified in Appendix C of IS : 2026 (Part 1)-1977*. The following, should in addition, be specified:

a) Skids and hauling lugs;

b) Magnetic oil level gauge with low level alarm contacts;

c) Rollers (bidirectional, if required). If flanged rollers are required, rail gauge should be specified;

d) Winding temperature indicator with electrical contacts for alarm/trip and controlling fans and pumps;

e) Gas and oil actuated relay with alarm and trip contacts. For OLTC tank, a separate relay or other suitable protective device may be specified;

f) Explosion vent;

g) Accessories for cooling arrangement;

h) Oil temperature indicator with alarm and trip contacts; and

j) Two sampling valves at top and bottom of the main tank.

*Specification for power transformers: Part 1 General (*first revision*).

6. CRITERIA FOR SELECTION OF GENERATOR TRANSFORMERS

6.1 Ratings — The MVA rating of the generator transformer should be at least equal to the full generator output without considering reduction for unit auxiliary requirements. The no-load voltage of the secondary winding should be specified about 5 percent more than the nominal value to compensate the transformer regulation partly.

6.2 Taps — The generator transformers are normaly provided with off-circuit tap changers except in cases where the system conditions warrant use of on-load tap changers. The standard range for off-circuit tap changer is 2·5 percent to 7·5 percent in steps of 2·5 percent. For 400 kV transformers, on-load/off-circuit taps should have tapping range of $\pm$ 5 percent in steps of $\pm$ 2·5 percent.

6.3 Connection Symbol — The preferred connection symbol for two winding transformers is YNd 11 or YNd 1 with the star neutral solidly earthed.

6.4 Impedance — The standard impedances are 12·5 to 14 percent with tolerance as given in IS : 2026 (Part 1)-1977*. The exact value is to be specified based on short-circuit level.

6.5 Termination Arrangement — The generator side LV terminals should be suitable for bus duct or cable connection. The HV side should have bare bushings suitable for outdoor installation. For 66 kV and above, oil-filled condenser type bushings should be specified. For installation in polluted atmospheres, the bushings shall be specified with extra creepage distance as given in IS : 2099-1973†.

6.6 Cooling — The type of cooling may be ONAN, OFAF or OFWF. The temperature-rise limits should be as given in IS : 2026 (Part 2)-1977‡ (*see* **5.6**). Following cooling arrangements are recommended:

Rating MVA	*Voltage Class* kV	*Cooling Type*	*Equipment*
Up to 250	Up to 400	ONAN (50 percent) / OFAN (62·5 percent) | ONAF (62·5 percent) / OFAF or OFAF/ODAF or OFWF/ODWF	As in **5.6** (c) and (d)

*Specification for power transformers: Part 1 General (*first revision*).

†Specification for bushings for alternating voltages above 1 000 volts (*first revision*).

‡Specification of power transformers: Part 2 Temperature-rise (*first revision*).

6.7 Fittings and Accessories — The fittings and accessories should be as specified in Appendix C of IS : 2026 (Part 1)-1977*. The following should, in addition, be specified:

a) Magnetic oil level gauge;

b) Gas and oil actuated relay;

c) Explosion vent;

d) Winding temperature indicator with electrical contacts for alram/trip and controlling fans and pumps;

e) Skids and hauling lugs;

f) Rollers (bidirectional, if required). If flanged rollers are required, rail gauge should be specified; and

g) Accessories for cooling arrangement.

7. CRITERIA FOR SELECTION OF AUXILIARY AND STATION TRANSFORMERS

7.1 Rating — The voltage rating should be specified in such a manner that the secondary voltages are about 5 percent more than the nominal voltages to compensate the transformer regulation.

The auxiliary loads of thermal power stations require two voltage levels. The high voltage level is 3·3 kV, 6·6 kV or 11 kV (6·6 kV being the preferred value) and the low voltage level is 415 V.

The number of unit auxiliary transformers (UAT) is one or two depending upon the capacity of the unit. The number of station transformers depends on the total number of generators in a power station. It is normal practice to provide one station transformer up to two units and two station transformers for two to five units.

The capacity of the unit auxiliary transformers is based on the total actual running auxiliary load of the particular unit with a 10 percent margin. If there are two auxiliary transformers per unit, each unit transformer should be rated for minimum 55 percent of the actual running auxiliary load of the unit.

7.1.1 The capacity of the station transformers should meet the following requirements:

a) All running auxiliaries for station services at full station load;

*Specification for power transformers: Part 1 General (*first revision*).

b) The running auxiliaries of one unit bus at full load in the event of outage of one UAT at a time in the power station; and

c) The auxiliary starting or coasting of another unit which may be taken as 40 percent of the normal auxiliary load.

7.2 Taps — The UATs are normally provided with off-circuit taps with $\pm$ 2·5 percent and $\pm$ 5 percent on HV side.

The station transformers are preferably provided with OLTC with $\pm$ 10 percent in steps of 1·25 percent on HV side.

7.3 Connection Symbol — The UATs are connected in delta/star or delta/delta. In case of delta/star, the star neutral is earthed through a resistor.

The station transformers are connected in star/delta or star/star. In case of star/star, neutral on LV side is earthed through a resistor.

7.4 Impedance — The impedance is specified taking into consideration the fault level of the auxiliary switchgear and the voltage dip during starting of large motors. Also for station transformers with two secondaries, the impedance shall be specified to limit the fault levels.

7.5 Termination Arrangement — The HV and LV terminals of the UATs should be suitable for bus duct or cable connection.

The HV terminals of the station transformer are to be bare bushings suitable for outdoor installation. For rating 66 kV and above, oil filled condenser type bushings should be specified. For installation in polluted atmosphere, bushings should be specified with extra creepage distance in accordance with IS : 2099-1973*. The LV terminals should be suitable for cable or bus duct connection.

The LV neutrals of UAT and station transformer, wherever applicable, should be brought out for connection to neutral earthing resistor.

7.6 Cooling — The UATs may be ONAN or ONAN/ONAF cooled (ONAN rating of 50 percent).

The station transformers may be ONAN or ONAN/ONAF (with ONAN rating of 60 percent) or ONAN/OFAF (with ONAN rating of 50 percent).

7.7 Fittings and Accessories — The fittings and accessories should be as specified in Appendix C of IS : 2026 (Part 1)-1977† with additional fittings as specified in **5.7**.

*Specification for bushings for alternating voltages above 1 000 volts (*first revision*).

†Specification for power transformers: Part 1 General (*first revision*).

(*Continued from page* 2)

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2