TRANSFORMERS

Electrical transformers are machines that transfer electricity from one circuit to another with changing voltage level but no frequency change. Transformers help improve safety and efficiency of power systems by raising and lowering voltage levels as and when needed. They are used in a wide range of residential and industrial applications, primarily and perhaps most importantly in the distribution and regulation of power across long distances.

Bureau of Indian Standards has published two important series of standards on transformers: **IS 1180 series on distribution transformers** and **IS 2026 series on power transformers**.

IS 1180 SERIES ON DISTRIBUTION TRANSFORMERS

A distribution transformer is a transformer that provides the final voltage transformation by stepping voltages down within a distribution circuit or from a distribution circuit to an end user or application. The distribution circuit voltages are 3.3 kV, 6.6 kV, 11 kV, 22 kV and 33 kV in the country. The power supply for the end users is 415 V, 3 Phase (240 V, 1 phase), 50 Hz. Transformers with primary voltages of 3.3, 6.6, 11, 22 or 33 kV and secondary voltage of 433 V, 3 Phase (and 250 V single phase) are called Distribution Transformers.

Distribution transformers are normally located at a service drop, where wires run from a utility pole or underground power lines to a customer's premises. Since the load at customer's premises varies widely, these distribution transformers cannot be run with constant load throughout 24 hours. Also, irrespective of the load, these are energized 24 hours a day. Therefore, the distribution transformers are designed to have minimum iron losses and maximum efficiency at lower loads.

IS 1180 series has been published in 02 parts: Part 1 covers Mineral Oil Immersed Distribution Transformers and Part 2 covers Natural/Synthetic Ester liquid Immersed Distribution Transformers.

A gist of the requirements covered in these standards is given below:

- IS 1180 series covers three phase distribution transformers (both sealed and non-sealed type) up to 2 500 kVA and single-phase distribution transformers (only sealed type) up to 100 kVA for use in power distribution systems up to and including 33 kV. The distribution transformers covered by this standard can be used for indoor as well as for outdoor use. Part 1 covers Mineral Oil Immersed Distribution Transformers and Part 2 covers Natural/Synthetic Ester liquid Immersed Distribution Transformers.

- The normal service conditions such as altitude, temperature of ambient air, wave shape of supply voltage, installation environment etc. and abnormal service conditions such as high altitude, extreme high or low temperature, tropical humidity, seismic activity etc. have been defined in these standards.

- These standards specify following standard ratings:

	Standard Ratings (kVA)
Three Phase Transformers	*6.3, *10,16, *20, 25, *40, 63, 100, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000 and 2500
Single Phase Transformers	5,10,16, 25, *50, *75 and *100

*ratings are non-preferred

- These standards also specify the rated frequency, nominal system voltage, minimum Basic Insulation Level (BIL) for different nominal system voltages.

- These standards also define the standard taping range and tapping methods for both off-circuit taping arrangement and on-load tap changers.

- The maximum flux density in any part of the core and yoke at rated voltage and frequency shall be such that the flux density with + 12.5 percent combined voltage and frequency variation from rated voltage and frequency shall not exceed 1.9 Tesla.

- No-load current up to 200 kVA shall not exceed 3 percent of full load current and will be measured by energizing the transformer at rated voltage and frequency. Increase of 12.5 percent of rated voltage shall not increase the no load current by 6 percent maximum of full load current.

- Limits of temperature rise shall be as below:

	IS 1180 (Part 1)		
	Three-phase		Single Phase
	Up to 200 kVA	250 kVA – 2500 kVA	Up to 100 kVA
Winding	40°C	45°C	40°C
Top oil	35°C	40°C	35°C

	IS 1180 (Part 3)					
	Three-phase				Single Phase	
	Up to 200 kVA		250 kVA – 2500 kVA		Up to 100 kVA	
Insulation System	Type A	Type B	Type A	Type B	Type A	Type B
Winding	45°C	55°C	50°C	60°C	45°C	55°C
Top oil	40°C	50°C	45°C	55°C	40°C	50°C

Type ‘A’ — Conventional Kraft paper immersed in ester liquid.
Type ‘B’ — Thermally Upgraded Paper (TUP) or class 130 °C/140 °C paper on immersed in ester liquid.

- Major material used in the transformer shall conform to the following Indian Standards:

Standard Material	Standards
Cold rolled grain oriented (CRGO) electrical steel	IS 3024
Amorphous core material	IS 16585
Copper/Aluminum conductor	IS 191, IS 1897, IS 7404, IS 12444, IS 13730/IS 6162 series
Kraft paper	IS 9335 series
Press board	IS 1576
Mineral oil	IS 335
Synthetic organic ester	IS 16081
Natural ester	IS 16659

- Maximum Total Losses and Energy Efficiency

These standards specify the maximum total losses and recommended percent impedance at 75°C as given below:

Sl No.	**Rating** (kVA)	**Impedance** (Percent)	**Maximum Total Loss** (W)									
			Energy Efficiency Level 1		Energy Efficiency Level 2		Energy Efficiency Level 3		Energy Efficiency Level 4		Energy Efficiency Level 5	
			50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	16	4.5	135	440	120	400	108	364	97	331	87	301
ii)	25	4.5	190	635	175	595	158	541	142	493	128	448
iii)	63	4.5	340	1140	300	1050	270	956	243	870	219	791
iv)	100	4.5	475	1650	435	1500	392	1365	352	1242	317	1130
v)	160	4.5	670	1950	570	1700	513	1547	462	1408	416	1281
vi)	200	4.5	780	2300	670	2100	603	1911	543	1739	488	1582
vii)	250	4.50	980	2930	920	2700	864	2488	811	2293	761	2113
viii)	315	4.50	1025	3100	955	2750	890	2440	829	2164	772	1920
ix)	400	4.50	1225	3450	1150	3330	1080	3214	1013	3102	951	2994
x)	500	4.50	1510	4300	1430	4100	1354	3909	1282	3727	1215	3554
xi)	630	4.50	1860	5300	1745	4850	1637	4438	1536	4061	1441	3717
xii)	800	5.00	2287	6403	2147	5838	2015	5323	1892	4853	1776	4425
xiii)	1 000	5.00	2790	7700	2620	7000	2460	6364	2310	5785	2170	5259
xiv)	1 250	5.00	3300	9200	3220	8400	3142	7670	3066	7003	2991	6394
xv)	1 600	6.25	4200	11800	3970	11300	3753	10821	3547	10363	3353	9924
xvi)	2 000	6.25	5050	15000	4790	14100	4543	13254	4309	12459	4088	11711
xvii)	2 500	6.25	6150	18500	5900	17500	5660	16554	5430	15659	5209	14813

Table 2 Maximum Total Losses of Single Phase Transformers Upto 11 Kv

Sl No.	**Rating** (kVA)	**Impedance** (Percent)	**Maximum Total Loss** (W)									
			Energy Efficiency Level 1		Energy Efficiency Level 2		Energy Efficiency Level 3		Energy Efficiency Level 4		Energy Efficiency Level 5	
			50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	5	2.50	35	95	30	75	27	68	24	62	21	57
ii)	10	4.00	60	170	55	150	50	135	45	122	40	112
iii)	16	4.00	82	224	63	190	58	175	54	164	50	145
iv)	25	4.00	110	300	95	260	88	240	80	225	74	210
v)	50	4.00	210	590	190	520	177	480	160	451	148	420
vi)	75	4.00	310	880	285	780	265	720	242	670	223	625
vii)	100	4.00	410	1 140	375	1 030	350	964	320	900	299	842

- These standards specify the requirements for terminal arrangement and minimum clearances in air.
- The standard fittings as per these standards shall be as below:

a) Two earthing terminals with the earthing symbol ⏚;
b) Liquid level gauge indicating level at minimum, 30°C and maximum operating temperature;
c) Air release device
d) Rating and terminal marking plates;
e) Dehydrating breather shall be provided for non-sealed type transformers.
f) Drain-cum-sampling valve preferably steel with plug for three phase transformers (for transformers above 500 kVA);
g) Thermometer pocket with cap;
h) Oil/Ester liquid/Nitrogen/Air filling hole having (11/4" nominal size thread) with cover (for sealed type transformers without conservator);
i) Lifting lugs for the complete transformer as well as for core and winding assembly;
j) Pressure relief device or explosion vent [for sealed type transformers (for all ratings) and non-sealed type transformers (for ratings above 200 kVA)];

k) One filter valve on the upper side of the tank (for transformers above 200 kVA);
l) HV side neutral grounding strip (where one of the HV bushing terminal is connected to earth);
m) LV earthing arrangement for single phase transformers;
n) Buchholz relay for transformers above 1 000 kVA;and
o) Arcing horns for HT side (one number per phase)

- The optional fittings as per these standards shall be as below:

a) Dehydrating breather in lieu of plain breathing device for transformers up to 200 kVA;
b) Filter valve for transformers up to 200 kVA;
c) Suitable rating lightning arrestors for HT side (one number per phase);
d) Bird guard;
e) Terminal connectors;
f) Liquid temperature indicator and winding temperature indicators for transformers above 200 kVA;
g) Jacking pads (for transformer above 1 600 kVA);
h) Buchholz relay (for transformers above 200 kVA);
i) Magnetic ester liquid level gauge (for transformer above 1 600 kVA) with low liquid level alarm contact;
j) Non-return valve (for conducting pressure test);
k) Pressure relief device or explosion vent (up to 200 kVA for non-sealed type transformers);
l) Protection relay for sealed type transformers for internal parameters that is pressure, temperature, liquid level and gas detection;
m) 4 No's Anti-Theft stainless steel Fasteners with breakaway nut shall be provided at top cover (up to 200 kVA);
n) Unidirectional flat rollers (for transformers above 200 kVA); and
o) Drain-cum-sampling valve preferably steel with plug for three phase transformers (for transformers up to 500 kVA).
p) Self protection/disconnection devices subject to agreement between the user and the supplier (applicable only for IS 1180-1):

- Thermo-magnetic circuit breaker as self protection device on secondary side as per IS/IEC 60947-2 : 2003; and
- Expulsion fuse as disconnection device on primary side as per IS 9385 (Part 2) : 1980.

- **TESTS AND REQUIREMENTS**

The tests defined in this standard shall be as below:

Routine Tests (to be conducted on all units)

i) Measurement of winding resistance [IS 2026 (Part 1)].
ii) Measurement of voltage ratio and check of phase displacement [IS 2026 (Part 1)].
iii) Measurement of short-circuit impedance (principal tapping, when applicable) and load loss at 50 percent and 100 percent load [IS 2026 (Part 1)].
iv) Measurement of no-load loss and current [IS 2026 (Part 1)].
v) Measurement of insulation resistance [IS 2026 (Part 1)].
vi) Induced over-voltage withstand test [IS 2026 (Part 3)].
vii) Separate-source voltage withstand test [IS 2026 (Part 3)].
viii) Pressure test
ix) Oil leakage test

Type Tests (to be conducted on one unit)

i) Lightning impulse test [IS 2026 (Part 3)]
ii) Temperature-rise test [IS 2026 (Part 2)]
iii) Short-circuit withstand test [IS 2026 (Part 5)] (up to 200 kVA).
NOTE — Routine tests before and after short circuit test shall be conducted as per IS 2026 (Part 1).
iv) Pressure test

Special Tests (to be conducted on one unit)

The following shall constitute the special tests which shall be carried out by mutual agreement between the user and the supplier.

i) Determination of sound levels [IS 2026 (Part 10)]
ii) Short-circuit withstand test [IS 2026 (Part 5)] (above 200 kVA)
NOTE — Routine tests before and after short circuit test shall be conducted as per IS 2026 (Part 1).
iii) No load current at 112.5 percent voltage
iv) *Paint adhesion tests*. The test is performed as per ASTM D3359 (Standard Test Methods for measuring adhesion by Tape test).
v) BDV and moisture content of oil/ester liquid in the transformer

IS 2026 SERIES ON POWER TRANSFORMERS

IS 2026 series has been published in following parts:

IS 2026 : Part 1 : 2011	Power transformers Part 1 General
IS 2026 : Part 2 : 2010	Power transformers Part 2 temperature - Rise
IS 2026 : Part 3 : 2018	Power transformers Part 3 insulation levels dielectric tests and external clearances in air
IS 2026 : Part 4 : 1977	Specification for power transformers Part 4 terminal markings tappings and connections
IS 2026 : Part 5 : 2011	Power transformers Part 5 ability to with stand short circuit
IS 2026 : Part 6 : 2017	Power transformers Part 6 reactors
IS 2026 : PART 7 : 2009	Power transformers Part 7 loading guide for oil - Immersed power transformers
IS 2026 : Part 8 : 2009	Power transformers Part 8 application guide
IS 2026 : Part 10 : 2009	Power transformers Part 10 determination of sound levels
IS 2026 : Part 10 : Sec 1 : 2018	Power transformers Part 10 determination of sound levels
IS 2026 : Part 11 : 2021	Power Transformers Part 11 Dry-Type Transformers
IS 2026 : Part 12 : 2018	Power transformers Part 12 loading guide for dry - Type power transformers
IS 2026 : Part 14 : 2018	Power transformers Part 14 liquid - Immersed power transformers using high - Temperature insulation materials
IS 2026 : Part 15 : 2018	Power transformers Part 15 gas - Filled power transformers
IS 2026 : Part 16 : 2018	Power transformers Part 16 transformers for wind turbine applications
IS 2026 : Part 18 : 2018	Power transformers Part 18 measurement of frequency response
IS 2026 : Part 19 : 2018	Power Transformers Part 19 Rules for the Determination of Uncertainties in the Measurement of the Losses on Power Transformers and Reactors

IS 2026 : Part 21 : 2018	Power transformers Part 21 standard requirements terminology and test code for step - Voltage regulators