Thereby, the series winding and the common winding together form one measuring circuit, and the common winding alone forms the other. The measurements are carried out with a current not exceeding the difference between the rated currents on the low-voltage side and the high voltage side.
NOTE 1 In conditions where winding balancing ampere-turns are missing, the relation between voltage and current is generally not linear. In that case, several measurements at different values of current may give useful information.

NOTE 2 The zero-sequence impedance is dependent upon the physical disposition of the windings and the magnetic parts, measurements on different windings may therefore not agree. In particular, for a transformer with a zigzag winding the zero sequence impedance measured between line terminals connected together and the neutral may result in a different value to that obtained when a three phase symmetrical voltage is applied and one line terminal is connected to the neutral.

NOTE 3 An additional zero-sequence impedance test may be required for transformers with delta windings with two connections to one corner brought out so that it can be either open or closed.

NOTE 4 Further guidance is given in IEC 60076-8.

315MVA, 500MVA 400/220/33kV Transformer Connections

Tap No.	**Current Applied**	**Open Terminals**	**3xU/I**	**%ZO**
1	Between HV (1U, 1V & 1W Shorted) and Neutral	2U, 2V, 2W and Tertiary		
9	-Do-	-Do-		
17	-Do-	-Do-		
1	Between HV (2U, 2V & 2W Shorted) and Neutral	1U, 1V, 1W and Tertiary		
9	-Do-	-Do-		
17	-Do-	-Do-		

The above measurements shall be repeated with Tertiary terminals shorted. Voltage and current shall be measured and recorded.

13. Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test)

Test shall be performed as per IEC 60076-10 and clause 7.8.12 of IEC 60076-6 (for reactor). The measured value shall not be exceeded the limit as specified at Annexure-A of this specification. Sound pressure levels shall be established in line with specification. Sound power level shall be calculated from sound pressure level using the method described in IEC 60076-10. Location of microphones shall be in line with IEC 60076-10.

Important check points

The available frequency response of the measuring instrument shall range from below the rated power frequency to above the upper limit of the human ear capability of 20 kHz.

The upper limit for the actual measurement shall be chosen in accordance with the highest emitted significant frequency, usually below 10 kHz. The selected frequency range for background noise measurements and the test measurement shall be the same.

Sound pressure measurements shall be made using a type 1 sound level meter complying with IEC 61672-1 and IEC 61672-2 and calibrated in accordance with 5.2 of ISO 3746:2010.

The sound pressure method of measurements described in this standard is based on ISO 3746. Measurements made in conformity with this standard tend to result in standard deviations of reproducibility between determinations made in different laboratories which are less than or equal to 3 dB.

The measuring equipment shall be calibrated in accordance with manufacturer's instructions immediately before and after the measurement sequence. If the calibration changes by more than 0.3 dB, the measurements shall be declared invalid and the test repeated.

All measurements shall be made using the energetic average over the measurement duration of the sound quantity (pressure). Statistically derived sound quantities such as percentiles shall not be applied.

The fast response indication of the meter shall be used to identify and avoid measurement errors due to transient background noise.

The sound level measurement is usually of manual operation but the errors introduced by varying distances will tend to average out. Their impact on the final measurement is of less significance than other acoustical factors. Nevertheless, all effort shall be made to keep the measurement distance as constant as possible.

Test Report shall be in line with Annexure-B of IEC 60076-10.

14. Measurement of power taken by fans and oil pumps (100 % cooler bank)

Losses of each fan and pumps including spare shall be measured at rated voltage (415V) and frequency. Fans and Pumps shall be mounted with cooler bank as per approved drawing during measurement. Serial No, Applied voltage, measured current, frequency and make shall be furnished in the test report.

15. High voltage with stand test on auxiliary equipment and wiring after assembly

The wiring for auxiliary power, and control circuitry shall be subjected to a 1 min AC separate source test of 2 kV to earth. The test is passed if no voltage collapse or other sign of breakdown occurs.

The wiring for current transformer secondary windings shall be tested at 2.5 kV AC to earth for 1 min. The test shall be carried out at the manufacturer's works. If the current transformer knee-point voltage exceeds 2 kV AC the test shall be performed at 4 kV AC. The test is passed if no voltage collapse or other sign of breakdown occurs.

16. Frequency Response analysis (SFRA)

Frequency Response Analysis (FRA) is conducted to assess the mechanical integrity of the transformer. FRA signatures will be taken at works in oil filled condition after completion of all tests.

It is recommended to follow the standard procedure for the SFRA measurement as per the below Table. It should be done on maximum, normal and minimum tap of the transformer.

Combination of test for Autotransformer

Test Type	Test	3- Phase	1-Phase
Series Winding (Open circuit) All other terminals floating	Test 1	H1-X1	H1-X1
	Test 2	H2-X2	
	Test 3	H3-X3	
Common Winding (Open circuit) All other terminals floating	Test 4	X1-H0X0	X1-H0X0
	Test 5	X2-H0X0	
	Test 6	X3-H0X0	
Tertiary Winding (Open circuit) All other terminals floating	Test 7	Y1-Y3	Y1-Y2 (Y1-Y0)
	Test 8	Y2-Y1	
	Test 9	Y3-Y2	
Short circuit (SC) High (H) to Low (L) Short (X1-X2-X3)	Test 10	H1-H0X0	H1-H0X0 Short (X1- H0X0)
	Test 11	H2-H0X0	
	Test 12	H3-H0X0	
Short circuit (SC) High (H) to Tertiary (Y) Short (Y1-Y2-Y3)	Test 13	H1-H0X0	H1-H0X0 Short (Y1-Y0)
	Test 14	H2-H0X0	
	Test 15	H3-H0X0	
Short circuit (SC) Low (L) to Tertiary (Y) Short (Y1-Y2-Y3)	Test 16	X1-H0X0	X1-H0X0 Short (Y1-Y2)
	Test 17	X2-H0X0	
	Test 18	X3-H0X0	

H1: HV Terminal; X1: IV Terminal; H0X0: Neutral

In case of Shunt Reactor, FRA to be done in following combinations:

- H1-H0
- H2-H0
- H3-H0

17. Tank Tests

i. Oil Leakage Test

All tanks and oil filled compartments shall be completely filled with oil of a viscosity not greater than that of insulating oil conforming to IEC 60296 at the ambient temperature and subjected to a pressure equal to normal head of oil plus 35 kN/sq.m (5 psi) measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil during which no leakage shall occur. Pressure may slightly vary with ambient temperature change during 12 hours.

ii. Vacuum Test

All transformer tanks shall be subjected to the specified vacuum. The tank designed for full vacuum shall be tested at an internal pressure of 3.33 KN/Sq.m absolute (25 torr) for one hour. The permanent deflection of flat plate after the vacuum has been released shall not exceed the values specified below:

Horizontal Length of flat plate (in mm)	**Permanent deflection (in mm)**
Up to 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

iii. Pressure Test

All transformer tanks, its radiator, conservator and other fittings together or separately shall be subjected to a pressure corresponding to twice the normal head of oil or normal oil head pressure plus 35 KN/sq.m whichever is lower, 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 figure specified above for vacuum test.

18. Appearance, construction and dimension check

At Complete assembled transformer, Dimensions, fittings/accessories, clearances shall be verified in line with approved General Arrangement drawing, Bill of material, drawings of other accessories (OLTC, Bushing, Online DGA, Drying system, Buchhoolz relay, PRD, SPR, OTI, WTI, etc. as applicable).

19. Dynamic Short circuit withstand Test

19.1 Reference Standard: IEC 60076-5 (Latest Standard)

19.2 The tests shall be carried out on a new transformer ready for service. Protection accessories, such as gas-and-oil-actuated relay and pressure-relief device, shall be mounted on the transformer during the test. However, Detachable type cooler bank may not be required to install during short circuit test.

19.3 Prior to the short-circuit tests, the transformer shall be subjected to the routine tests and type tests as per POWERGRID specification (including routine tests which are specified in IEC 60076-1). If the windings are provided with tappings, the reactance and, if required, also the resistance shall be measured for the tapping positions at which short-circuit tests will be carried out. All the reactance measurements shall be to a repeatability of better than ±0.2 %. A report containing the result of the routine tests shall be available at the beginning of short-circuits tests.

Manufacturers shall compare the reactance measured at short circuit test lab with the value measured at their manufacturing works before proceeding to short circuit test.

19.4 At the beginning of short-circuit tests, the average temperature of the oil/winding shall preferably be between 10 °C and 40 °C (see 4.2.2.3 of IEC 60076-5).

19.5 During the tests, winding temperature may increase owing to the circulation of the short-circuit current. This aspect shall be taken into consideration when arranging the test circuit for transformers of category I.

19.6 **Test current peak value *î* for two-winding transformers**

The test shall be performed with current holding maximum asymmetry as regards the phase under test. The amplitude $\hat{\imath}$ of the first peak of the asymmetrical test current is calculated as follows:

$\hat{\imath} = I \cdot k \cdot \sqrt{2}$, where I the is symmetrical short-circuit current (see 4.1.2 of IEC 60076-5).

The factor k accounts for the initial offset of the test current and $\sqrt{2}$ accounts for the peak to-r.m.s. value of a sinusoidal wave. The factor $k\sqrt{2}$, or peak factor, depends on the ratio X/R

Where, X is the sum of the reactances of the transformer and the system (Xt + Xs), in ohms (Ω); R is the sum of resistances of the transformer and the system (Rt + Rs), in ohms (Ω), where Rt is at reference temperature (see 10.1 of IEC 60076-1).

In the case X/R >14 the factor $k \cdot \sqrt{2}$ is assumed to be equal to

1.8 $\sqrt{2}$ = 2.55 for transformers of category II;

1.9 $\sqrt{2}$ = 2.69 for transformers of category III.

19.7 **Tolerance on the asymmetrical peak and symmetrical r.m.s. value of the short-circuit test current**

If the duration of the short-circuit test is sufficiently long, the asymmetrical current having first peak amplitude î will change into the symmetrical current having r.m.s. value I (see 4.1.2 of IEC 60076-5). The peak value of the current obtained in testing shall not deviate by more than 5 % and the symmetrical current by more than 10 % from the respective specified value. However any positive tolerance may be acceptable subject to meeting the other requirements as per IEC.

The short-circuiting of the winding may either follow (post-set short circuit) or precede (pre-set short circuit) the application of the voltage to the other winding of the transformer.

If the post-set short circuit is used, the voltage shall not exceed 1.15 times the rated voltage of the winding

19.8 In order to avoid injurious overheating, an appropriate time interval (minimum 15 minutes between two consecutive shots) shall occur between successive overcurrent applications.

19.9 In order to check the values î and I of the test currents, oscillographic records shall always be taken.

19.10 The frequency of the test supply shall be, in principle, the rated frequency of the transformer.

19.11 Test connection shall be followed as per Clause 4.2.5.4 of IEC 60076-5.

19.12 The number of tests on three-phase and single-phase transformers is determined as follows, not including preliminary adjustment tests carried out at less than 70 % of the specified current to check the proper functioning of the test set-up with regard to the moment of switching on, the current setting, the damping and the duration.

19.13 For categories I, II & III single-phase transformers, the number of tests shall be three. The three tests on a single-phase transformer with tappings are made in a different position of the tap-changer, i.e. one test in the position corresponding to the highest voltage ratio, one test on the principal tapping and one test in the position corresponding to the lowest voltage ratio.\

19.14 For categories I, II & III three-phase transformers, the total number of tests shall be nine, i.e. three tests on each phase. Unless otherwise specified, the nine tests on a three-phase transformer with tappings are made in different positions of the tap changer, i.e. three tests in the position corresponding to the highest voltage ratio on one of the outer phases, three tests on the principal tapping on the middle phase and three tests in the position corresponding to the lowest voltage ratio on the other outer phase (manufacturer may change sequence).

19.15 For particular winding combination (HV-IV, HV-LV or HV-LV) number of shots shall be as per the following:

– for single-phase transformers: three;

– for three-phase transformers: nine.

19.16 For Tertiary winding dynamic short circuit shall be carried out either on HV-LV or IV-LV combination, whichever draws higher short circuit current as per calculation.

19.17 The duration of each test shall be 0.5 s for transformers of category I & 0.25 s for transformers of categories II and III, with a tolerance of ±10 %.

19.18 Detection of faults and evaluation of test results including acceptance criteria shall be followed as Clause 4.2.7 of IEC 60076-5. However, variations of short-circuit reactance (Acceptable limit) values shall be as per the following :

19.18.1 Transformers of categories I and II

2% for transformers with circular concentric coils and sandwich non-circular coils. However, for transformers having metal foil as a conductor in the low-voltage winding and with rated power up to 10 000 kVA, higher values, not exceeding 4 %,are acceptable for transformers with a short-circuit impedance of 3 % or more.

7,5 % for transformers with non-circular concentric coils having a short-circuit impedance of 3 % or more.

19.18.2 Transformers of categories III

The short-circuit reactance values, in ohms, evaluated for each phase at the end of the tests do not differ from the original values by more than 1 %.

Detail information pertaining to sort circuit test shall be furnished as per the format attached in Annexure-A.

ANNEXURE-A

Sr. No.	Parameters	Data
1	MVA Rating	
2	Phase	
3	Voltage Rating	
4	Tapping Range & Variation	
5	Fault MVA	
6	Fault Current	
7	Short circuit current feed to HV/LV	*Ex. From HV side for HV-IV Combination* *From LV side for HV-LV combination*

Tap Position	Maximum Voltage Tap	Normal Voltage Tap	Minimum Voltage Tap
Combination	HV-IV		
Short circuit method (Pre/Post short circuit connection)			
Precaution for saturation of the magnetic core / inrush of magnetizing current considered or not			
Transformer Impedance at Base MVA			
System Impedance			
Symmetrical short circuit current (Feeding current)			
k .√2 Value			
Asymmetrical short circuit current			
No of Shots			
Combination	IV-LV		
Short circuit method (Pre/Post short circuit connection)			
Precaution for saturation of the magnetic core / inrush of magnetizing current considered or not			
Transformer Impedance at Base MVA			
System Impedance			
Symmetrical short circuit current (Feeding current)			
k .√2 Value			
Asymmetrical short circuit current			
No of Shots			