

Medium Voltage Transformer Testing

Class 7200, 7300, 7400

Retain for future use.

Introduction

Transformer testing has evolved over the years to help determine the electrical, thermal, and mechanical suitability of transformers for operation on modern electrical systems. The types of tests and the procedures for conducting them have been defined by the IEEE Transformers Committee and are published in IEEE Standard C57.12.90 for liquid-filled transformers and IEEE Standard C57.12.91 for dry-type transformers.

This data bulletin provides general information on the various tests available and on the tests that Schneider Electric routinely performs on all medium voltage transformers. For a more detailed description of the tests and detailed test procedures, please see the IEEE Standards referenced below.

Standards

IEEE C57.12.00—IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE C57.12.01—IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin Encapsulated Windings

IEEE C57.12.90—IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE C57.12.91—IEEE Standard Test Code for Dry-Type Distribution and Power Transformers

Kinds of Tests

The following definitions for the kinds of tests to be performed are from the IEEE Standards.

Routine Tests: Routine tests made for quality control by the manufacturer on every transformer manufactured or representative samples, or on parts or materials as required, to verify during production that the product meets the design specifications.

Design Tests: Design tests made to determine the adequacy of the design of a particular type, style, or model of transformer or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions, if specified, and to demonstrate compliance with appropriate standards. Design tests are made only on representative apparatus to substantiate the ratings assigned to all other apparatus of basically the same design. These tests are not intended to be used as a part of normal production. Test data from previous similar designs may be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

Conformance Tests: Conformance tests that are specifically made to demonstrate conformity with applicable standards.

Other Tests: Other tests so identified in individual product standards that may be specified by the purchaser in addition to design and routine tests and may depend on the size, voltage, and type of transformer involved (Examples: insulation power factor, audible sound).

Table 1: Routine, Design, and Other Tests

Routine Tests	Design Tests	Other Tests
Turns Ratio	Temperature Rise	Zero Sequence Impedance
Polarity and Phase Relation	Audible Sound Level	Radio Influence Voltage
Resistance		Short Circuit
No-Load Loss		Insulation Power Factor ¹
Excitation Current		Insulation Resistance
Impedance		Gas Analysis
Load Loss		
Quality Control Impulse		
Applied Potential		
Induced Potential		
Partial Discharge (cast only)		
Leak (liquid-filled only)		
Regulation ²		
Efficiency ²		

¹ Routine for liquid-filled, substation transformers.

² Calculated from test results.

Type and Purpose of Test

Turns Ratio: The turns ratio test determines the ratio of turns in the primary winding to that in all other windings of the transformer, so that when rated voltage is applied to one winding of the transformer, all other winding voltages will be correct within one half of one percent of the rated nameplate voltages. The only deviation allowed by the standards is when the volts per turn exceed the one half of one percent of the rated voltage. The turns ratio test is performed on all taps of every winding.

Polarity and Phase Relation: Polarity and phase relation tests are important when transformers are to be paralleled. Paralleled transformers must have the same polarity and phase relation to avoid short circuits. For single phase transformers, the polarity test determines whether the primary and secondary windings are connected for additive or subtractive polarity. For three-phase transformers, the phase relation test determines if the angular displacement and relative phase sequence of the vectors representing the transformer windings are correct.

Resistance: The DC winding resistance is used to calculate the I^2R component of load losses. It is also used to calculate winding temperature during the temperature test.

No-Load Loss: The no-load losses or excitation losses consist of the iron loss of the core, the dielectric loss in the insulation, and the winding loss due to the circulation of the exciting current. Normally, the dielectric loss and winding loss are negligible when compared to the iron loss. No-load losses, as the name implies, are losses generated in the transformer with no load on the secondary terminals. No-load loss tests are measured at 100% of rated voltage.

Excitation Current: This test determines the current required to maintain the magnetic excitation of the core. It is expressed in per unit or percent of the rated transformer winding current. Excitation current is measured at 100% of rated voltage.

Impedance: The impedance is normally expressed in terms of percent of rated voltage. The impedance voltage is that voltage required to circulate rated current in one winding with the other winding shorted. Due to manufacturing and material tolerances, the impedance will vary from the design and guaranteed value. For this reason, the IEEE Standards have established impedance tolerances of $\pm 7.5\%$ for two-winding transformers, and $\pm 10\%$ for three-winding transformers.

Load Loss: This test measures the losses in the transformer when it is operating at full load. Load loss is the sum of the I^2R losses in the windings, stray losses due to stray fluxes in the windings, tank, enclosure, assembly parts, etc., and the eddy losses due to circulating currents. The I^2R loss component is by far the largest component of the load loss.

**Table 2: Basic Impulse Levels—
Distribution Class**

Voltage Class	Dry-Type Transformers		Liquid -Filled Transformers	
	Full Wave	Chopped Wave	Full Wave	Chopped Wave
1.2	10	10	30	36
2.5	20	20	45	54
5	30	30	60	69
8.7	45	45	75	88
15	60	60	95	110
25	110	110	125	145
34.5	150	150	150	175
46	—	—	250	290

Quality Control Impulse: This test is not a routine test for all transformers; however the test is performed on every Schneider Electric transformer to verify the Basic Impulse Level (BIL) rating of the transformer. The test consists of one reduced and one full wave. The wave shape and voltage level is determined by the voltage class of the transformer and the BIL specified for that voltage class. When an ANSI impulse test is specified, two chopped waves will be applied to the transformer terminals in addition to the reduced and full waves. A full wave represents a disturbance that occurs some distance from the transformer and travels along the transmission line to the transformer. The chopped wave represents a traveling wave created by a disturbance that occurs some distance from the transformer that flashes to ground near the transformer terminals. For distribution class transformers with low voltages less than the 5 kV class, the impulse tests are normally performed only on the high voltage terminals.

Applied Potential: This test is sometimes referred to as the high-pot or low frequency test. The purpose of this test is to verify the adequacy of the insulation between the winding being tested to all other windings and to ground. The test is made at 60 Hz for one minute.

Induced Potential: This test is made to verify the adequacy of the turn-to-turn insulation, layer-to-layer insulation, and phase-to-phase insulation. The test is made at twice the rated voltage, with a 400 Hz source, and is applied for 7200 cycles.

Partial Discharge: This test is a routine test for all cast coil transformers. The purpose of the test is to verify that the casting process has not left any voids (air pockets) in the windings.

Leak: All liquid-filled transformers are tested under pressure during the final assembly and preparation for shipment. Any reduction in pressure or visible sign of liquid seepage will be repaired before shipment.

Regulation and Efficiency: Regulation is the change, or drop, in secondary voltage as the load is increased on the transformer and is expressed as a percentage of the rated secondary voltage. Efficiency is the ratio of output watts to the input watts and is expressed as a percentage. Regulation and efficiency are calculated values from impedance and loss testing.

Temperature Rise: This test is a design test and is performed to verify that the average winding temperatures do not exceed the guaranteed values specified for the temperature rating of the insulation system. The tests are made by circulating rated current in the windings until the temperature has stabilized. The change in winding resistance from a cold start to the resistance at the stabilized temperature is used to calculate the average winding temperature rise.

Audible Sound Level: This is a design test that measures the average sound level generated by the transformer when energized at rated voltage and no-load applied to the terminals.

Zero Sequence Impedance: This test measures the line to neutral impedance when the transformer has a wye connected winding(s). The zero sequence impedance is also expressed as a percentage of rated voltage.

Radio Influence Voltage (RIV): Also known as Telephone Influence Factor (TIF). This test, which is performed on liquid-filled transformers, is similar to the partial discharge test performed on cast coil transformers. The purpose of this test is to determine the amount of electrical discharges that occur in the electrical insulation as a result of high velocity ionization under the influence of an electrical field, and to ensure the dielectric strength of the insulation is not exceeded.

Short Circuit: This test is performed only on prototype transformers only to verify the mechanical and thermal integrity of the core and coil assembly and other electrical components during a through-fault on the transformer. Because of the power required to perform this test, it has to be performed at a high power test laboratory which has the high power equipment necessary to perform the test.

Insulation Power Factor: The ratio of power dissipated in the insulation in watts to the product of the effective voltage and current in volt-amperes when tested with a sinusoidal voltage. This test is used to give an indication of the condition (dryness) of the transformer insulation. Presently, there are no established limits for acceptable power factor readings in the transformer standards. Acceptable power factor readings are a matter of judgment and experience. However, a power factor value of 1.0% or less for distribution transformers and 0.5% or less for large power transformers are generally used as acceptable values.

Insulation Resistance: This test is also used to give an indication of the dryness of the transformer insulation. Although not considered a routine test, it is often performed by manufacturers to give an indication of the condition of the transformer insulation. The insulation resistance varies with moisture content, cleanliness, and temperature of all insulating parts.

Gas Analysis: This test does not measure the performance of the transformer, but is a chemical analysis of the liquid to determine the levels of gases being produced by the operation of the transformer. When a transformer is operated, gases are generated from the insulation materials in the transformer. Gas generation is a natural phenomenon within transformers that can come from a variety of events, including electrical disturbances, thermal events, conductor losses, and other temperature effects. Although not common, it is possible for some transformers to operate throughout their useful life with large quantities of combustible gases present. Dissolved Gas Analysis (DGA) is most effective when performed over time on a periodic basis starting when the transformer is put into service. This becomes the baseline for future comparisons.