



IEEE Standard Terminology for Power and Distribution Transformers

STANDARDS

IEEE Power and Energy Society

Developed by the
Transformers Committee

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IEEE Standard Terminology for Power and Distribution Transformers

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

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IEEE SA Standards Board

Abstract: Terminology and definitions related to electric power and distribution transformers and associated apparatus are compiled in this standard. Similar terminology relating to power systems and insulation that is commonly involved in transformer technology is also included in the standard.

Keywords: definitions, distribution transformers, IEEE C57.12.80™, insulation, power systems, power transformers, terminology

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Introduction

This introduction is not part of IEEE Std C57.12.80-2024, IEEE Standard Terminology for Power and Distribution Transformers.

This revision of IEEE Std C57.12.80™ includes several changes since the last revision in 2010. These changes include the following:

- a) Updated normative references.
- b) Updated the acronyms for dry-type transformer cooling class designations.
- c) Replaced the reference of IEC 50 with IEC 60050.
- d) Updated the informative note for *design tests, phase-shifting transformer (phase-angle regulator), synthetic ester insulating fluid, and watertight*.
- e) Replaced the term of *liquid-immersed* with *liquid-type*. The terms of *liquid-immersed* and *liquid-filled* are retained as synonyms.
- f) Added definitions for *low-frequency dielectric test, stray gassing, and hottest spot temperature*.
- g) Updated the definitions for *alternating current, ambient sound pressure level, coefficient of grounding, duplex transformer, effectively grounded, enclosure, furnace transformer, inhibited oil, lightning impulse tests, live-metal part, mobile transformer, network transformer, non-self-restoring insulation, primary winding, radial-feed transformer, rainproof, rectifier transformer, secondary winding, self-restoring insulation, single-phase circuit, tap, tap changer for de-energized operation, thermally upgraded paper, thermometer method of temperature determination, three-phase circuit, two-phase circuit, and uninhibited oil*.
- h) Added *polychlorinated biphenyls* to the definitions.
- i) Updated the equations for *harmonic factor* to include both odd and even harmonics.
- j) Updated Annex B (Bibliography).
- k) Removed automatic numbering of each term which is no longer supported by IEEE.
- l) General updates to match the current *IEEE Standards Style Manual*.

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IEEE Standard Terminology for Power and Distribution Transformers

1. Overview

1.1 Scope

This standard is a compilation of terminology and definitions related to electric power and distribution transformers and associated apparatus. It also includes similar terminology relating to power systems and insulation materials commonly associated with transformer technology.

1.2 Purpose

The purpose of this standard is to provide definitions and consistent interpretation of commonly used terminology related to electric power and distribution transformers and associated apparatus.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM D6871, Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus.⁸

ASTM D5222, Standard Specification for High Fire-Point Mineral Electrical Insulating Oils.

IEC 60050TM, International Electrotechnical Vocabulary (IEV).⁹

IEEE Std 4TM, IEEE Standard for High-Voltage Testing Techniques.^{10,11}

IEEE Std C57.12.52TM, IEEE Standard for Sealed Dry-Type Power Transformers, 501 kVA and Higher, Three-Phase, with High-Voltage 601 to 34500 Volts, Low-Voltage 208Y/120 to 4160 Volts—General Requirements

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

IEEE Std C57.12.91TM, IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.

IEEE Std C57.100TM, IEEE Standard for Test Procedure for Thermal Evaluation of Insulation Systems for Liquid-Immersed Distribution, Power, and Regulating Transformers.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹²

accessible: Admitting close approach because not guarded by locked doors, elevation, or other effective means.

accessories: Devices that perform a secondary or minor duty as an adjunct or refinement to the primary or major duty of a unit of equipment.

additive: A chemical compound or compounds added to an insulating fluid for the purpose of imparting new properties or altering those properties that the fluid already has.

AF: The cooling class for a dry-type forced-air-cooled transformer that derives its cooling by the forced circulation of air. *Syn:* AF (IEC 60050).^{13,14}

⁸ ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

⁹ IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

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¹² *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹³ Cross-references are made to certain terms that appear in IEC 60050 [B6], the international standard for International Electrotechnical Vocabulary. These terms can be identified when “(IEC 60050)” follows the term.

¹⁴ The numbers in brackets correspond to those of the bibliography in Annex B.

AFWF: The cooling class for a dry-type transformer inside a non-ventilated enclosure with forced air using a pumped water heat exchanger. *See also:* **water cooled transformer.**

alternating current: A periodic current the average value of which over a full steady-state cycle is zero.

NOTE—Unless distinctly specified otherwise, the term *alternating current* refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values.¹⁵

alternating-current saturable reactor: A reactor whose impedance varies cyclically with the alternating current (or voltage).

alternating-current winding of a rectifier transformer: The primary winding that is connected to the alternating-current circuit and usually has no conductive connection with the main electrodes of the rectifier.

ambient sound pressure level: The sound pressure level measured at the test facility or at the installed location without the transformer energized.

ambient temperature: The temperature of the medium such as air, water, or earth into which the heat of the equipment is dissipated.

NOTE 1—For self-ventilated equipment, the ambient temperature is the average temperature of the air in the immediate vicinity of the equipment.

NOTE 2—For air- or gas-cooled equipment with forced ventilation or secondary water cooling, the ambient temperature is taken as that of the in-going air or cooling gas.

NOTE 3—For self-ventilated enclosed (including oil-immersed) equipment considered as a complete unit, the ambient temperature is the average temperature of the air outside of the enclosure in the immediate neighborhood of the equipment.

ampacity: Current-carrying capacity, expressed in amperes, of a wire or cable under stated thermal conditions.

AN: The cooling class for a dry-type self-cooled transformer or reactor that is cooled by the natural circulation of air. *Syn:* AN (IEC 60050).

AN/AF: The base kilovoltampere (kVA) rating of the dry-type transformer that has a self-cooled rating with cooling obtained by the natural circulating of air and a forced-air-cooled rating with cooling obtained by the forced circulation of air. *Syn:* AN/FA.

ANAF: The transformer is inside an enclosure that provides no intentional circulation of external air through the transformer and that operates at zero gauge pressure but includes means to circulate the air inside the enclosure.

ANAN: The cooling class for a dry-type nonventilated self-cooled transformer, which is so constructed as to provide no intentional circulation of external air through the transformer and that operates at zero gauge pressure. *Syn:* ANAN (IEC 60050).

AN/FA: The cooling class for a dry-type transformer that has a self-cooled rating with cooling obtained by the natural circulation of air and a forced-air-cooled rating with cooling obtained by the forced circulation of air. *Syn:* AN/AF (IEC 60050).

¹⁵ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

angular displacement of a polyphase transformer: The phase angle expressed in degrees between the line-to-neutral voltage of the reference identified high-voltage terminal and the line-to-neutral voltage of the corresponding identified low-voltage terminal.

NOTE—The preferred connection and arrangement of terminal markings for polyphase transformers are those that have the smallest possible phase-angle displacements and are measured in a clockwise direction from the line-to-neutral voltage of the reference identified high-voltage terminal. Thus, standard three-phase transformers have angular displacements of either zero degrees or 30 degrees.

anode paralleling reactor: A reactor used with rectifiers with a set of mutually coupled windings connected to anodes operating in parallel from the same transformer terminal.

apparatus: A general designation for large electrical equipment such as generators, motors, transformers, circuit breakers, and so forth.

apparent charge: A charge that, if it could be injected instantaneously between the terminals of a test object, would momentarily change the voltage between its terminals by the same amount as the partial discharge itself. It is expressed in coulombs, abbreviated as C. One pC is equal to 10^{-12} C.

applied voltage tests: Dielectric tests in which the test voltages are low-frequency alternating voltages from an external source applied between conducting parts and ground without exciting the core of the transformer being tested. *See also:* **induced voltage tests; low-frequency dielectric tests.**

arcing switch [in a load tap changer (LTC)]: A switching device used in conjunction with a tap selector to carry, make, and break currents in circuits that have already been selected. *See also:* diverter switch (IEC 60050).

arcing tap switch [in a load tap changer (LTC)]: A switching device capable of carrying current and also breaking and making current while selecting a tap position. It, thereby, combines the duties of an arcing switch and a tap selector. *See also:* **selector switch** (IEC 60050).

articulated unit substation: A unit substation in which the incoming, transforming, and outgoing sections are manufactured as one or more subassemblies intended for connection in the field.

askarel: A generic term for a group of synthetic, fire-resistant, chlorinated, aromatic hydrocarbons used as electrical insulating liquids. They have a property under arcing conditions such that any gases produced will consist predominantly of noncombustible hydrogen chloride with lesser amounts of combustible gases.

autotransformer: A transformer in which at least two windings have a common section.

average winding rise: *See:* **average winding temperature rise.**

average winding temperature: The average temperature of a winding as determined from the ohmic resistance measured across the terminals of the winding in accordance with the cooling curve procedure specified in IEEE Std C57.12.90 or IEEE Std C57.12.91.¹⁶

average winding temperature rise: The arithmetic difference between the average winding temperature of a winding and the ambient temperature.

average winding temperature rise of a transformer: The arithmetic difference between the average winding temperature of the hottest winding and the ambient temperature.

¹⁶ Information on references can be found in Clause 2.

A-weighted sound level: Loudness that is measured with a sound-level meter using the A-weighted response filter that is built into the meter circuitry. The A-weighting filter is commonly used to measure community noise, and it simulates the frequency response of the human ear.

bar-type current transformer: A current transformer that has a fixed and straight single primary winding turn passing through the magnetic circuit. The primary winding and secondary winding(s) are insulated from each other and from the core(s) and are assembled as an integral structure.

basic lightning impulse insulation level (BIL): A specific insulation level expressed in kilovolts of the crest value of a standard lightning impulse.

basic switching impulse insulation level (BSL): A specific insulation level expressed in kilovolts of the crest value of a standard switching impulse.

bottom-oil temperature: The temperature of the liquid in a liquid-type transformer as measured at an elevation just below the bottom of the coils or in the oil flowing from the liquid cooling equipment into the transformer.

bottom-oil temperature rise: The arithmetic difference between the bottom-oil temperature and the ambient air temperature.

burden of an instrument transformer: That property of the circuit connected to the secondary winding that determines the active and reactive power at the secondary terminals.

NOTE—The burden is expressed either as total ohms impedance with the effective resistance and reactance components or as the total voltamperes and power factor at the specified value of current or voltage and frequency.

bus reactor: A current-limiting reactor for connection between two different buses or two sections of the same bus for the purpose of limiting and localizing the disturbance due to a fault in either bus.

bushing: An insulating structure including a central conductor, or providing a central passage for a conductor, with provision for mounting on a barrier, conducting or otherwise, for the purpose of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

bushing elbow: An insulated device used to connect insulated conductors to separable insulated connectors on dead-front, pad-mounted transformers and to provide a fully insulated connection. *Syn:* **elbow connector.**

bushing insert: That component of a separable insulated connector that is inserted into a bushing well to complete a dead-front, load break or non-load break, separable insulated connector (bushing).

bushing test tap: A connection to one of the conducting layers of a capacitance graded bushing for measurement of partial discharge, power factor, and capacitance values.

bushing-type current transformer: A current transformer that has an annular core and a secondary winding insulated from and permanently assembled on the core but has no primary winding nor insulation for a primary winding. This type of current transformer is for use with a fully insulated conductor as the primary winding. A bushing-type current transformer usually is used in equipment where the primary conductor is a component part of other apparatus.

bushing voltage tap: A connection to one of the conducting layers of a capacitance graded bushing providing a capacitance voltage divider.

bushing well: A component of a separable insulated connector, either permanently welded or clamped to an enclosure wall or barrier, having a cavity that receives a replaceable component (bushing insert) to complete the separable insulated connector (bushing).

capacitance graded bushing: A bushing in which metallic or nonmetallic conducting layers are arranged within the insulating material for the purpose of controlling the distribution of the electric field of the bushing, both axially and radially.

cascade-type voltage transformer: A voltage transformer that has an insulated-neutral or grounded-neutral terminal and that has the primary winding subdivided into two or more (usually equal) series-connected sections, mounted on one or more magnetic cores, and that has the secondary winding located about the core at the neutral end of the primary winding. The sections of the primary winding are coupled by “coupling windings.” The cores, if more than one, are insulated from each other and connected to definite voltage levels along the primary winding.

cast coil transformer: A dry-type transformer in which the coils of at least one winding are cast (encapsulated) into a thermosetting resin that solidifies to become a solid, rigid, insulating system protecting the coils from contact with water, some contaminants, and damage due to casual physical contact.

change-over selector [in a load tap changer (LTC)]: A device designed to carry, but not to make or break current, used in conjunction with a tap selector or arcing tap switch to enable its contacts, and the connected taps, to be used more than once when moving from one extreme position to the other. This device is commonly referred to as a reversing switch. *See also:* **change-over selector** (IEC 60050).

chopped-wave lightning impulse test: A voltage impulse that is terminated intentionally by sparkover of a gap, which occurs subsequent to the maximum crest of the impulse wave voltage, with a specified minimum crest voltage and a specified minimum time to flashover.

circulating current [in a load tap changer (LTC)]: The current that flows through the transition impedance as a result of two taps being bridged during a tap change operation for resistance type load tap changers (LTCs) or being in the bridging position for reactance type LTCs. *See also:* **circulating current** (IEC 60050).

Class 105 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of 105 °C.

Class 130 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of 130 °C.

Class 155 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of 155 °C.

Class 180 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of 180 °C.

Class 220 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of 220 °C.

Class over-220 insulation system: Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature at temperatures over 220 °C.

NOTE—The six class insulation system temperatures defined above are and have been, in most cases over a long period of time, benchmarks descriptive of the various classes of insulating materials, and various accepted test procedures have been or are being developed for use in their identification. They should not be confused with the actual temperatures at which these same classes of insulating materials may be used in the various specific types of equipment nor with the temperatures on which specified temperature rises in equipment standards are based.

In the previous definitions the words *accepted tests* are intended to refer to recognized test procedures established for the thermal evaluation of materials by themselves or in simple combinations. Experience or test data, used in classifying insulating materials, are distinct from the experience or test data derived for the use of materials in complete insulation systems. The thermal endurance of complete systems may be determined by test procedures specified by the responsible technical committees. A material that is classified as suitable for a given temperature may be found suitable for a different temperature, either higher or lower, by performing an insulation system test procedure. For example, it has been found that some materials suitable for operation at one temperature in air may be suitable for a higher temperature when used in a system operated in an inert gas atmosphere. Likewise, some insulating materials when operated in dielectric liquids will have lower or higher thermal endurance than in air.

It is important to recognize that other characteristics, in addition to thermal endurance, such as mechanical strength, moisture resistance, and partial discharge (corona) endurance, are required in varying degrees in different applications for the successful use of insulating materials.

Class A insulation (obsolete designation): *See: Class 105 insulation system.*

Class B insulation (obsolete designation): *See: Class 130 insulation system.*

Class F insulation (obsolete designation): *See: Class 155 insulation system.*

Class H insulation (obsolete designation): *See: Class 180 insulation system.*

Class >H insulation (obsolete designation): *See: Class 220 insulation system.*

coefficient of grounding: The ratio (E_{L-G}/E_{L-L}) expressed as a percentage, of the highest root-mean square (rms) line-to-ground power-frequency voltage (E_{L-G}) on a sound phase, at a selected location, during a fault to earth affecting one or more phases to the line-to-line power-frequency voltage (E_{L-L}) that would be obtained, at the selected location, with the fault removed.

NOTE 1—Coefficients of grounding for three-phase systems are calculated from the phase-sequence impedance components as viewed from the selected location. For machines, use the subtransient reactance.

NOTE 2—The coefficient of grounding is useful in the determination of a surge arrester rating for a selected location.

NOTE 3—A value not exceeding 80% is obtained approximately when for all system conditions the ratio of zero-sequence reactance to positive-sequence reactance is positive and less than three, and the ratio of zero-sequence resistance to positive-sequence reactance is positive and less than one.

coil (of a transformer): The assemblage of windings that encircle a ferromagnetic core leg (limb) for the purpose of producing or linking magnetic flux. *See also: winding (of a transformer).*

combustible material: Materials that are external to the apparatus and made of or surfaced with wood, compressed paper, plant fibers, or other materials that will ignite and support flame.

common winding of an autotransformer: That part of the autotransformer winding that is common to both the primary and the secondary circuits.

commutating reactor: A reactor used with rectifiers primarily to modify the rate of current transfer between rectifying elements.

compound-filled transformer: A transformer in which the windings are enclosed with an insulating fluid that becomes solid, or remains slightly plastic, at normal operating temperatures.

NOTE—The shape of the compound-filled transformer is determined in large measure by the shape of the container or mold used to contain the fluid before solidification.