IEEE Standards

IEEE Std C57.12.80™-2002
(Revision of
IEEE Std C57.12.80-1978)

C57.12.80™

IEEE Standard Terminology for Power and Distribution Transformers

IEEE Power Engineering Society

Sponsored by the
Transformers Committee

IEEE

Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

13 November 2002

Print: SH94994
PDF: SS94994

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IEEE Standard Terminology for Power and Distribution Transformers

Sponsor

Transformers Committee
of the
IEEE Power Engineering Society

Approved 13 May 2002

IEEE-SA Standards Board

Abstract: This standard is a compilation of terminology and definitions primarily related to electrical transformers and associated apparatus included within the scope of C57, Transformers, Regulators, and Reactors standards. It also includes similar data relating to power systems and insulation, which is commonly involved in transformer technology.
Keywords: definitions, distribution transformers, insulation, power systems, power transformers, terminology

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Print: ISBN 0-7381-3283-7 SH94994
PDF: ISBN 0-7381-3284-5 SS94994

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Introduction

(This introduction is not part of IEEE Std C57.12.80-2002, IEEE Standard Terminology for Power and Distribution Transformers.)

This revision of ANSI/IEEE C57.12.80 incorporates a substantial number of changes since the last major revision in 1978. In addition to providing many new terms, some of the more significant changes include:

a) The terms and their definitions are now listed in alphabetical order.

b) Cross-references are made to certain terms that appear in the International Electrotechnical Commission Multilingual Dictionary of Electricity, Electronics and Telecommunications. These terms can be identified when "(IEC)" follows the term.

c) Numerous cross-references have been added to related terms in the standard. These appear following the definition and are denoted by *See also, Syn, See,* and *Contrast*.

d) Obsolete cooling class designations (OA, OA/FA, etc.) have been so designated and the corresponding new terms (ONAN, ONAN/ONAF, etc.) have been added.

e) More precise definitions have replaced some previous definitions and miscellaneous corrections have been made.

Participants

At the time this standard was completed, the working group on Standard Terminology for Power and Distribution Transformers had the following membership:

Thomas P. Traub, *Chair*

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IEEE Standard Terminology for Power and Distribution Transformers

1. Scope

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

Cross-references are made to certain terms that appear in IEC 50, the international standard for International Electrotechnical Vocabulary. These terms can be identified when "(IEC)" follows the term.

2. References

IEC 50, International Electrotechnical Commission, International Electrotechnical Vocabulary.[1]

IEEE Std 1™-1986, IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.[2,3,4]

IEEE Std 4™–1995, IEEE Standard Techniques for High-Voltage Testing.

IEEE C57.12.00™–2000, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE C57.12.01™–1998, 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™–1999, Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

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[1]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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[4]IEEE Std 1-1986 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

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IEEE C57.12.91™-1995 (Reaff 2001), IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.

3. Definitions

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

3.2 AA/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).

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

3.4 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.

3.5 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.

3.6 AFA: The cooling class for a dry-type forced-air-cooled transformer that derives its cooling by the forced circulation of air. *Syn:* **AF** (IEC).

3.7 alternating current: A periodic current the average value of which over a period 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.

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

3.9 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.

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

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

NOTES:

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

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.

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.

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

3.13 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 or 30 degrees.

3.14 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.

3.15 ANV: 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).

3.16 apparatus: A general designation for large electrical equipment such as generators, motors, transformers, circuit breakers, etc.

3.17 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 and abbreviated as C. One pC is equal to 10^{-12} C.

3.18 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.**

3.19 arcing switch (in an 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).

3.20 arcing tap switch (in an 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).

3.21 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.

3.22 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.

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

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

3.25 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 C57.12.90.

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

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

3.28 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.

3.29 bar-type current transformer: One 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.

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

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

3.32 bottom-oil temperature: The temperature of the liquid in a liquid-immersed 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.

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

3.34 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 volt-amperes and power factor at the specified value of current or voltage and frequency.

3.35 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.

3.36 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.**

3.37 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).

3.38 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.

3.39 bushing-type current transformer: One 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.

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

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3.41 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).

3.42 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.

3.43 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.

3.44 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.

3.45 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.

3.46 change-over selector (in an 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).

3.47 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.

3.48 circulating current (in an 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 LTCs or being in the bridging position for reactance type LTCs. *See also:* **circulating current** (IEC).

3.49 Class 2 transformer: A step-down transformer of the low-secondary-voltage type, suitable for use in Class 2 remote-control low-energy circuits. It shall be of the energy-limiting type or of a non-energy-limiting type equipped with an overcurrent device.

NOTE—"Low-secondary-voltage," as used here, has a value of approximately 24 V.

3.50 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.

3.51 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.

3.52 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.

3.53 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.

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3.54 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.

3.55 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 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.

3.56 Class A insulation: *See:* **class 105 insulation system.**

3.57 Class B insulation: *See:* **class 130 insulation system.**

3.58 Class F insulation: *See:* **class 155 insulation system.**

3.59 Class H insulation: *See:* **class 180 insulation system.**

3.60 Class >H insulation: *See:* **class 220 insulation system.**

3.61 coefficient of grounding: The ratio (E_{LG}/E_{LL}) expressed as a percentage, of the highest root-mean-square line-to-ground power-frequency voltage (E_{LG}) 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_{LL}) that would be obtained, at the selected location, with the fault removed.

NOTES:

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.

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

3—A value not exceeding 80 percent 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.

3.62 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.**

3.63 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.

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

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

3.66 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.

3.67 concentric winding: An arrangement of transformer windings where the primary and secondary windings, and the tertiary winding, if any, are located in radial progression about a common core.

3.68 conduit knockout: *See:* **knockout.**

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

3.70 conservator: An oil preservation system in which the oil in the main tank is isolated from the atmosphere, over the temperature range specified, by means of an auxiliary tank partly filled with oil and connected to the completely filled main tank.

3.71 constant-current transformer: A transformer that automatically maintains an approximately constant current in its secondary circuit under varying conditions of load impedance when supplied from an approximately constant-voltage source. *See also:* **current regulation of a constant-current transformer; impedance voltage of a constant-current transformer; rated kilowatts of a constant-current transformer; rated primary voltage of a constant-current transformer; rated secondary current of a current transformer.**

3.72 constant-voltage transformer: A transformer that maintains an approximately constant-voltage ratio over the range from zero to rated output.

3.73 contactor: A device for repeatedly establishing and interrupting an electric power circuit.

3.74 continuous duty: A duty that demands operation at a substantially constant load for an indefinitely long time.

3.75 continuous rating: The maximum constant load that can be carried continuously without exceeding established temperature-rise limitations under prescribed conditions.

3.76 continuous thermal current rating factor (RF): The number by which the rated primary current of a current transformer is multiplied to obtain the maximum primary current that can be carried continuously without exceeding the limiting temperature rise from 30° C average ambient air temperature. The RF of tapped-secondary or multiratio current transformers applies to the highest ratio, unless otherwise stated.

NOTE—When current transformers are incorporated internally as parts of larger transformers or power circuit breakers, they shall meet allowable average winding and hot-spot temperature limits under the specific conditions and requirements of the larger apparatus.

3.77 control power winding: The winding (or transformer) that supplies power to motors, relays, and other devices used for control purposes.

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3.78 control transformers: Step-down transformers generally used in circuits that are characterized by low power levels and that contribute to a control function, such as in heating and air conditioning, printing, and general industrial controls.

3.79 core: An element made of magnetic material, serving as part of a path for magnetic flux.

3.80 core form transformer: A transformer in which those parts of the magnetic circuit surrounded by the windings have the form of legs with two common yokes. *See also:* **shell form transformer.**

3.81 core loss: The power dissipated in a magnetic core subjected to a time-varying magnetizing force. Core loss includes hysteresis and eddy-current losses of the core.

3.82 corona: Obsolete term. *See:* **partial discharge (PD).**

3.83 corrosion-resistant: So constructed, protected, or treated that corrosion will not exceed specified limits under specified test conditions.

3.84 creepage distance: The shortest distance between two conducting parts measured along the surface or joints of the insulating material between them.

3.85 crest factor: For a periodic function, the ratio of its crest (peak, maximum) value to its root-mean-square (rms) value.

3.86 crest value: The maximum absolute value of a function when such a maximum exists.

3.87 current-limiting fuse: A fuse that, when it is melted by a current within its specified current-limiting range, abruptly introduces a high arc voltage to reduce the current magnitude and duration.

NOTE—The values specified in standards for the threshold ratio, peak let-through current, and I^2t characteristic are used as the measures of current-limiting ability.

3.88 current-limiting reactor: A reactor intended for limiting the current that can flow in a circuit under short-circuit conditions, or under other operating conditions such as starting, synchronizing, etc. *Syn:* **series reactor** (IEC).

3.89 current regulation of a constant-current transformer: The maximum departure of the secondary current from its rated value with rated primary voltage at rated frequency applied, and at rated secondary power factor, and with the current variation taken between the limits of a short circuit and rated load.

NOTE—This regulation may be expressed in per unit, or percent, on the basis of the rated secondary current.

3.90 current transformer: An instrument transformer intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled.

NOTE—In window-type current transformers, the primary winding is provided by the line conductor and is not an integral part of the transformer.

3.91 C-weighted sound level: Loudness that is measured with a sound level meter using the C-weighted filter that is built into the sound level meter. The C-weighting has only little dependence on frequency over the greater part of the audible frequency range.

3.92 cycle: The complete series of values of a periodic quantity that occurs during a period.

NOTE—It is one complete set of positive and negative values of an alternating current.

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3.93 dead-break connector: A separable insulated connector designed to be separated and engaged on de-energized circuits only.

3.94 dead front: A pad-mounted transformer that utilizes elbow (or separable, insulated) connectors to terminate the high-voltage cables.

3.95 dead-metal part: A part, accessible or inaccessible, which is conductively connected to the grounded circuit under conditions of normal use of the equipment.

3.96 degree of polymerization (of cellulosic paper): The average number of anhydrous-b-glucose monomer, $C_6H_{10}O_5$, in the cellulose molecules.

3.97 delta connection: So connected that the windings of a three-phase transformer (or the windings for the same rated voltage of single-phase transformers associated in a three-phase bank) are connected in series to form a closed circuit.

3.98 design family: A group of transformer designs that share common characteristics such as design arrangement, materials, and design stresses to meet performance characteristics such as temperature rise, impedance, losses, and seismic capability. Due to different ratings, the transformers may have dimensional differences.

3.99 design tests: Those tests made to determine the adequacy of the design of a particular type, style, or model of equipment 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 of the industry. *Syn:* **type test** (IEC).

NOTE—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. The applicable portion of these design tests may also be used to evaluate modifications of a previous design and to assure that performance has not been adversely affected. 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.

3.100 dielectric withstand voltage tests: Tests made to determine the ability of insulating materials and spacings to withstand specified overvoltages for a specified time without flashover or puncture.

NOTE—The purpose of the tests is to determine the adequacy against breakdown of insulating materials and spacings under normal or transient conditions.

3.101 direct buried transformer: A transformer designed to be buried in the earth with connecting cables.

3.102 direct-current winding of rectifier transformer: The secondary winding that is conductively connected to the main electrodes of the rectifier, and that conducts the direct current of the rectifier.

3.103 directed flow: The principal part of the pumped insulating fluid from heat exchangers or radiators is forced, or directed, to flow through specific paths in the winding. *See also:* **ODAF** and **ODWF.**

3.104 distributed-network type unit substation: A unit substation that has a single step-down transformer having its outgoing side connected to a bus through a circuit breaker equipped with relays that are arranged to trip the circuit breaker on reverse power flow to the transformer and to reclose the circuit breaker upon the restoration of the correct voltage, phase angle, and phase sequence at the transformer secondary. The bus has one or more outgoing radial (stub-end) feeders and one or more tie connections to a similar unit substation.

3.105 distribution transformer: A transformer for transferring electrical energy from a primary distribution circuit to a secondary distribution circuit or consumer's service circuit. *See also:* **power transformer.**

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3.106 double-secondary current transformer: One that has two secondary coils each on a separate magnetic circuit with both magnetic circuits excited by the same primary winding.

3.107 double-secondary voltage transformer: One that has two secondary windings on the same magnetic circuit insulated from each other and the primary.

3.108 draw-lead bushing: A bushing that will allow the use of a draw-lead conductor.

3.109 draw-lead conductor: A cable or solid conductor that has one end connected to the transformer or reactor winding and the other end drawn through the central tube of the bushing and connected to the top of the bushing.

3.110 dripproof enclosure: An enclosure, usually for indoor application, so constructed or protected that falling drops of liquid or solid particles that strike the enclosure at any angle within a specified variation from the vertical shall not interfere with the successful operation of the enclosed equipment.

3.111 driptight enclosure: An enclosure so constructed that falling drops of liquid or solid particles striking the enclosure at any angle within a specified variation from the vertical cannot enter the enclosure either directly or by striking and running along a horizontal or inwardly inclined surface.

3.112 dry-type forced-air-cooled transformer: *See:* **AFA.**

3.113 dry-type nonventilated self-cooled transformer: *See:* **ANV.**

3.114 dry-type self-cooled transformer: *See:* **AA.**

3.115 dry-type self-cooled/forced-air-cooled transformer: *See:* **AA/FA.**

3.116 dry-type transformer: A transformer in which the core and coils are in a gaseous or dry compound insulating medium. *See also:* **cast coil transformer; gas-filled transformer; nonventilated dry-type transformer; sealed transformer; ventilated dry-type transformer.**

3.117 duplex transformer: A transformer consisting of two single-phase transformers, of equal or unequal ratings, in a common enclosure, generally for the purpose of supplying a load consisting of a large single-phase load and a smaller three-phase load in combination. The two single-phase transformers may be connected open wye-open delta, or open delta-open delta.

3.118 duplex-type unit substation: A unit substation that has two step-down transformers, each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a radial (stub-end) feeder. These feeders are joined on the feeder side of the power circuit breakers by a normally open-tie circuit breaker.

3.119 dusttight enclosure: An enclosure so constructed that dust will not enter the enclosing case under specified conditions.

3.120 duty: A requirement of service that defines the degree of regularity of the load.

3.121 eddy-current loss: The energy loss in conductors resulting from the flow of eddy currents and circulating currents (if any) in parallel windings or in parallel winding strands. There is no test method to determine individual winding eddy loss or to separate transformer stray loss from eddy loss. The total stray and eddy loss is determined by measuring the total load loss during the impedance test. The total stray and eddy loss is determined by subtracting the I^2R loss from the load loss as follows:

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$$P_{EC} + P_{SL} = P_{LL} - I^2R$$

where

P_{EC} is the eddy current loss, watts,
P_{SL} is the stray loss, watts,
P_{LL} is the load loss, watts,
I^2R is the loss due to current and resistance, watts.

3.122 eddy currents: The currents that are induced in the body of a conducting mass by the time variation of magnetic flux.

3.123 effectively grounded: An expression that means grounded through a grounding connection of sufficiently low impedance (inherent or intentionally added, or both) that fault grounds that may occur cannot build up voltages in excess of limits established for apparatus, circuits, or systems so grounded.

NOTE—An alternating-current system or portion thereof may be said to be effectively grounded when, for all points on the system or specified portion thereof, the ratio of zero-sequence reactance to positive-sequence reactance is less than three and the ratio of zero-sequence resistance to positive-sequence reactance is less than one for any condition of operation and for any amount of connected generator capacity.

3.124 efficiency: The ratio of the useful power output to the total power input.

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

3.126 enclosure: A surrounding case or housing used to protect the contained equipment and prevent personnel from accidentally contacting live parts.

3.127 energy limiting transformer: A transformer that is intended for use on an approximately constant-voltage supply circuit and that has sufficient inherent impedance to limit the output current to a thermally safe maximum value.

3.128 equipment: A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like, as a part of, or in connection with, an electrical installation.

3.129 equivalent two-winding kVA rating: The equivalent two-winding rating of multiwinding transformers or autotransformers is one-half the sum of the kVA ratings of all windings.

NOTE—It is customary to base this equivalent two-winding kVA rating on the self-cooled rating of the transformer.

3.130 excitation current: The current that flows in any winding used to excite the transformer when all other windings are open-circuited. It is usually expressed in percent of the rated current of the winding in which it is measured.

3.131 excitation losses for an instrument transformer: The watts required to supply the energy necessary to excite the transformer, which includes the dielectric watts, the core watts, and the watts in the excited winding due to the excitation current.

3.132 excitation-regulating winding of a two-core regulating transformer: A two-core regulating transformer design in which the main unit has one winding operating as an autotransformer that performs

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both functions listed under **excitation winding of a two-core regulating transformer** and **regulating winding of a two-core regulating transformer.**

3.133 excitation winding of a two-core regulating transformer: The winding of the main unit, which draws power from the system to operate the two-core transformer.

3.134 excited winding of a two-core regulating transformer: The winding of the series unit that is excited from the regulating winding of the main unit.

3.135 extended delta connection: A connection similar to a delta, but with a winding extension at each corner of the delta, each of which is 120 degrees apart in phase relationship.

NOTE—This connection may be used as an autotransformer to obtain a voltage change or a phase shift, or a combination of both.

3.136 external insulation: The external insulating surfaces and the surrounding air.

NOTE—The dielectric strength of external insulation is dependent on atmospheric conditions.

3.137 feeder reactor: A current-limiting reactor for connection in series with an alternating-current feeder circuit for the purpose of limiting and localizing the disturbance due to faults on the feeder.

3.138 ferroresonance: A phenomenon usually characterized by overvoltages and very irregular wave shapes and associated with the excitation of one or more saturable inductors through capacitance in series with the inductor.

3.139 filter reactor: A reactor used to reduce harmonic voltage in alternating-current or direct-current circuits.

3.140 flush-mounted device: A device in which the body projects only a small specified distance in front of the mounting surface.

3.141 FOA: Obsolete term. *See:* **ODAF** or **OFAF.**

3.142 FOW: Obsolete term. *See:* **ODWF** or **OFWF.**

3.143 frequency: The number of periods occurring per unit time.

3.144 front-plate: The sidewall of a tank enclosing the core and coils of a liquid-immersed, pad-mounted transformer, on which the bushing terminals are mounted.

3.145 front-of-wave lightning impulse test: A voltage impulse, with a specified rate-of-rise, that is terminated intentionally by sparkover of a gap that occurs on the rising front of the voltage wave with a specified time to sparkover and a specified minimum crest voltage.

3.146 full-wave lightning impulse test: Application of the "standard lightning impulse" wave, a full wave having a front time of 1.2 μs and a time to half value of 50 μs, described as a 1.2/50 μs impulse. *See also:* **standard lightning impulse.**

3.147 furnace transformer: A transformer that is designed to be connected to an electric arc furnace. *Syn:* **arc furnace transformer** (IEC).

3.148 fused-type voltage transformer: One that is provided with the means for mounting a fuse, or fuses, as an integral part of the transformer in series with the primary winding.

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3.149 GA: The cooling class for a sealed dry-type self-cooled transformer with a hermetically sealed tank.

NOTE—The insulating gas may be air, nitrogen, or other gases (such as fluorocarbons) with high dielectric strength.

3.150 gas-filled transformer: A sealed transformer, except that the windings are immersed in a dry gas that is other than air or nitrogen.

3.151 gas-oil sealed system: A system in which the interior of the tank is sealed from the atmosphere, over the temperature range specified, by means of an auxiliary tank or tanks to form a gas-oil seal operating on the manometer principle.

3.152 general purpose transformers: Step-up or step-down transformers or autotransformers generally used in secondary distribution circuits of 600 V or less in connection with power and lighting service.

3.153 grounded: Connected to earth or to some extended conducting body that serves instead of the earth, whether the connection is intentional or accidental. *Syn:* **earthed** (IEC).

3.154 grounded system: A system of conductors in which at least one conductor or point (usually the middle wire or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current-limiting device.

3.155 ground-fault neutralizer grounded (resonant grounded): Reactance grounded through such values of reactance that, during a fault between one of the conductors and earth, the rated-frequency current flowing in the grounding reactances and the rated-frequency capacitance current moving between the unfaulted conductors and earth shall be substantially equal.

NOTES:

1—In the fault these two components of current will be substantially 180 degrees out of phase.

2—When a system is ground-fault neutralizer grounded, it is expected that the quadrature component of the rated-frequency single-phase-to-ground fault current will be so small that an arc fault in air will be self-extinguishing.

3.156 grounding transformer: A transformer intended primarily to provide a neutral point for grounding purposes. *Syn:* **three phase earthing transformer** (IEC). *See also:* **rated kVA of a grounding transformer; voltage rating of a grounding transformer.**

NOTE—A grounding transformer may be provided with a Δ winding in which resistors or reactors are connected. *See also:* **stabilizing winding.**

3.157 group-series loop insulating transformer: An insulating transformer whose secondary is arranged to operate a group of series lamps or a series group of individual-lamp transformers.

3.158 harmonic factor: The ratio of the effective value of all the harmonics to the effective value of the fundamental.

$$\text{Harmonic factor} = \sqrt{\frac{E_3^2 + E_5^2 + E_7^2}{E_1}} \ldots \text{ (for voltage)}$$

$$\text{Harmonic factor} = \sqrt{\frac{I_3^2 + I_5^2 + I_7^2}{I_1}} \ldots \text{ (for current)}$$

3.159 heat exchanger: A device attached to an oil-filled transformer for the purpose of exchanging heat from the transformer oil to either ambient air or to water.

3.160 hertz: The unit of frequency (cycles per second).

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3.161 high fire point fluid: *See:* **less-flammable insulating fluid**

3.162 high molecular weight hydrocarbon (HMWH) insulating fluid: A specially refined paraffinic hydrocarbon based less-flammable insulating liquid and coolant for use in fire-resistant indoor and outdoor transformers, which generally conforms to ASTM D5222 when new.

3.163 high power factor transformer: A high-reactance transformer that has a power-factor-correcting device, such as a capacitor, so that the input current is at a power factor of not less than 90 percent when the transformer delivers rated current to its intended load device.

3.164 high-reactance transformer: An energy-limiting transformer that has sufficient inherent reactance to limit the output current to a maximum value.

3.165 high-voltage and low-voltage windings: The terms high voltage and low voltage are used to distinguish the winding having the greater from that having the lesser voltage rating.

3.166 hoeppner connection: A three-phase transformer connection involving transformation from a wye winding to the combination of a delta winding and a zigzag winding, which are connected permanently in parallel.

NOTE—This connection is used when a wye-delta connection is needed, with ground connections on both primary and secondary windings.

3.167 hot-spot: A nonrecommended, abbreviated term occasionally used as a synonym for either hottest-spot temperature, or hottest-spot temperature rise.

3.168 hottest-spot rise: *See:* **hottest-spot temperature rise.**

3.169 hottest-spot temperature: The hottest temperature of the current carrying components of a transformer in contact with insulation or insulating fluid.

3.170 hottest-spot temperature rise: The arithmetic difference between the hottest-spot temperature and the ambient temperature.

3.171 hysteresis loss: The energy loss in magnetic material that results from an alternating magnetic field as the elementary magnets within the material seek to align themselves with the reversing magnetic field.

3.172 ignition transformer: Step-up transformer generally used for electrically igniting oil, gas, or gasoline in domestic, commercial, or industrial heating equipment.

3.173 impedance drop: The phasor sum of the resistance voltage drop and the reactance voltage drop.

NOTE—For transformers, the resistance drop, the reactance drop, and the impedance drop are, respectively, the sum of the primary and secondary drops reduced to the same terms. They are determined from the load-loss measurements and are usually expressed in per unit or in percent.

3.174 impedance grounded: Grounded through impedance.

NOTE—The component of the impedance need not be at the same location as the device to be grounded.

3.175 impedance kVA (rated): The kVA measured in the excited winding with the other winding short-circuited and with sufficient voltage applied to the excited winding to cause rated current to flow in the winding.

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3.176 impedance voltage of a constant-current transformer: The measured primary voltage required to circulate rated secondary current through the short-circuited secondary coil for a particular coil separation.

NOTE—It is usually expressed in per unit or percent of the rated primary voltage.

3.177 impedance voltage of a transformer: The voltage required to circulate rated current through one of two specified windings of a transformer when the other winding is short-circuited, with the windings connected as for rated voltage operation.

NOTE—It is usually expressed in per unit, or percent, of the rated voltage of the winding in which the voltage is measured.

3.178 impulse test: An insulation test in which the voltage applied is an impulse voltage of specified wave shape.

3.179 individual-lamp autotransformer: A series autotransformer that transforms the primary current to a higher or lower current as required for the operation of an individual street light.

3.180 individual-lamp insulating transformer: An insulating transformer used to protect the secondary circuit, casing, lamp, and associated luminaire of an individual street light from the high-voltage hazard of the primary circuit.

3.181 indoor: When used as a prefix, meaning not suitable for exposure to the weather.

NOTE—For example, indoor equipment designed for indoor service or for use in a weatherproof housing.

3.182 indoor transformer: A transformer that, because of its construction, must be protected from the weather.

3.183 induced voltage tests: Induced voltage tests are dielectric tests on transformer windings in which the appropriate test voltages are developed in the windings by magnetic induction. *See also:* **applied voltage tests, low-frequency dielectric tests.**

NOTE—Power for induced voltage tests is usually supplied at higher-than-rated frequency to avoid core saturation and excessive excitation current.

3.184 induction voltage regulator: A regulating transformer having a primary winding in shunt and a secondary winding in series with a circuit, for gradually adjusting the voltage or the phase relation, or both, of the circuit by changing the relative magnetic coupling of the exciting (primary) and series (secondary) windings.

3.185 inert gas-pressure system: A system in which the interior of the tank is sealed from the atmosphere, over the temperature range specified, by means of a positive pressure of inert gas maintained from a separate inert gas source and reducing valve system.

3.186 inhibited oil: Mineral transformer oil to which a synthetic oxidation inhibitor has been added.

3.187 inhibitor: Any substance that when added to an electrical insulating fluid retards or prevents undesirable reactions.

3.188 inside top air temperature: The temperature of the air inside a dry-type transformer enclosure, measured in the space above the core and coils.

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3.189 instrument transformer: A transformer that is intended to reproduce in its secondary circuit, in a definite and known proportion, the current or voltage of its primary circuit, with the phase relations and waveform substantially preserved.

3.190 insulated-neutral terminal-type voltage transformer: A voltage transformer that has the neutral end of the high-voltage winding insulated from the case or base and connected to a terminal that provides insulation for a lower voltage than required for the line terminal.

3.191 insulating transformer: A transformer used to insulate one circuit from another.

3.192 insulation class (nonpreferred term) *See:* **insulation level.**

3.193 insulation coordination: The process of correlating the insulation strengths of electrical equipment with expected overvoltages and with the characteristics of surge protective devices.

3.194 insulation level: An insulation strength expressed in terms of a withstand voltage.

3.195 insulation power factor: The ratio of the power dissipated in the insulation, in watts, to the product of the effective voltage and current in volt-amperes, when tested under a sinusoidal voltage and prescribed conditions.

NOTE—If the current is also sinusoidal, the insulation power factor is equal to the cosine of the phase angle between the applied voltage and the resulting current.

3.196 insulation system: An assembly of insulating materials in a particular type, and sometimes size, of equipment.

3.197 integral unit substation: A unit substation in which the incoming, transforming, and outgoing sections are manufactured as a single compact unit.

3.198 interconnected delta connection: A three-phase connection using six windings (two per phase) connected in a six-sided circuit with six bushings to provide a fixed phase-shift between two three-phase circuits without change in voltage magnitude.

NOTE—The interconnected delta connection is sometimes described as a “hexagon autotransformer,” or a “squashed delta.”

3.199 interlacing impedance voltage of a Scott-connected transformer: The single-phase voltage applied from the midtap of the main transformer winding to both ends, connected together, which is sufficient to circulate in the supply lines a current equal to the rated three-phase line current. The current in each half of the winding is 50 percent of this value.

NOTES:

1—The per-unit or percent interlacing resistance is the measured watts expressed on the base of the rated kVA of the teaser winding.

2—The per-unit or percent interlacing impedance is the measured voltage expressed on the base of the teaser voltage.

3.200 interleaved winding: An arrangement of transformer windings where the primary and secondary windings, and the tertiary windings, if any, are subdivided into disks (or pancakes) or layers and interleaved on the same core. Also, a type of winding in which the conductors are arranged out of sequence in the turns to increase the series capacitance of the winding.

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3.201 interlock: A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices.

NOTE—Interlocks may be either electric or mechanical.

3.202 intermittent duty: A requirement of service that demands operation for alternate periods of (a) load and no load; or (b) load and rest; or (c) load, no load, and rest; such alternate intervals being definitely specified.

3.203 internal insulation: The insulation that is not directly exposed to atmospheric conditions.

3.204 interphase transformer: An autotransformer, or a set of mutually coupled reactors, used to obtain parallel operation between two or more simple rectifiers that have ripple voltages that are out of phase.

3.205 IR-drop compensation transformer: A provision in the transformer by which the voltage drop due to transformer load current and internal transformer resistance is partially or completely neutralized. Such transformers are suitable only for one-way transformation, that is, not interchangeable for step-up and step-down transformations.

3.206 I^2R loss: The loss that is due to the currents in, and the direct-current resistance of, the windings. The I^2R loss is determined by measuring the direct-current resistances using a direct current and voltage and then a calculation is performed using the winding currents.

3.207 KDAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. *See also:* **directed flow.**

3.208 KDWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. *See also:* **directed flow.**

3.209 KFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. *See also:* **non-directed flow.**

3.210 KFWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. *See also:* **non-directed flow.**

3.211 KNAN: The cooling class for a transformer or reactor having its core and coils immersed in insulating liquid with fire point greater than 300 ºC, the cooling being effected by the natural circulation of air over the cooling surface.

3.212 KNAN/KFAF/KFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and two forced insulating liquid-cooled ratings obtained by forced circulation of the insulating liquid over the core and coils, utilizing non-directed flow. *See also:* **non-directed flow.**

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3.213 KNAN/KNAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface.

3.214 KNAN/KNAF/KFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface, and a forced insulating liquid-cooled rating with cooling obtained by the forced circulation of the insulating liquid over the core and coils utilizing non-directed flow. The insulating liquid is cooled by the same cooling surface over which the air is being forced circulated. *See also:* **non-directed flow.**

3.215 KNAN/KNAF/KNAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and having a self-cooled rating obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating obtained by the forced circulation of air over a portion of the cooling surface, and an increased forced-air-cooled rating obtained by the increased forced circulation of air over a portion of the cooling surface.

3.216 knockout: A portion of the wall of a box or cabinet so fashioned that it may be readily removed by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment of a raceway cable or fitting.

3.217 KNWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC, the cooling being effected by the natural circulation of the insulating liquid over a water-cooled surface.

3.218 KNWF/KNAN: The cooling class for a transformer having its core and coils immersed in insulating liquid with fire point greater than 300 ºC and having a water-cooled rating with cooling obtained by the natural circulation of the insulating liquid over the water-cooled surface, and a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface.

3.219 kVA or volt-ampere short-circuit input rating of a high-reactance transformer: One that designates the input kVA or volt-amperes at rated primary voltage with the secondary terminals short-circuited.

3.220 LDAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. *See also:* **directed flow.**

3.221 LDWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. *See also:* **directed flow.**

3.222 lead: A conductor that connects a winding to its termination (that is, terminal, bushing, terminal board, or connection to another winding).

3.223 lead polarity: A designation of the relative instantaneous direction of the currents in the leads of a transformer. Primary and secondary leads are said to have the same polarity when, at a given instant, the current enters the primary lead in question and leaves the secondary lead in question in the same direction as though the two leads formed a continuous circuit. The lead polarity of a single-phase distribution or power

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transformer may be either additive or subtractive. If adjacent leads from each of the two windings in question are connected together and voltage applied to one of the windings:

a) The lead polarity is additive if the voltage across the other two leads of the windings in question is greater than that of the higher voltage winding alone.
b) The lead polarity is subtractive if the voltage across the other two leads of the windings in question is less than that of the higher voltage winding alone. The polarity of a polyphase transformer is fixed by the internal connections between phases; it is usually designated by means of a phasor diagram showing the angular displacements of the voltages in the windings and a sketch showing the marking of the leads. The phasors of the phasor diagrams represent induced voltages. The standard rotation of phasors is counterclockwise. *See also:* **polarity.**

3.224 less-flammable insulating fluid: Electrical insulating fluid that has a fire point greater than or equal to 300 ºC per ASTM D92 as defined in Article 450-23 of the National Electrical Code® (NEC®) (NFPA 70-1999).

3.225 less-flammable liquid-insulated transformers insulating fluid: Transformers insulated with less-flammable liquids to provide increased fire safety.

3.226 LFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. *See also:* **non-directed flow.**

3.227 LFWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. *See also:* **non-directed flow.**

3.228 lightning impulse insulation level: An insulation level expressed in kilovolts of the crest value of a lightning impulse withstand voltage.

3.229 lightning impulse protection level (of a protective device): The maximum lightning impulse voltage expected at the terminals of a surge protective device under specified conditions of operation.

3.230 lightning impulse test: Application of the following sequence of impulse waves:

a) One reduced full wave
b) Two chopped waves
c) One full wave

See also: **standard lightning impulse.**

3.231 limiting insulation system temperature (limiting hottest-spot temperature): The maximum temperature selected for correlation with a specified test condition of the equipment with the object of attaining a desired service life of the insulation system.

3.232 limiting temperature: The maximum temperature at which a component or material may be operated continuously with no sacrifice in normal life expectancy.

3.233 line-drop compensator: A device that causes the voltage-regulating relay to increase the output voltage by an amount that compensates for the impedance drop in the circuit between the regulator and a predetermined location on the circuit (sometimes referred to as the load center).

3.234 liquid-immersed transformer: A transformer in which the core and coils are immersed in an insulating liquid.

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3.235 live front: A pad-mounted transformer in which the high-voltage cables are terminated on live-metal parts.

3.236 live-metal part: A part consisting of electrically conductive material that can be energized under conditions of normal use of the equipment.

3.237 LNAN: The cooling class for a transformer or reactor having its core and coils immersed in insulating liquid with no measurable fire point, the cooling being effected by the natural circulation of air over the cooling surface.

3.238 LNAN/LFAF/LFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and two forced insulating liquid-cooled ratings obtained by forced circulation of the insulating liquid over the core and coils, utilizing non-directed flow. *See also:* **non-directed flow.**

3.239 LNAN/LNAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface.

3.240 LNAN/LNAF/LFAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface, and a forced insulating liquid-cooled rating with cooling obtained by the forced circulation of the insulating liquid over the core and coils, utilizing non-directed flow. The insulating liquid is cooled by the same cooling surface over which the air is being forced circulated. *See also:* **non-directed flow.**

3.241 LNAN/LNAF/LNAF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, and having a self-cooled rating obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating obtained by the forced circulation of air over a portion of the cooling surface, and an increased forced-air-cooled rating obtained by the increased forced circulation of air over a portion of the cooling surface.

3.242 LNWF: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, the cooling being effected by the natural circulation of the insulating liquid over a water-cooled surface.

3.243 LNWF/LNAN: The cooling class for a transformer having its core and coils immersed in insulating liquid with no measurable fire point, and having a water-cooled rating with cooling obtained by the natural circulation of the insulating liquid over the water-cooled surface, and a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface.

3.244 load (output): The apparent power in megavolt-amperes, kilovolt-amperes, or volt-amperes that may be transferred by the transformer.

3.245 load-break bushing: A bushing capable of interrupting rated maximum load current as it is disconnected and that safely extinguishes the arc that occurs during the current interruption.

3.246 load-break connector. A separable insulated connector designed to close and interrupt current on energized circuits.

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3.247 load-break switch: A switch capable of interrupting rated maximum load current as it is disconnected and that safely extinguishes the arc that occurs during the current interruption.

3.248 load losses: Those losses that are incident to the carrying of a specified load. Load losses include I^2R loss in the current carrying parts (windings, leads, busbars, bushings), eddy losses in conductors due to eddy currents and circulating currents (if any) in parallel windings or in parallel winding strands, and stray loss induced by leakage flux in the tank, core clamps, or other structural parts. In equation form:

$$P_{LL} = I^2R + P_{EC} + P_{SL} \quad (1)$$

where

P_{LL} is the load loss (W)
I^2R is the loss due to current and resistance (W)
P_{EC} is the eddy current loss (W)
P_{SL} is the stray loss (W).

See also: **no-load (excitation) losses.**

3.249 load tap changer (LTC): A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load. *Syn:* **on-load tap-changer** (IEC).

3.250 load tap changing transformer: A transformer used to vary the voltage, or the phase angle, or both, of a regulated circuit in steps by means of a device that connects different taps of tapped winding(s) without interrupting the load.

3.251 loop-feed transformer: A transformer, generally with two primary bushings per terminal, such that the primary source may be obtained from either, or both, of two connecting cables that are connected to other transformers and the source in a loop arrangement.

3.252 low-frequency dielectric tests: Dielectric tests in which the test voltages are low-frequency alternating voltages from an external source. *Contrast:* **lightning impulse test, switching impulse test;** *see also:* **applied voltage tests, induced voltage tests.**

3.253 low power factor transformer: A high-reactance transformer that does not have means for power-factor correction.

3.254 luminous tube transformers: Transformers, autotransformers, or reactors (having a secondary open-circuit rms of 1000 V or more) for operation of cold-cathode and hot-cathode luminous tubing generally used for signs, illumination, and decoration purposes.

3.255 machine-tool control transformers: Step-down transformers, which may be equipped with a fuse or other overcurrent protection device, that are generally used for the operation of solenoids, contactors, relays, portable tools, and localized lighting.

3.256 main transformer of a Scott-connected transformer: The term "main transformer," as applied to two single-phase Scott-connected units for three-phase to two-phase or two-phase to three-phase operation, designates the transformer that is connected directly between two of the phase wires of the three-phase lines. *See also:* **teaser transformer of a Scott-connected transformer.**

NOTE—A tap is provided at the midpoint for connection to the teaser transformer.

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3.257 main unit of a two-core regulating transformer: The core and coil unit that furnishes excitation to the series unit.

3.258 marked ratio: For instrument transformers, the ratio of the rated primary value to the rated secondary value as stated on the nameplate.

3.259 maximum design voltage: The highest rms phase-to-phase voltage that equipment components are designed to withstand continuously, and to operate in a satisfactory manner without derating of any kind.

3.260 maximum system voltage: The highest rms phase-to-phase voltage that occurs on the system under normal operating conditions, and the highest rms phase-to-phase voltage for which equipment and other system components are designed for satisfactory continuous operation without derating of any kind. (This voltage excludes voltage transients and temporary overvoltages caused by abnormal system conditions such as faults, load rejection, etc.)

3.261 mercury vapor lamp transformers (multiple-supply type): Transformers, autotransformers, or reactors for operating mercury or metallic iodide vapor lamps for all types of lighting applications, including indoor, outdoor area, roadway, uviarc, and other process and specialized lighting.

3.262 mineral oil: A specially refined oil for use as a insulating liquid and coolant in transformers. Generally conforms to ASTM D3487 when new.

3.263 mineral-oil-immersed transformer: A liquid-immersed transformer in which the insulating and cooling liquid is a mineral oil specifically refined for use in transformers (transformer oil) *Syn:* **oil-immersed transformer.**

3.264 mobile transformer: A transformer designed to provide temporary or emergency replacement power when the primary device is unavailable for service.

NOTE—A mobile transformer is typically mounted on a trailer for easy transportation to the point of use. These units are usually provided with a wide range of voltage adjustments on both the high- and low-voltage sides to allow flexibility in use. These units are typically compact in size, have minimum oil volume, and are generally forced air and forced oil cooled (OFAF).

3.265 multigrounded neutral system: A distribution system of the four-wire type where all transformer neutrals are grounded, and neutral conductors are directly grounded at frequent points along the circuit.

3.266 multiratio current transformer: One with three or more ratios obtained by the use of taps on the secondary winding.

3.267 multiple-secondary current transformer: One that has three or more secondary windings, each on a separate magnetic circuit, with all magnetic circuits excited by the same primary winding.

3.268 network protector: An assembly comprising a circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electric conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control responsive to predetermined electrical conditions on the feeder and the secondary network.

NOTE—The network protector is usually arranged to connect automatically its associated transformer to the network when conditions are such that the transformer, when connected, will supply power to the network and to automatically disconnect the transformer from the network when power flows from the network to the transformer.

3.269 network transformer: A transformer designed for use in a vault to feed a variable capacity system of interconnected secondaries.

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NOTE—A network transformer may be of the submersible or of the vault type. It usually, but not always, has provision for attaching a network protector.

3.270 neutral ground: An intentional ground applied to the neutral conductor or neutral point of a circuit, transformer, machine, apparatus, or system.

3.271 neutral grounding reactor: A current-limiting inductive reactor for connection in the neutral for the purpose of limiting and neutralizing disturbances due to ground faults.

3.272 neutral point: (A) The common point of a wye-connection in a polyphase system. (B) the point of a symmetrical system that is normally at zero voltage.

3.273 no-load current: *See:* **excitation current.**

3.274 no-load (excitation) losses: Those losses that are incident to the excitation of the transformer. No-load (excitation) losses include core loss, dielectric loss, conductor loss in the winding due to exciting current, and conductor loss due to circulating current in parallel windings. These losses change with the excitation voltage. *See also:* **load losses.**

3.275 nominal rate of rise (impulse): The slope of the line that determines the virtual zero.

NOTE—It is usually expressed in volts or amperes per microsecond.

3.276 nominal system voltage: The system voltage by which the system is designated and to which certain operating characteristics of the system are related. (The nominal voltage of a system is near the voltage level at which the system normally operates and provides a per-unit base voltage for system study purposes. To allow for operating contingencies, systems generally operate at voltage levels about 5 to 10 percent below the maximum system voltage for which system components are designed.)

3.277 non-directed flow: Indicates that the pumped insulating fluid from heat exchangers or radiators flows freely inside the tank and is not forced to flow through the windings. *See also:* **OFAF, OFWF.**

3.278 non-energy-limiting transformer: A constant-potential transformer that does not have sufficient inherent impedance to limit the output to a thermally safe maximum value.

3.279 non-self-restoring insulation: An insulation that loses its insulating properties or does not recover them completely, after a disruptive discharge caused by the application of a test voltage; insulation of this kind is generally, but not necessarily, internal insulation.

3.280 nonventilated: So constructed as to provide no intentional circulation of external air through the enclosure.

3.281 nonventilated dry-type transformer: A dry-type transformer that is so constructed as to provide no intentional circulation of external air through the transformer and operating at zero gauge pressure.

3.282 OA: Obsolete term. *See:* **ONAN.**

3.283 OA/FA: Obsolete term. *See:* **ONAN/ONAF.**

3.284 OA/FA/FA: Obsolete term. *See:* **ONAN/ONAF/ONAF.**

3.285 OA/FA/FOA: Obsolete term. *See:* **ONAN/ONAF/ODAF** or **ONAN/ONAF/OFAF.**

3.286 OA/FOA/FOA: Obsolete term. *See:* **ONAN/ODAF/ODAF** or **ONAN/OFAF/OFAF.**

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3.287 ODAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. (**ODAF** was previously termed **FOA**). *See also:* **directed flow.**

3.288 ODWF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and cooled by forced circulation of the insulating liquid utilizing directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. (**ODWF** was previously termed **FOW**). *See also:* **directed flow.**

3.289 OFAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface. (**OFAF** was previously termed **FOA**). *See also:* **non-directed flow.**

3.290 OFWF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and cooled by forced circulation of the insulating liquid utilizing non-directed flow. The insulating liquid is cooled by external insulating liquid-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface. (**OFWF** was previously termed **FOW**). *See also:* **non-directed flow.**

3.291 oil-immersed forced-oil-cooled transformer with forced-air cooler (Class FOA): Obsolete term. *See:* **ODAF** or **OFAF.**

3.292 oil-immersed forced-oil-cooled transformer with forced-water cooler (Class FOW): Obsolete term. *See:* **ODWF** or **OFWF.**

3.293 oil-immersed self-cooled/forced-air, forced-oil-cooled/forced-air, forced-oil-cooled transformer (Class OA/FOA/FOA): Obsolete term. *See:* **ONAN/OFAF/OFAF.**

3.294 oil-immersed self-cooled/forced-air-cooled transformer (Class OA/FA): Obsolete term. *See:* **ONAN/ONAF.**

3.295 oil-immersed self-cooled/forced air-cooled/forced-air-cooled transformer (OA/FA/FA): Obsolete term. *See:* **ONAN/ONAF/ONAF.**

3.296 oil-immersed self-cooled/forced-air-cooled/forced-oil-cooled transformer (Class OA/FA/FOA): Obsolete term. *See:* **ONAN/ONAF/OFAF** or **ONAN/ONAF/ODAF.**

3.297 oil-immersed self-cooled transformer (Class OA): Obsolete term. *See:* **ONAN.**

3.298 oil-immersed transformer: *See:* **mineral-oil-immersed transformer.**

3.299 oil-immersed water-cooled transformer (Class OW): Obsolete term. *See:* **ONWF.**

3.300 oil-immersed water-cooled/self-cooled transformer (Class OW/A): Obsolete term. *See:* **ONWF/ ONAN.**

3.301 oil resistant gaskets: Those gaskets made of material that is resistant to oil or oil fumes.

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3.302 oiltight: So constructed as to exclude oils, coolants, and similar liquids under specified test conditions.

3.303 ONAN: The cooling class for a transformer or reactor having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC, the cooling being effected by the natural circulation of air over the cooling surface. (**ONAN** was previously termed **OA**).

3.304 ONAN/OFAF/OFAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and two forced insulating liquid-cooled ratings obtained by forced circulation of the insulating liquid over the core and coils, utilizing non-directed flow. (**ONAN/OFAF/OFAF** was previously termed **OA/FOA/FO**A). *See also:* **non-directed flow.**

3.305 ONAN/ONAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface. (**ONAN/ONAF** was previously termed **OA/FA**).

3.306 ONAN/ONAF/OFAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface, and a forced insulating liquid-cooled rating with cooling obtained by the forced circulation of the insulating liquid over the core and coils, utilizing non-directed flow. The insulating liquid is cooled by the same cooling surface over which the air is being forced circulated. (**ONAN/ONAF/OFAF** was previously termed **OA/FA/FOA**). *See also:* **non-directed flow.**

3.307 ONAN/ONAF/ONAF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and having a self-cooled rating obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating obtained by the forced circulation of air over a portion of the cooling surface, and an increased forced-air-cooled rating obtained by the increased forced circulation of air over a portion of the cooling surface. (**ONAN/ONAF/ONAF** was previously termed **OA/FA/FA**).

3.308 ONWF: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC the cooling being effected by the natural circulation of the insulating liquid over a water-cooled surface. (**ONWF** was previously termed **OW**).

3.309 ONWF/ONAN: The cooling class for a transformer having its core and coils immersed in mineral oil or synthetic insulating liquid with fire point less than or equal to 300 ºC and having a water-cooled rating with cooling obtained by the natural circulation of the insulating liquid over the water-cooled surface, and a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface. (**ONWF/ONAN** was previously termed **OW/A**).

3.310 open-delta connection: A connection similar to a delta-delta connection utilizing three single-phase transformers, but with one single-phase transformer removed.

NOTE—The two remaining transformers of an open-delta bank will carry 57.7% of the load carried by the bank using three identical transformers connected delta-delta.

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3.311 other tests: Tests so identified in individual product standards that may be specified by the purchaser in addition to design and routine tests. (Examples: impulse, insulation power factor, audible sound.)

NOTE—Transformer "General Requirements" Standards (such as IEEE Std C57.12.00-2000) classify various tests as "routine," "design," or "other" depending on the size, voltage, and type of transformer involved.

3.312 outdoor: Suitable for installation where exposed to the weather.

3.313 outdoor transformer: A transformer of weather-resistant construction suitable for service without additional protection from the weather.

3.314 overcurrent protection: A form of protection that operates when current exceeds a predetermined value.

3.315 overload (general): Output of current, power, or torque, by a device, in excess of the rated output of the device on a specified rating basis.

3.316 overvoltage: Abnormal voltage between two points of a system that is greater than the highest value appearing between the same two points under normal service conditions. Overvoltages may be low frequency, temporary, and transient—meaning a lightning or switching surge overvoltage.

3.317 OW: Obsolete term. *See:* **ONWF.**

3.318 OW/A: Obsolete term. *See:* **ONWF/ONAN.**

3.319 oxidation inhibitor: Any substance added to an insulating fluid to improve its resistance to deleterious attack in an oxidizing environment.

3.320 pad-mounted enclosure: An enclosure containing electrical apparatus typically located outdoors at ground level where the general public has direct contact with the exterior surfaces of the equipment. The general construction of this equipment shall be such that authorized personnel may obtain access to the apparatus inside the equipment compartment.

3.321 pad-mounted transformer: An outdoor transformer utilized as part of an underground distribution system, with enclosed compartment(s) for high-voltage and low-voltage cables entering from below, and mounted on a foundation pad.

3.322 paralleling reactor: A current-limiting reactor for correcting the division of load between parallel-connected transformers that have unequal impedance voltages.

3.323 parking stand: A standardized bracket attached near the primary bushings of dead-front equipment for the purpose of attaching grounding bushings, feed-through devices, and other accessories used to insulate primary elbow terminals.

3.324 partial discharge (PD): An electric discharge that only partially bridges the insulation between conductors, and which may or may not occur adjacent to a conductor.

NOTES:

1—Partial discharges occur when the local electric field intensity exceeds the dielectric strength of the dielectric involved, resulting in local ionization and breakdown. Depending on intensity, partial discharges are often accompanied by emission of light, heat, sound, and radio influence voltage (with a wide frequency range).

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2—The relative intensity of partial discharge can be observed at the transformer terminals by measurement of the apparent charge (coulombs). However, the apparent charge (terminal charge) should not be confused with the actual charge transferred across the discharging element in the dielectric which, in most cases, cannot be ascertained.

Partial discharge tests using the radio influence voltage techniques that are responsive to the apparent terminal charges are generally used for measurement of relative discharge intensity.

3—Partial discharges can also be detected and located using sonic techniques.

4—"Corona" has also been used to describe partial discharges. This is a non-preferred term since it has other unrelated meanings.

3.325 pcb: *See:* **askarel.**

3.326 peak value: *See:* **crest value.**

3.327 percent ratio: For instrument transformers, the true ratio expressed in percent of the marked ratio.

3.328 percent ratio correction of an instrument transformer: The difference between the ratio correction factor and unity, expressed in percent [(RCF – 1) × 100]. *See also:* **ratio correction factor.**

NOTE—The percent ratio correction is positive if the ratio correction factor is greater than unity. If the percent ratio correction is positive, the measured secondary current or voltage will be less than the primary value divided by the marked ratio.

3.329 performance characteristics: Those characteristics (such as impedance, losses, dielectric test levels, temperature rise, sound level, etc.) that describe the performance of the equipment under specified conditions of operation.

3.330 periodic duty: A type of intermittent duty in which the load conditions are regularly recurrent.

3.331 phase angle of an instrument transformer: The phase displacement, in minutes, between the primary and secondary values.

NOTE—The phase angle of a current transformer is designated by the Greek letter beta (ß) and is positive when the current leaving the identified secondary terminal leads the current entering the identified primary terminal.

The phase angle of a voltage transformer is designated by the Greek letter gamma (γ) and is positive when the secondary voltage from the identified to the unidentified terminal leads the corresponding primary voltage.

3.332 phase-angle correction factor: The ratio of the true power factor to the measured power factor. It is a function of both the phase angles of the instrument transformers and the power factor of the primary circuit being measured. *See also:* **phase angle of an instrument transformer.**

NOTE—The phase-angle correction factor corrects for the phase displacement of the secondary current or voltage, or both, due to the instrument transformer phase angle(s). For a current transformer, the phase-angle correction factor:

$$PACF = \cos(\theta_2 + \beta)/\cos(\theta_2)$$

For a voltage transformer, the phase-angle correction factor:

$$PACF = \cos(\theta_2 - \beta)/\cos(\theta_2)$$

When both voltage and current transformers are used, the combined phase-angle correction:

$$PACF = \cos(\theta_2 + \beta - \gamma)/\cos(\theta_2)$$

where

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θ_2 is the apparent power factor angle of the circuit being measured,
ß is the current transformer phase angle,
γ is the voltage transformer phase angle.

3.333 phase sequence: The order in which the voltages successively reach their positive maximum values.

3.334 phase-shifting transformer (phase-angle regulator): A transformer that advances or retards the voltage phase-angle relationship of one circuit with respect to another.

NOTES:

1—The terms "advance" and "retard" describe the electrical angular position of the load voltage with respect to the source voltage.

2—If the load voltage reaches its positive maximum sooner than the source voltage, this is an "advance" position.

3—Conversely, if the load voltage reaches its positive maximum later than the source voltage, this is a "retard" position.

3.335 phase-to-ground per-unit overvoltage: The ratio of a phase-to-ground overvoltage to the phase-to-ground voltage corresponding to the maximum system voltage.

3.336 phase-to-phase per-unit overvoltage: The ratio of a phase-to-phase overvoltage to the phase-to-phase voltage corresponding to the maximum system voltage.

3.337 polarity: The designation of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle. *See also:* **lead polarity.**

NOTE—Primary and secondary terminals are said to have the same polarity, when, at a given instant during most of each half cycle, the current enters the identified, similarly marked primary lead and leaves the identified, similarly marked secondary terminal in the same direction as though the two terminals formed a continuous circuit.

3.338 pole-type transformer: A transformer that is suitable for mounting on a pole or similar structure.

3.339 positive pressure oil preservation system: A gas-oil sealed system, in which a positive gage pressure is maintained on the oil preservation system by a pressure regulator control system connected to a compressed gas or compressed air bottle.

3.340 power rectifier transformer: A rectifier transformer connected to mercury-arc or semiconductor rectifiers for electrochemical service, steel processing applications, electric furnace applications, mining applications, transportation applications, and direct-current transmissions.

3.341 power transformer: A transformer that transfers electric energy in any part of the circuit between the generator and the distribution primary circuits. *See also:* **distribution transformer.**

3.342 preventive autotransformer: An autotransformer (or center-tapped reactor) used in load-tap-changing and regulating transformers or step-voltage regulators to limit the circulating current when operating on a position in which two adjacent taps are bridged or during the change of taps between adjacent positions. *See also:* **transition reactor** (IEC).

3.343 primary circuit of a regulating transformer: The circuit on the input side of the regulator.

3.344 primary voltage rating of a general-purpose specialty transformer: The input circuit voltage for which the primary winding is designed, and to which operating and performance characteristics are referred.

3.345 primary unit substation: A substation in which the low-voltage section is rated above 1000 V.

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3.346 primary winding: The winding on the energy input side.

3.347 proof (suffix): Apparatus is designed as splash-proof, dust-proof, etc., when so constructed, protected, or treated that its successful operation is not interfered with when subjected to the specified material or condition.

3.348 radial-feed transformer: A pad-mounted transformer with only one set of primary bushings, designed for connection to only one set of primary cables and not equipped for loop-feed connection.

3.349 radial-type unit substation: A unit substation that has a single step-down transformer and that has an outgoing section for the connection of one or more outgoing radial (stub-end) feeders.

3.350 radiator: An insulating fluid to air heat exchanging device attached to a transformer for the purpose of exchanging heat from the transformer insulating fluid to the ambient air.

3.351 radio influence voltage (RIV): A radio frequency voltage generally produced by partial discharge and measured at the equipment terminals for the purpose of determining the electromagnetic interference effect of the discharges.

NOTES:

1—"RIV" can be measured with a coupled radio interference measuring instrument and is commonly measured at approximately 1 MHz, although a wide frequency range is involved.

2—"RIV" values are often used as an "index" of "partial discharge" intensity.

3—The RIV of equipment was historically measured to determine the influence of energized equipment on radio broadcasting, hence—RIV.

3.352 rainproof: So constructed, protected, or treated as to prevent rain under specified test conditions from interfering with successful operation of the apparatus.

3.353 raintight: So constructed or protected as to exclude rain under specified test conditions.

3.354 rated current of a current transformer: The primary current upon which the performance specifications are based.

3.355 rated kilowatts of a constant-current transformer: The kilowatt output at the secondary terminals with rated primary voltage and frequency, and with rated secondary current and power factor, and within the limitations of established standards.

3.356 rated kVA of a grounding transformer: The short-time kilovolt-ampere rating is the product of the rated line-to-neutral voltage at rated frequency, and the maximum constant current that can flow in the neutral for the specified time without causing specified temperature-rise limitations to be exceeded, and within the limitations of established standards for such equipment.

3.357 rated kVA of a transformer: The output that can be delivered for the time specified at rated secondary voltage and rated frequency without exceeding the specified temperature-rise limitations under prescribed conditions.

3.358 rated kVA tap: A tap through which the transformer can deliver its rated kVA output without exceeding the specified temperature rise.

3.359 rated primary voltage of a constant-current transformer: The primary voltage for which the transformer is designed and to which operation and performance characteristics are referred.

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3.360 rated primary voltage of a constant-voltage transformer: The voltage calculated from the rated secondary voltage by turn ratio.

NOTES:

1—See **turn ratio of a transformer** and its note, for the definition of the turn ratio to be used.

2—In the case of a multiwinding transformer, the rated voltage of any other winding is obtained in a similar manner.

3.361 rated secondary current of a constant-current transformer: The secondary current for which the transformer is designed and to which operation and performance characteristics are referred.

3.362 rated secondary current of a constant-voltage transformer: The secondary current obtained by dividing the rated kVA by the rated secondary voltage, in kV.

3.363 rated secondary current of a current transformer: The rated current divided by the marked ratio.

3.364 rated secondary voltage of a constant-voltage transformer: The voltage at which the transformer is designed to deliver rated kVA and to which operating and performance characteristics are referred.

3.365 rated secondary voltage of a voltage transformer: The rated voltage divided by the marked ratio.

3.366 rated voltage: The voltage to which operating and performance characteristics of apparatus and equipment are referred.

NOTE—Deviation from rated voltage may not impair operation of equipment, but specified performance characteristics are based on operation under rated conditions. However, in many cases apparatus standards specify a range of voltage within which successful performance may be expected.

3.367 rated voltage of a voltage transformer: The primary voltage selected for the basis of performance specifications of a voltage transformer.

NOTE—The relationship above applies directly for single-phase transformers, but requires additional consideration of the connections involved in three-phase transformers.

3.368 rated voltage of a winding: The voltage to which operating and performance characteristics are referred.

3.369 rating of a transformer: The rating of a transformer consists of a volt-ampere output together with any other characteristics, such as voltage, current, frequency, power factor, and temperature rise, assigned to it by the manufacturer. It is regarded as a rating associated with an output that can be taken from the transformer under prescribed conditions and limitations of established standards.

3.370 rating of interphase transformer: The root-mean-square current, root-mean-square voltage, and frequency at the terminals of each winding, when the rectifier unit is operating at rated load and with a designated amount of phase control.

3.371 rating of rectifier transformer: The kilovolt-ampere output, voltage, current, frequency, and number of phases at the terminals of the alternating-current winding; the voltage (based on turn ratio of the transformer), root-mean-square current, and number of phases at the terminals of the direct-current winding, to correspond to the rated load of the rectifier unit.

NOTES:

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1—Because of the current wave shapes in the alternating- and direct-current windings of the rectifier transformer, these windings may have individual ratings different from each other and from those of power transformers in other types of service. The ratings are regarded as test ratings that define the output that can be taken from the transformer under prescribed conditions of test without exceeding any of the limitations of the standards.

2—For rectifier transformers covered by established standards, the root-mean-square current ratings and kilovolt-ampere ratings of the windings are based on values derived from rectangular rectifier circuit element currents without overlap.

3.372 ratio correction factor (RCF): For instrument transformers, the ratio of the true ratio to the marked ratio. The primary current or voltage is equal to the secondary current or voltage multiplied by the marked ratio times the ratio correction factor.

3.373 reactance drop: The component of the impedance voltage drop in quadrature with the current.

3.374 reactance grounded: Grounded through impedance, the principal element of which is reactance.

NOTE—The reactance may be inserted either directly, in the connection to ground, or indirectly, by increasing the reactance of the ground return circuit. The latter may be done by intentionally increasing the zero-sequence reactance of apparatus connected to ground, or by omitting some of the possible connections from apparatus neutrals to ground.

3.375 reactor: An electromagnetic device, the primary purpose of which is to introduce inductive reactance into a circuit.

3.376 readily accessible: Capable of being reached quickly, for operation, renewal, or inspection, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

3.377 reclamation: The restoration to usefulness by the removal of contaminants and products of degradation such as polar, acidic, or colloidal materials from used electrical insulating liquids by chemical or adsorbent means. Reclaiming typically includes treatment with clay or other adsorbents. *See also:* **reconditioning.**

NOTE—The methods listed under **reconditioning** are usually performed in conjunction with reclaiming.

3.378 reconditioning: The removal of insoluble contaminants, moisture, and dissolved gases from used electrical insulating liquids by mechanical means.

NOTE—The typical means employed are settling, filtering centrifuging, and vacuum drying or degassing.

3.379 rectifier transformer: A transformer that operates at the fundamental frequency of an alternating-current system and designated to have one or more output windings conductively connected to the main electrodes of a rectifier. *See also:* **direct-current winding of rectifier transformer, interphase transformer, power rectifier transformer, interphase transformer, rating of interphase transformer, rating of rectifier transformer.**

3.380 reduced full-wave test: A wave similar in shape and duration to that involved in a "full-wave lightning impulse test," but reduced in magnitude.

NOTE—The reduced full wave normally has a crest value between 50 and 70 percent of the full-wave value involved, and is used for comparison of oscillograms in failure detection.

3.381 reduced kVA tap (in a transformer): A tap through which the transformer can deliver only an output less than rated kVA without exceeding the specified temperature rise. The current is usually that of the rated kVA tap.

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3.382 regulated circuit of a regulating transformer: The circuit on the output side of the regulator, and in which it is desired to control the voltage, or the phase relation, or both.

NOTE—The voltage may be held constant at any selected point on the regulated circuit.

3.383 regulating transformer: A transformer used to vary the voltage, or the phase angle, or both, of an output circuit (referred to as the "regulated circuit") controlling the output within specified limits, and compensating for fluctuations of load and input voltage (and phase angle, when involved) within specified limits.

3.384 regulating winding: The winding or portion of a winding in which taps are changed to control the voltage or phase angle of a winding which is regulated.

3.385 regulating winding of a two-core regulating transformer: The winding of the main unit in which taps are changed to control the voltage or phase angle of the regulated circuit through the series unit.

3.386 re-refining: The use of primary refining processes on used electrical insulating liquids to produce liquids that are suitable for further use as electrical insulating liquids.

NOTE—Techniques may include a combination of distillation and acid, caustic solvent, clay or hydrogen treating, and other physical and chemical means.

3.387 resin-encapsulated winding: A dry-type transformer winding that has been dipped in a thermosetting insulating varnish and cured to provide adhesion of the insulation and conductors and protection from moisture and contaminants. The thermosetting resin may not necessarily penetrate and fill all voids in the winding.

3.388 resistance drop: The component of the impedance voltage drop in phase with the current.

3.389 resistance grounded: Grounded through impedance, the principal element of which is resistance.

NOTE—The resistance may be inserted either directly, in the connection to the ground, or indirectly, as for example, in the secondary of a transformer the primary of which is connected between neutral and ground, or in series with the delta-connected secondary of a wye-delta grounding transformer.

3.390 resistance method of temperature determination: The determination of the temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance at a known temperature.

3.391 resistant (used as a suffix): So constructed, protected, or treated that the apparatus will not be damaged when subjected to the specified material or conditions for a specified time.

3.392 reversing switch: *See:* **change-over selector (in an LTC).**

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

3.394 saturable reactor (saturable-core reactor): (A) A magnetic-core reactor whose reactance is controlled by changing the saturation of the core through variation of a superimposed unidirectional flux. (B) A magnetic-core reactor operating in the region of saturation without independent control means.

NOTE—Thus a reactor whose impedance varies cyclically with the alternating current (or voltage).

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3.395 Scott or T-connected transformer: An assembly used to transfer energy from a three-phase circuit to a two-phase circuit, or vice versa; or from a three-phase circuit to another three-phase circuit. The assembly consists of a main transformer with a tap at its midpoint connected directly between two of the phase wires of a three-phase circuit, and of a teaser transformer connected between the mid-tap of the main transformer and a third phase wire of the three-phase circuit. The other windings of the transformers may be connected to provide either a two-phase or a three-phase output. Alternatively, this may be accomplished with an assembly utilizing a three-legged core with main and teaser coil assemblies located on the two outer legs, and with a center leg that has no coil assembly and provides a common magnetic circuit for the two outer legs. *See also:* **interlacing impedance voltage of a Scott-connected transformer, main transformer of a Scott-connected transformer, teaser transformer of a Scott-connected transformer.**

3.396 sealed: So constructed that the enclosure will remain hermetically sealed within specified limits of temperature and pressure.

3.397 sealed conservator: A system in which the completely filled main tank is connected to an auxiliary (conservator) tank mounted on top of the transformer, with the oil in the conservator completely sealed from the atmosphere by means of a diaphragm or air cell. As oil expands and contracts within a specified temperature range the system remains completely sealed with an approximately constant pressure.

3.398 sealed dry-type transformer, self-cooled: *See:* **GA.**

3.399 sealed-tank system: A method of oil preservation in which the interior of the tank is sealed from the atmosphere and in which the gas plus the oil volume remains constant over the temperature range.

3.400 sealed transformer: A dry-type transformer with a hermetically sealed tank.

3.401 secondary-selective type unit substation (low-voltage-selective type): A unit substation that has two step-down transformers each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a separate bus through a suitable switching and protective device. The two sections of bus are connected by a normally open switching and protective device. Each bus has one or more outgoing radial (stub-end) feeders.

3.402 secondary short-circuit current rating of a high-reactance transformer: One that designates the current in the secondary winding when the primary winding is connected to a circuit of rated primary voltage and frequency and when the secondary terminals are short-circuited.

3.403 secondary unit substation: A substation in which the low-voltage section is rated 1000 V and below.

3.404 secondary voltage rating: The load circuit voltage for which the secondary winding is designed.

3.405 secondary winding: The winding on the energy output side.

3.406 secondary winding of an instrument transformer: The winding that is intended to be connected to the measuring or control devices.

3.407 sectionalizing switch: A load-break switch that may provide any of a number of switching functions connecting or disconnecting a transformer to one or more primary circuits.

3.408 self-restoring insulation: Insulation that completely recovers its insulating properties after a disruptive discharge caused by the application of a test voltage; insulation of this kind is generally, but not necessarily, external insulation.

3.409 separable insulated connector: A system for terminating and electrically connecting an insulated power cable to electrical apparatus, other power cables, or both, so designed that the electrical connection

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can be readily established or broken by engaging or separating mating parts of the connector at the operating interface.

3.410 series circuit lighting transformer: Dry-type individual lamp insulating transformer, autotransformer, and group series loop transformers for operation of incandescent or mercury lamps on series lighting circuits such as for street and airport lighting.

3.411 series street-lighting transformer: A series transformer that receives energy from a current-regulating series circuit and that transforms the energy to another winding at the same or different current from that in the primary.

3.412 series transformer: A transformer with a "series" winding and an "exciting" winding, in which the "series" winding is placed in a series relationship in a circuit to change voltage or phase, or both, in that circuit as a result of input received from the "exciting" winding. *Syn:* **booster transformer** (IEC).

NOTE—Applications of series transformers include: a) Use in a transformer such as a load-tap-changing or regulating transformer to change the voltage or current duty of the load-tap-changing mechanism; b) Inclusion in a circuit for power factor correction to indirectly insert series capacitance in a circuit by connecting capacitors to the exciting winding.

3.413 series unit of a two-core regulating transformer: The core and coil unit that has one winding connected in series in the line circuit.

3.414 series winding of an autotransformer: That portion of the autotransformer winding, which is not common to both the primary and the secondary circuits, but is connected in series between the input and output circuits.

3.415 series winding of a two-core regulating transformer: The winding of the series unit that is connected in series in the line circuit.

NOTE—If the main unit of a two-core transformer is an autotransformer, both units will have a series winding. In such cases, one is referred to as the series winding of the autotransformer and the other, the series winding of the series unit.

3.416 shell form transformer: A transformer in which the laminations constituting the iron core surround the windings and usually enclose the greater part of them. *See also:* **core form transformer.**

3.417 shield: A conductive protective member placed in relationship to apparatus or test components to control the shape or magnitude, or both, of electric or magnetic fields, thereby improving performance of apparatus or test equipment by reducing losses, voltage gradients, or interference.

3.418 short-time duty: A duty that demands operation at a substantially constant load for a short and definitely specified time.

3.419 short-time rating: Defines the maximum constant load that can be carried for a specified short time without exceeding established temperature-rise limitations, under prescribed conditions.

3.420 shunt reactor: A reactor intended for connection in shunt to an electric system for the purpose of drawing inductive current.

NOTE—The normal use for shunt reactors is to compensate for capacitive currents from transmission lines, cable, or shunt capacitors. The need for shunt reactors is most apparent at light load.

3.421 signaling and doorbell transformers: Step-down transformers (having a secondary of 30 V or less), generally used for the operation of signals, chimes, and doorbell.

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3.422 silicone fluid: A specially formulated polydimethyl siloxane less-flammable insulating liquid and coolant for use in fire-resistant indoor and outdoor transformers.

NOTE—Such insulating fluids, when new, generally conform to the requirements of ASTM D4652, "Specification for Silicone Fluid Used for Electrical Insulation."

3.423 single-phase circuit: An alternating-current circuit consisting of two or three intentionally interrelated conductors that enter (or leave) a delimited region at two or three terminals of entry. If the circuit consists of two conductors, it is intended to be so energized that, in the steady state, the voltage between the two terminals of entry is an alternating voltage. If the circuit consists of three conductors, it is intended to be so energized that, in steady state, the alternating voltages between any two terminals of entry have the same period and are in phase or in phase opposition.

3.424 six-phase circuit: A combination of circuits energized by alternating electromotive forces that differ in phase by one-sixth of a cycle, that is, 60 degrees.

NOTE—In practice, the phases may vary several degrees from the specified angle.

3.425 sleetproof: So constructed or protected that the accumulation of sleet (ice) under specified test conditions will not interfere with the successful operation of the apparatus.

3.426 sodium vapor lamp transformers (multiple-supply type): Transformers, autotransformers, or reactors for operating sodium vapor lamps for all types of lighting applications, including indoor, outdoor area, roadway, and other process and specialized lighting.

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

3.428 solidly grounded: Grounded through an adequate ground connection in which no impedance has been inserted intentionally.

NOTE—Adequate as used herein means suitable for the purpose intended.

3.429 specialty transformer: A transformer generally intended to supply electric power for control, machine tool, Class 2, signaling, ignition, luminous-tube, cold-cathode lighting, series street-lighting, low-voltage general purpose, and similar applications. *See also:* **control transformers, electronic transformer, energy limiting transformer, general purpose transformers, group-series loop insulating transformer, high power factor transformer, high-reactance transformer, ignition transformer, individual-lamp autotransformer, individual-lamp insulating transformer, insulating transformer, low power factor transformer, luminous tube transformers, machine-tool control transformers, mercury vapor lamp transformers (multiple-supply type), non-energy-limiting transformer, saturable reactor (saturable-core reactor), series circuit lighting transformer, series street-lighting transformer, signaling and doorbell transformers, sodium vapor lamp transformers (multiple-supply type).**

3.430 spot-network type unit substation: A unit substation that has two step-down transformers, each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a common bus through circuit breakers equipped with relays that are arranged to trip the circuit breaker on reverse power flow to the transformer and to reclose the circuit breaker upon the restoration of the correct voltage, phase angle, and phase sequence at the transformer secondary. The bus has one or more outgoing radial (stub-end) feeders.

3.431 stabilizing winding: A delta-connected auxiliary winding used particularly in wye-connected three-phase transformers for such purposes as the following:

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a) To stabilize the neutral point of the fundamental frequency voltages
b) To minimize third-harmonic voltage and the resultant effects on the system
c) To mitigate telephone influence due to third-harmonic currents and voltages
d) To minimize the residual direct-current magnetomotive force on the core
e) To decrease the zero-sequence impedance of transformers with Y-connected windings. *See also:* **tertiary winding.**

NOTE—A winding is regarded as a stabilizing winding if its terminals are not brought out for connection to an external circuit. However, one or two points of the winding that are intended to form the same corner point of the delta may be brought out for grounding or grounded internally to the tank. For a three-phase transformer, if other points of the winding are brought out, the winding should be regarded as a normal winding as otherwise defined.

3.432 standard lightning impulse: An impulse that rises to crest value of voltage in 1.2 μs (virtual time) and drops to 0.5 crest value of voltage in 50 μs (virtual time), both times being measured from the same origin and in accordance with established standards of impulse testing techniques. It is described as a 1.2/50 μs impulse. [See ANSI C68.1-1992 (IEEE Std 4-1995)] *See also:* **lightning impulse** (IEC).

NOTE—The virtual value for the duration of the wavefront is 1.67 times the time taken by the voltage to increase from 30 percent to 90 percent of its crest value. The origin from which time is measured is the intersection with the zero axis of a straight line drawn through points on the front of the voltage wave at 30 percent and 90 percent crest value.

3.433 standard switching impulse: A full impulse having a front time of 250 μs and a time to half value of 2500 μs. It is described as a 250/2500 impulse. *See also:* **switching impulse** (IEC).

NOTE—It is recognized that some apparatus standards may have to use a modified wave shape where practical test considerations or particular dielectric strength characteristics make some modification imperative. Transformers, for example, use a modified switching impulse wave with the following characteristics:

a) Time to crest greater than 100 μs.
b) Exceeds 90 percent of crest value for at least 200 μs.
c) Time to first voltage zero on tail not less than 1000 μs, except where core saturation causes the tail to become shorter. (See IEEE C57.12.90.)

3.434 star connection: *See:* **wye connection.**

3.435 starting reactor: A current-limiting reactor for decreasing the starting current of a machine or device.

3.436 station-type transformer: A transformer designed for installation in a station or substation.

3.437 step-down transformer: A transformer in which the power transfer is from a higher voltage source circuit to a lower voltage circuit.

3.438 step-up transformer: A transformer in which the power transfer is from a lower voltage source circuit to a higher voltage circuit.

3.439 step voltage regulator: A regulating transformer in which the voltage of the regulated circuit is controlled in steps by means of taps and without interrupting the load.

NOTE—Such units are generally 833 kVA (output) and below, single-phase; or 2500 kVA (output) and below, three-phase.

3.440 stray loss: The loss that is due to the stray leakage flux, which introduces losses in the core, clamps, tank, and other structural parts. There is no test method to determine individual winding eddy loss or to separate transformer stray loss from eddy loss. The total stray and eddy loss is determined by measuring the total load loss during the impedance test. The total stray and eddy loss is determined by subtracting the I^2R loss from the load loss as follows:

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$$P_{EC} + P_{SL} = P_{LL} - I^2R \quad (2)$$

where

P_{EC} is the eddy current loss (W)
P_{SL} is the stray loss (W)
P_{LL} is the load loss (W)
I^2R is the loss due to current and resistance (W).

3.441 striking distance: The shortest unobstructed distance measured through a dielectric medium such as liquid, gas, or vacuum; between parts of different electric potential.

3.442 submersible: So constructed as to be successfully operable when submerged in water under specified conditions of pressure and time.

3.443 submersible transformer: A transformer so constructed as to be successfully operable when submerged in water under predetermined conditions of pressure and time.

3.444 subsurface transformer: A transformer utilized as part of an underground distribution system, connected below ground to high-voltage and low-voltage cables, and located below the surface of the ground.

3.445 subway transformer: A submersible-type distribution transformer suitable for installation in an underground vault.

3.446 switching impulse insulation level: An insulation level expressed in kilovolts of the crest value of a switching impulse withstand voltage.

3.447 switching impulse protection level (of a protective device): The maximum switching impulse expected at the terminals of a surge protective device under specified conditions of operation.

3.448 switching impulse test: Application of the "standard switching impulse," a full wave having a front time of 250 μs and a time to half value of 2500 μs, described as a 250/2500 impulse.

NOTE—It is recognized that some apparatus standards may have to use a modified wave shape where practical test considerations or particular dielectric strength characteristics make some modification imperative. Transformers, for example, use a modified switching impulse wave with the following characteristics:

a) Time to crest greater than 100 μs.
b) Exceeds 90 percent of crest value for at least 200 μs.
c) Time to first voltage zero on tail not less than 1000 μs, except where core saturation causes the tail to become shorter.

3.449 synchronizing reactor: A current-limiting reactor for connecting momentarily across the open contacts of a circuit-interrupting device for synchronizing purposes.

3.450 synthetic ester insulating fluid: A specially formulated polyol ester based less-flammable insulating liquid and coolant for use in fire-resistant indoor and outdoor transformers, which generally conforms to IEC 1099 when new.

3.451 system voltage: A root-mean-square (rms) phase-to-phase power frequency voltage on a three-phase alternating-current electrical system.

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3.452 t-connected (or tee-connected) transformer: A three-phase to three-phase transformer, similar to a Scott-connected transformer.

3.453 tap: A connection brought out of a winding at some point between its extremities, to permit changing the voltage, or current, ratio.

3.454 tap changer for de-energized operation: A selector switch device used to change transformer taps with the transformer de-energized.

3.455 tap selector (in an LTC): A device designed to carry, but not to make or break current, used in conjunction with an arcing switch to select tap connections. *See also:* **tap selector** (IEC).

3.456 teaser transformer of a Scott-connected transformer: The term "teaser transformer," as applied to two single-phase Scott-connected units for three-phase to two-phase or two-phase to three-phase operation, designates the transformer that is connected between the midpoint of the main transformer and the third-phase wire of the three-phase system. *See also:* **main transformer of a Scott-connected transformer.**

3.457 telephone influence factor (TIF): Of a voltage or current wave in an electric supply circuit, the ratio of the square root of the sum of the squares of the weighted root-mean-square values of all the sine-wave components (including in alternating-current waves both fundamental and harmonics) to the root-mean-square value (unweighted) of the entire wave.

NOTE—This factor was formerly known as telephone interference factor, a term still used occasionally when referring to values based on the original (1919) weighting curve.

3.458 temperature rise: The difference between the temperature of the part under consideration (commonly the "average winding rise" or the "hottest-spot winding rise") and the ambient temperature.

3.459 temperature index: An index that allows relative comparisons of the temperature capability of insulating materials or insulation systems based on specified controlled test conditions. Preferred values of temperature index numbers are:

Number range	Preferred temperature index
90–104	90
105–129	105
130–154	130
155–179	155
180–199	180
200–219	200
220 and above	No preferred indices established

NOTE—See IEEE Std 1.

3.460 temporary overvoltage: An oscillatory phase-to-ground or phase-to-phase overvoltage at a given location of relatively long duration and which is undamped or only weakly damped. Temporary overvoltages usually originate from switching operations or faults (for example, load rejection, single-phase faults) or from non-linearities (ferroresonance effects, harmonics), or both. They may be characterized by their amplitude, their oscillation frequencies, their total duration, or their decrement.

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3.461 terminal: (A) A conducting element of an equipment or a circuit intended for connection to an external conductor. (B) A device attached to a conductor to facilitate connection with another conductor.

3.462 terminal board: A plate of insulating material that is used to support terminations of winding leads.

NOTES:

1—The terminations, which may be mounted studs or blade connectors, are used for making connections to the supply line, the load, other external circuits, or among the windings of the machine.

2—Small terminal boards may also be termed terminal blocks or terminal strips.

3.463 terminal connector: A connector for attaching a conductor to a lead, terminal block, or stud of electric apparatus.

3.464 tertiary winding: An additional winding in a transformer that can be connected to a synchronous condenser, a reactor, an auxiliary circuit, etc. For transformers with wye-connected primary and secondary windings, it may also help

a) To stabilize voltages to the neutral, when delta connected.
b) To reduce the magnitude of third harmonics when delta connected.
c) To control the value of the zero-sequence impedance.
d) To serve load.

See also: **stabilizing winding.**

3.465 thermal burden rating of a voltage transformer: The volt-ampere output that the transformer will supply continuously at rated secondary voltage without causing the specified temperature limitations to be exceeded.

3.466 thermal duplicate: A transformer whose thermal design characteristics are identical to a design previously tested, or whose differences in thermal characteristics are within agreed upon variations, such that the thermal performance of the thermal duplicate transformer shall comply with performance guarantees established by standards or specifications.

3.467 thermometer method of temperature determination: The determination of the temperature by mercury, alcohol, resistance, or thermocouple thermometer, any of these instruments being applied to the hottest accessible part of the device.

3.468 three-phase circuit: A three-phase circuit is a combination of circuits energized by alternating electromotive forces that differ in phase by one third of a cycle, that is, 120 degrees.

NOTE—In practice, the phases may vary several degrees from the specified angle.

3.469 three-wire type current transformer: One that has two insulated primary windings and one secondary winding and is for use on a three-wire, single-phase service.

NOTE—The primary windings and the secondary winding are permanently assembled on the core as an integral structure. The secondary current is proportional to the phasor sum of the primary currents.

3.470 tight (suffix): Apparatus is designed as watertight, dusttight, etc., when so constructed that the enclosing case will exclude the specified material under specified conditions.

3.471 top-oil temperature: The temperature of the top layer of the insulating liquid in a transformer, representative of the temperature of the top liquid in the cooling flow stream. Generally measured 50 mm below the surface of the liquid.

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3.472 top-oil temperature rise: The arithmetic difference between the top-oil temperature and the ambient temperature. *Syn:* **top-oil rise.**

3.473 total losses (transformer or regulator): The sum of the no-load and load losses, excluding losses due to accessories.

3.474 transformer: A static electric device consisting of a winding, or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits. Transformers are extensively used in electric power systems to transfer power by electromagnetic induction between circuits at the same frequency, usually with changed values of voltage and current.

3.475 transformer correction factor (TCF): The ratio of the true watts or watthours to the measured secondary watts or watthours, divided by the marked ratio.

NOTE: The transformer correction factor for a current or voltage transformer is the ratio correction factor multiplied by the phase-angle correction factor for a specified primary circuit power factor.

The true primary watts or watthours are equal to the watts or watthours measured, multiplied by the transformer correction factor and the marked ratio.

The true primary watts or watthours, when measured using both current and voltage transformers, are equal to the current transformer ratio correction factor multiplied by the voltage transformer ratio correction factor multiplied by the marked ratios of the current and voltage transformers multiplied by the observed watts or watthours. It is usually sufficiently accurate to calculate true watts or watthours as equal to the product of the two transformer correction factors multiplied by the marked ratios multiplied by the observed watts or watthours.

3.476 transient insulation level (TIL): An insulation level expressed in kilovolts of the crest value of the withstand voltage for a specified transient wave shape; that is, lightning or switching impulse.

3.477 transient impedance (in an LTC): A resistor or reactor consisting of one or more units that bridge adjacent taps for the purpose of transferring load from one tap to the other without interruption or appreciable change in the load current, at the same time limiting the circulating current for the period that both taps are used. Normally, reactance type LTCs use the bridging position as a service position, and therefore, the reactor is designed for continuous loading. *See also:* **transition impedance (IEC).**

3.478 triplex transformer: A transformer constructed of three coils, each having its own core, magnetically independent from each other, and contained in one enclosure to function as a three phase transformer.

3.479 true ratio: The ratio of the root-mean-square (rms) primary voltage or current to the rms secondary voltage or current under specified conditions.

3.480 turn ratio of a current transformer: The ratio of the secondary winding turns to the primary winding turns.

3.481 turn ratio of a transformer: The ratio of the number of turns in a higher voltage winding to that in a lower voltage winding.

NOTE—In the case of a constant-voltage transformer having taps for changing its voltage ratio, the nominal turn ratio is based on the number of turns corresponding to the normal rated voltage of the respective windings, to which operating and performance characteristics are referred.

3.482 turn ratio of a voltage transformer: The ratio of the primary winding turns to the secondary winding turns.

3.483 two-core regulating transformer: A phase-shifting and/or regulating transformer consisting of a series unit, which is connected in series in the line circuit and a main or exciting unit that excites the secondary of the series unit to produce the phase-angle shift or voltage change.

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3.484 two-phase circuit: A polyphase circuit of three, four, or five distinct conductors intended to be so energized that in the steady state the alternating voltages between two selected pairs of terminals of entry, other than the neutral terminal when one exists, have the same periods, are equal in amplitude, and have a phase difference of 90 degrees. When the circuit consists of five conductors, but not otherwise, one of them is a neutral conductor.

NOTE—A two-phase circuit as defined here does not conform to the general pattern of polyphase circuits. Actually, a two-phase, four-wire or five-wire circuit could more properly be called a four-phase circuit, but the term two-phase is in common usage. A two-phase three-wire circuit is essentially a special case, as it does not conform to the general pattern of other polyphase circuits.

3.485 ungrounded: A system, circuit, or apparatus without an intentional connection to ground except through potential-indicating or measuring devices or other very high impedance devices.

3.486 unit substation: A substation consisting primarily of one or more transformers that are mechanically and electrically connected to and coordinated in design with one or more switchgear or motor control assemblies, or combinations thereof.

3.487 unit substation transformer: A transformer that is mechanically and electrically connected to, and coordinated in design with, one or more switchgear or motor-control assemblies, or combinations thereof. *See also:* **articulated unit substation, integral unit substation, primary unit substation, secondary unit substation.**

3.488 variable voltage transformer: An autotransformer in which the output voltage can be changed (essentially from turn to turn) by means of a movable contact device sliding on the shunt winding turns.

3.489 varying duty: A requirement of service that demands operation at loads, and for periods of time, both of which may be subject to wide variation.

3.490 vault-type transformer: A transformer that is so constructed as to be suitable for occasional submerged operation in water under specified conditions of time and external pressure.

3.491 ventilated: Provided with a means to permit circulation of the air sufficiently to remove an excess of heat, fumes, or vapors.

3.492 ventilated dry-type transformer: A dry-type transformer that is so constructed that the ambient air may circulate through its enclosure to cool the transformer core and windings.

3.493 voltage rating of a grounding transformer: The maximum “line-to-line” voltage at which it is designed to operate continuously from line to ground without damage to the grounding transformer.

3.494 voltage ratio of a transformer: The ratio of the rms terminal voltage of a higher voltage winding to the rms terminal voltage of a lower voltage winding, under specified conditions of the load.

3.495 voltage regulation of a constant-voltage transformer: The change in output (secondary) voltage that occurs when the load (at a specified power factor) is reduced from rated value to zero, with the primary impressed terminal voltage maintained constant.

NOTE—In case of multiwinding transformers, the loads on all windings, at specified power factors, are to be reduced from rated kVA to zero simultaneously. The regulation may be expressed in per unit, or percent, on the base of the rated output (secondary) voltage at full load.

3.496 voltage regulating relay: A voltage-sensitive device that is used on an automatically operated voltage regulator to control the voltage of the regulated circuit.

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3.497 voltage regulator (transformer type): An induction device having one or more windings in shunt with and excited from the primary circuits, and having one or more windings in series between the primary circuits and the regulated circuit, all suitably adapted and arranged for the control of the voltage, or of the phase angle, or of both, of the regulated circuit.

3.498 voltage to ground: The voltage between any live conductor of a circuit and the earth.

NOTE—Where safety considerations are involved, the voltage to ground that may occur in an ungrounded circuit is usually the highest voltage normally existing between the conductors of the circuit, but in special circumstances, higher voltages may occur.

3.499 voltage transformer: An instrument transformer intended to have its primary winding connected in shunt with a power supply circuit, the voltage of which is to be measured or controlled.

3.500 voltage winding (or transformer) for regulating equipment: The winding (or transformer) that supplies voltage within close limits of accuracy to instruments, such as contact-making voltmeters.

3.501 uninhibited oil: Mineral transformer oil to which no synthetic oxidation inhibitor has been added.

3.502 watertight: So constructed that water will not enter the enclosing case under specified conditions.[5]

3.503 water cooled transformer: A liquid-immersed transformer that is cooled by the interchange of heat to cooling water flowing through a liquid-water heat exchanger. *See also:* **ONWF.**

3.504 winding (of a transformer): The assembly of turns forming an electric circuit associated with one of the voltages assigned to the transformer or to the reactor. *See also:* **coil (of a transformer), high-voltage and low-voltage windings, primary winding, secondary winding, tertiary winding, winding** (IEC).

3.505 winding hottest-spot temperature: The highest temperature inside the transformer winding. It is greater than the measured average temperature (using the resistance change method) of the coil conductors.

3.506 window-type current transformer: One that has a secondary winding insulated from and permanently assembled on the core, but has no primary winding as an integral part of the structure. Complete insulation is provided for a primary winding in the window through which one turn of the line conductor can be passed to provide the primary winding. *Syn:* **bus type current transformer** (IEC).

3.507 withstand voltage: The voltage that electric equipment is capable of withstanding without failure or disruptive discharge when tested under specified conditions.

3.508 wound type current transformer: One that has a primary winding consisting of one or more turns mechanically encircling the core or cores. The primary and secondary windings are insulated from each other and from the core(s) and are assembled as an integral structure.

3.509 wye connection: So connected that one end of each of the windings of a polyphase transformer (or of each of the windings for the same rated voltage of single-phase transformers associated in a polyphase bank) is connected to a common point (the neutral point) and the other end to its appropriate line terminal.

3.510 yoke: An element of ferromagnetic material, not surrounded by windings, used to connect the ferromagnetic legs (limbs) that the windings encircle.

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[5]A common form of specification for water-tight is: So constructed that there shall be no leakage of water into the enclosure when subjected to a stream from a hose with a 1 in nozzle and delivering at least 65 gal/min, with the water directed at the enclosure from a distance of not less than 10 ft for a period of 5 min, during which period the water may be directed in one or more directions as desired.

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3.511 zero-sequence impedance: An impedance voltage measured between a set of primary terminals and one or more sets of secondary terminals when a single-phase voltage source is applied between the three primary terminals connected together and the primary neutral, with the secondary line terminals shorted together and connected to their neutral (if one exists).

NOTES:

1—For two-winding transformers, the other winding is short-circuited. For multiwinding transformers, several tests are required, and the zero-sequence impedance characteristics are represented by an impedance network.

2—In some transformers, the test must be made at a voltage lower than that required to circulate rated current in order to avoid magnetic core saturation or to avoid excessive current in other windings.

3—Zero-sequence impedances are usually expressed in per unit or percent on a suitable voltage and kVA base.

3.512 zigzag connection: A polyphase transformer with wye connected windings, each one of which is made up of parts in which phase-displaced voltages are induced.

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Annex A

Bibliography

(informative)

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition, New York, Institute of Electrical and Electronics Engineers, Inc.[6]

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