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IEEE Standard Terminology for Power and Distribution Transformers

IEEE Power Engineering Society

Sponsored by the
Transformers Committee



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IEEE Standard Terminology for Power and Distribution Transformers

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Transformers Committee
of the
IEEE Power Engineering Society

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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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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.

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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 1TM-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 4TM-1995, IEEE Standard Techniques for High-Voltage Testing.

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

IEEE C57.12.01TM-1998, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid Cast and/or Resin Encapsulated Windings.

IEEE C57.12.90TM-1999, Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

¹IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, 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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³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁴IEEE 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/>).

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.

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.

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.

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.

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.

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.

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.

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**.