

ANSI/IEEE C57.12.80-1978

(Reaffirmed 1986)

(Revision of C57.12.80-1958)

An American National Standard

IEEE Standard Terminology for Power and Distribution Transformers

Sponsor

**Transformers Committee of the
IEEE Power Engineering Society**

Approved June 3, 1976

Reaffirmed June 19, 1986

Reaffirmed May 1, 1992

IEEE Standards Board

Secretariat

**National Electric Manufacturers Association
Edison Electric Institute
Institute of Electrical and Electronics Engineers**

Approved April 7, 1977

Reaffirmed December 2, 1992

American National Standards Institute

Published by

The Institute of Electrical and Electronics Engineers, Inc

345 East 47th Street, New York, NY 10017

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Foreword

(This Foreword is not a part of ANSI/IEEE C57.12.80-1978, American National Standard Terminology for Power and Distribution Transformers.)

This revision of ANSI C57.12.80 incorporates a substantial number of changes since the last major revision occurred in 1958. In addition to providing many new terms, some of the more significant changes which have been introduced include:

- 1) Change in organization structure, as shown in the table of contents
- 2) Addition of reference standards
- 3) A section of Transformer Definitions considering general and specialized types and classified by size, insulation, and location. These are cross-referenced to other sections where appropriate.
- 4) Grouping of terms relating to rating data in a separate section
- 5) A new section relating to insulation terms. This includes numerous terms concerning the new insulation temperature class ratings, including identification by temperature index, and new insulation coordination terms.
- 6) A new section on Testing
- 7) Expansion of terms concerning construction and location in a separate section
- 8) Addition of a section of Terminology for Specialized Types of Transformers
- 9) Addition of a number of system terms applicable to transformers.

One of the significant goals in this new revision was to also provide input for revision of IEEE Std 100-1972 (ANSI C42.100-1972), IEEE Standard Dictionary of Electrical and Electronics Terms. An effort has been made to use common terms whenever possible.

The IEEE Transformers Committee of the IEEE Power Engineering Society provided many very helpful questions and comments, and the IEEE Standards Board was particularly helpful in furnishing a broad perspective and many constructive inputs.

Suggestions for improvement of this standard will be welcome. They should be sent to the

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An American National Standard

IEEE Standard Terminology for Power and Distribution Transformers

1. Scope and Reference Standards

1.1 Scope

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

1.2 Reference Standards

[1] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.

[2] Glossary of ASTM Definitions, 1986.

[3] ASTM D17111-1983, Standard Definitions of Terms Relating to Electrical Insulation.

[4] ASTM D2864-1984, Standard Definitions of Terms Relating to Electrical Insulating Liquids and Gases.¹

2. Transformer Definitions

2.1 General

2.1.1 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.

NOTE — 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.

¹ASTM documents are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103.

2.1.2 Step-Down Transformer

A transformer in which the power transfer is from a higher voltage source circuit to a lower voltage circuit.

2.1.3 Step-Up Transformer

A transformer in which the power transfer is from a lower voltage source circuit to a higher voltage circuit.

2.1.4 Autotransformer

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

2.1.5 Constant-Voltage Transformer

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

2.1.6 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.

NOTE — Additional related terms defined in 7.5.

2.2 Transformers — Specialized Types

2.2.1 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.

2.2.2 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.

2.2.3 Phase-Shifting Transformer

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.
- 4 — Additional related terms defined in 7.2.

2.2.4 Furnace Transformer

A transformer that is designed to be connected to an electric arc furnace.

2.2.5 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.

NOTE — Additional related terms defined in 7.6.

2.2.6 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 which has no coil assembly and provides a common magnetic circuit for the two outer legs.

NOTE — Additional related terms defined in 7.3.

2.2.7 Grounding Transformer

A transformer intended primarily to provide a neutral point for grounding purposes.

NOTES:

1 — It may be provided with a Δ winding in which resistors or reactors are connected. See also 6.3.5 concerning “stabilizing windings.”

2 — Additional related terms defined in 7.4.

2.2.8 Instrument Transformer

A transformer which 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.

NOTE — Additional related terms defined in 7.8.

2.2.9 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.

NOTE — Additional related terms defined in 7.9.

2.2.10 Other Electromagnetic Inductive Apparatus

2.2.10.1 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.

2.2.10.2 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.

2.2.10.3 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.

2.3 Transformers — Classified by Size, Insulation, and Location

2.3.1 Size

2.3.1.1 Distribution Transformer.

A transformer for transferring electrical energy from a primary distribution circuit to a secondary distribution circuit or consumer's service circuit.

NOTE — Distribution transformers are usually rated in the order of 5—500 kVA.

2.3.1.2 Power Transformer.

A transformer which transfers electric energy in any part of the circuit between the generator and the distribution primary circuits.

2.3.2 Insulation

2.3.2.1 Liquid-Immersed Transformer.

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

2.3.2.2 Dry-Type Transformer.

A transformer in which the core and coils are in a gaseous or dry compound insulating medium.

NOTE — Additional related terms defined in 7.10.

2.3.3 Location

2.3.3.1 Indoor Transformer.

A transformer which, because of its construction, must be protected from the weather.

2.3.3.2 Outdoor Transformer.

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

2.3.3.3 Pole-Type Transformer.

A transformer which is suitable for mounting on a pole or similar structure.

2.3.3.4 Station-Type Transformer.

A transformer designed for installation in a station or substation.

2.3.3.5 Unit-Substation Transformer.

A transformer which is mechanically and electrically connected to, and coordinated in design with, one or more switchgear or motor-control assemblies, or combinations thereof.

NOTE — Additional related terms defined in 7.1.

2.3.3.6 Submersible Transformer.

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

2.3.3.7 Subway Transformer.

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

2.3.3.8 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.

2.3.3.9 Network Transformer.

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

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.

2.3.3.10 Sub-Surface 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.

2.3.3.11 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.

2.3.3.12 Direct-Buried Transformer.

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

3. Rating Data

3.1 Performance Characteristics

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

3.2 Duty

A requirement of service that defines the degree of regularity of the load.

3.2.1 Continuous Duty

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

3.2.2 Short-Time Duty

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

3.2.3 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.

3.2.4 Periodic Duty

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

3.2.5 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.

3.3 Rating

3.3.1 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 which can be taken from the transformer under prescribed conditions and limitations of established standards.

3.3.2 Continuous Rating

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

3.3.3 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.

3.4 kVA Rating

3.4.1 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.

3.4.2 Rated kVA Tap (in a Transformer)

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

3.4.3 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.

3.4.4 Equivalent Two-Winding kVA Rating

The equivalent two-winding rating of multi-winding 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.

3.4.5 Load (Output)

The apparent power in megavolt-amperes, kilovolt-amperes, or volt-amperes that may be transferred by the transformer.

3.5 Voltage and Current Rating

3.5.1 Rated Voltage of a Winding

The voltage to which operating and performance characteristics are referred.

3.5.2 Rated Primary Voltage (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.

3.5.3 Rated Secondary Voltage (Constant Voltage Transformer)

The voltage at which the transformer is designed to deliver rated kVA and to which operating and performance characteristics are referred.

3.5.4 Rated Secondary Current (Constant Voltage Transformer)

The secondary current obtained by dividing the rated kVA by the rated secondary voltage, in kV.

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

3.6 Polarity, Angular Displacement, and Phase Sequence

3.6.1 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 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: (1) 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; (2) 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.

3.6.2 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 which 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.

3.6.3 Definition of Phase Sequence

The order in which the voltages successively reach their positive maximum values.

3.6.4 Direction of Rotation of Phasors

Phasor diagrams should be drawn so that an advance in phase of one phasor with respect to another is in the counterclockwise direction. In the following figure, phasor 1 is 120 degrees in advance of phasor 2, and the phase sequence is 1, 2, 3.

3.7 Losses, Excitation Current, and Impedance Voltage

3.7.1 Efficiency

The ratio of the useful power output to the total power input.

3.7.2 Losses

3.7.2.1 Total Losses (transformer or regulator)

The sum of the no-load and load losses, excluding losses due to accessories.

3.7.2.2 No-Load (Excitation) Losses.

Those losses which 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.

3.7.2.3 Load Losses.

Those losses which are incident to the carrying of a specified load. Load losses include I^2R loss in the windings due to load and eddy currents; stray loss due to leakage fluxes in the windings, core clamps, and other parts, and the loss due to circulating currents (if any) in parallel windings, or in parallel winding strands.

3.7.2.4 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.

3.7.3 Excitation Current (No-Load Current)

The current which 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.

3.7.4 Impedance

3.7.4.1 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.

3.7.4.2 Resistance Drop.

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

3.7.4.3 Reactance Drop.

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

3.7.4.4 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.

3.7.4.5 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.

3.7.4.6 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.

3.7.4.7 Interlacing Impedance of Scott-Connected Transformer.

See 7.3.4.

3.8 Ratio and Regulation

3.8.1 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.

3.8.2 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.

3.8.3 Voltage Regulation of a Constant-Voltage Transformer

The change in output (secondary) voltage which 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.

4. Insulation

4.1 Major Insulation

4.1.1 Liquid-Immersed Transformer

See 2.3.2.1.