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Power transformators - Part 1: General

Power transformers - Part 1: General

Transformateurs de puissance - Partie 1: Généralités

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Power transformers

Part 1:
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS

Part 1: General

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

This International Standard has been prepared by IEC by technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 1976 as well as the first edition of IEC 76-4 published in 1976.

The text of this standard is based on the following documents:

Six Month's Rule	Report on Voting
14(CO)75	14(CO)77

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

IEC 76 consists of the following parts, under the general title: Power transformers.

Part 1: 1993, General.

Part 2: 1993, Temperature rise.

Part 3: 1980, Insulation levels and dielectric tests.

Part 5: 1976, Ability to withstand short circuit.

Annexes A and E form an integral part of this standard.

Annexes B, C and D are for information only.

POWER TRANSFORMERS

Part 1: General

1 Scope and service conditions

1.1 *Scope*

This part of International Standard IEC 76 applies to three-phase and single-phase power transformers (including auto-transformers) with the exception of certain categories of small and special transformers such as:

- single-phase transformers with rated power less than 1 kVA and three-phase transformers less than 5 kVA;
- instrument transformers;
- transformers for static convertors;
- traction transformers mounted on rolling stock;
- starting transformers;
- testing transformers;
- welding transformers.

When IEC standards do not exist for such categories of transformers, this part of IEC 76 may still be applicable either as a whole or in part.

For those categories of power transformers and reactors which have their own IEC standards, this part is applicable only to the extent in which it is specifically called up by cross-reference in the other standard.*

At several places in this part it is specified or recommended that an 'agreement' shall be reached concerning alternative or additional technical solutions or procedures. Such agreement is to be made between the manufacturer and the purchaser. The matters should preferably be raised at an early stage and the agreements included in the contract specification.

1.2 *Service conditions*

1.2.1 *Normal service conditions*

This part of IEC 76 gives detailed requirements for transformers for use under the following conditions:

a) Altitude

A height above sea-level not exceeding 1 000 m (3 300 ft).

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* Such standards exist for dry-type transformers (IEC 726), for reactors in general (IEC 289), for traction transformers and reactors (IEC 310), and are under preparation for static convertor transformers.

b) Temperature of ambient air and cooling medium

A temperature of ambient air not below –25 °C and not above +40 °C. For water-cooled transformers, a temperature of cooling water at the inlet not exceeding +25 °C.

Further limitations, with regard to cooling are given for:

- oil-immersed transformers in IEC 76-2;
- dry-type transformers in IEC 726.

c) Wave shape of supply voltage

A supply voltage of which the wave shape is approximately sinusoidal.

NOTE - This requirement is normally not critical in public supply systems but may have to be considered in installations with considerable convertor loading. In such cases there is a conventional rule that the deformation shall neither exceed 5 % total harmonic content nor 1 % even harmonic content. Also note the importance of current harmonics for load loss and temperature rise.

d) Symmetry of three-phase supply voltage

For three-phase transformers, a set of three-phase supply voltages which are approximately symmetrical.

e) Installation environment

An environment with a pollution rate (see IEC 137 and IEC 815) that does not require special consideration regarding the external insulation of transformer bushings or of the transformer itself.

An environment not exposed to seismic disturbance which would otherwise require special consideration in the design. (This is assumed to be the case when the ground acceleration level a_g is below 2 m/s^2.)*

1.2.2 *Provision for unusual service conditions*

Any unusual service conditions which may lead to special consideration in the design of a transformer shall be stated in the enquiry and the order. These may be factors such as high altitude, extreme high or low temperature, tropical humidity, seismic activity, severe contamination, unusual voltage or load current wave shapes and intermittent loading. They may also concern conditions for shipment, storage and installation, such as weight or space limitations (see annex A).

Supplementary rules for rating and testing are given in other publications for:

- Temperature rise and cooling in high ambient temperature or at high altitude: IEC 76-2 for oil-immersed transformers, and IEC 726 for dry-type transformers.

- External insulation at high altitude: IEC 76-3 and IEC 76-3-1 for oil-immersed transformers, and IEC 726 for dry-type transformers.

* See IEC 68-3-3.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 76. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 76 are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(421): 1990, *International Electrotechnical Vocabulary – Chapter 421: Power transformers and reactors*

IEC 68-3-3: 1991, *Environmental testing – Part 3: Guidance. Seismic test methods for equipments*

IEC 76-2: 1993, *Power transformers – Part 2: Temperature rise*

IEC 76-3: 1980, *Power transformers – Part 3: Insulation levels and dielectric tests*

IEC 76-3-1: 1987, *Power transformers – Part 3: Insulation levels and dielectric tests. External clearances in air*

IEC 76-5: 1976, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 137: 1984, *Bushings for alternating voltages above 1 000 V*

IEC 354: 1991, *Loading guide for oil-immersed power transformers*

IEC 529: 1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 551: 1987, *Determination of transformer and reactor sound levels*

IEC 606: 1978, *Application guide for power transformers*

IEC 726: 1982, *Dry-type power transformers*

IEC 815: 1986, *Guide for the selection of insulators in respect of polluted conditions*

IEC 905: 1987, *Loading guide for dry-type power transformers*

ISO 3: 1973, *Preferred numbers – Series of preferred numbers*

ISO 9001: 1987, *Quality systems – Model for quality assurance in design/development, production, installation and servicing*

3 Definitions

For the purpose of this part of IEC 76, the following definitions shall apply. Other terms use the meanings ascribed to them in the International Electrotechnical Vocabulary (IEV).

3.1 *General*

3.1.1 power transformer: A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power. [IEV 421-01-01, modified]

3.1.2 auto-transformer*: A transformer in which at least two windings have a common part. [IEV 421-01-11]

3.1.3 booster transformer: A transformer of which one winding is intended to be connected in series with a circuit in order to alter its voltage and/or shift its phase. The other winding is an energizing winding. [IEV 42-01-12, modified]

3.1.4 oil-immersed type transformer: A transformer of which the magnetic circuit and windings are immersed in oil. [IEV 421-01-14]

NOTE - For the purpose of this part any insulating liquid, mineral oil or other product, is regarded as oil.

3.1.5 dry-type transformer: A transformer of which the magnetic circuit and windings are not immersed in an insulating liquid. [IEV 421-01-16]

3.1.6 oil preservation system: The system in an oil-immersed transformer by which the thermal expansion of the oil is accommodated. Contact between the oil and external air may sometimes be diminished or prevented.

3.2 *Terminals and neutral point*

3.2.1 terminal: A conducting element intended for connecting a winding to external conductors.

3.2.2 line terminal: A terminal intended for connection to a line conductor of a network. [IEV 421-02-01]

3.2.3 neutral terminal:

a) For three-phase transformers and three-phase banks of single-phase transformers:

The terminal or terminals connected to the common point (the neutral point) of a star-connected or zigzag connected winding.

b) For single-phase transformers:

The terminal intended for connection to a neutral point of a network. [IEV 421-02-02, modified]

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* Where there is a need to express that a transformer is not auto-connected, use is made of terms such as separate winding transformer, or double-wound transformer (see IEV 421-01-13).

3.2.4 neutral point: The point of a symmetrical system of voltages which is normally at zero potential.

3.2.5 corresponding terminals: Terminals of different windings of a transformer, marked with the same letter or corresponding symbol. [IEV 421-02-03]

3.3 *Windings*

3.3.1 winding: The assembly of turns forming an electrical circuit associated with one of the voltages assigned to the transformer.

NOTE - For a three-phase transformer, the 'winding' is the combination of the phase windings (see 3.3.3). [IEV 421-03-01, modified]

3.3.2 tapped winding: A winding in which the effective number of turns can be changed in steps.

3.3.3 phase winding: The assembly of turns forming one phase of a three-phase winding.

NOTE - The term 'phase winding' should not be used for identifying the assembly of all coils on a specific leg. [IEV 421-03-02, modified]

3.3.4 high-voltage winding*: The winding having the highest rated voltage. [IEV 421-03-03]

3.3.5 low-voltage winding*: The winding having the lowest rated voltage. [IEV 421-03-04]

NOTE - For a booster transformer, the winding having the lower rated voltage may be that having the higher insulation level.

3.3.6 intermediate-voltage winding*: A winding of a multi-winding transformer having a rated voltage intermediate between the highest and lowest winding rated voltages. [IEV 421-03-05]

3.3.7 auxiliary winding: A winding intended only for a small load compared with the rated power of the transformer. [IEV 421-03-08]

3.3.8 stabilizing winding: A supplementary delta-connected winding provided in a star-star-connected or star-zigzag-connected transformer to decrease its zero-sequence impedance, see 3.7.3. [IEV 421-03-09, modified]

NOTE - A winding is referred to as a stabilizing winding only if it is not intended for three-phase connection to an external circuit.

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* The winding which receives active power from the supply source in service is referred to as a 'primary winding', and that which delivers active power to a load as a 'secondary winding'. These terms have no significance as to which of the windings has the higher rated voltage and should not be used except in the context of direction of active power flow (see IEV 421-03-06 and 07). A further winding in the transformer, usually with lower value of rated power than the secondary winding, is then often referred to as 'tertiary winding', see also definition 3.3.8.

3.3.9 common winding: The common part of the windings of an auto-transformer. [IEV 421-03-10]

3.3.10 series winding: The part of the winding of an auto-transformer or the winding of a booster transformer which is intended to be connected in series with a circuit. [IEV 421-03-11]

3.3.11 energizing winding: The winding of a booster transformer which is intended to supply power to the series winding. [IEV 421-03-12]

3.4 *Rating*

3.4.1 rating: Those numerical values assigned to the quantities which define the operation of the transformer in the conditions specified in this part of IEC 76 and on which the manufacturer's guarantees and the tests are based.

3.4.2 rated quantities: Quantities (voltage, current, etc.), the numerical values of which define the rating.

NOTES

1 For transformers having tappings, rated quantities are related to the principal tapping (see 3.5.2), unless otherwise specified. Corresponding quantities with analogous meaning, related to other specific tappings, are called tapping quantities (see 3.5.10).

2 Voltages and currents are always expressed by their r.m.s. values, unless otherwise specified.

3.4.3 rated voltage of a winding (U_r): The voltage assigned to be applied, or developed at no-load, between the terminals of an untapped winding, or of a tapped winding connected on the principal tapping (see 3.5.2). For a three-phase winding it is the voltage between line terminals. [IEV 421-04-01, modified]

NOTES

1 The rated voltages of all windings appear simultaneously at no-load when the voltage applied to one of them has its rated value.

2 For single-phase transformers intended to be connected in star to form a three-phase bank, the rated voltage is indicated as phase-to-phase voltage, divided by $\sqrt{3}$ for exemple $U_r = 400/\sqrt{3}$ kV.

3 For the series winding of a three-phase booster transformer which is designed as an open winding (see 3.10.5) the rated voltage is indicated as if the winding were connected in star, for example $U_r = 23/\sqrt{3}$ kV.

3.4.4 rated voltage ratio: The ratio of the rated voltage of a winding to the rated voltage of another winding associated with a lower or equal rated voltage. [IEV 421-04-02]

3.4.5 rated frequency (f_r): The frequency at which the transformer is designed to operate. [IEV 421-04-03, modified]

3.4.6 rated power (S_r): A conventional value of apparent power assigned to a winding which, together with the rated voltage of the winding, determines its rated current.

NOTES

1 Both windings of a two-winding transformer have the same rated power which by definition is the rated power of the whole transformer.

2 For a multi-winding transformer, half the arithmetic sum of the rated power values of all windings (separate windings, not auto-connected) gives a rough estimate of its physical size as compared with a two-winding transformer.

3.4.7 rated current (I_r): The current flowing through a line terminal of a winding which is derived from rated power S_r and rated voltage U_r for the winding. [IEV 421-04-05, modified]

NOTES

1 For a three-phase winding the rated current I_r is given by:

$$I_r = \frac{S_r}{\sqrt{3} \times U_r} \text{ A}$$

2 For single-phase transformer windings intended to be connected in delta to form a three-phase bank the rated current is indicated as line current divided by $\sqrt{3}$, for example:

$$I_r = \frac{500}{\sqrt{3}} \text{ A}$$

3.5 *Tappings*

3.5.1 tapping: In a transformer having a tapped winding, a specific connection of that winding, representing a definite effective number of turns in the tapped winding and, consequently, a definite turns ratio between this winding and any other winding with fixed number of turns.

NOTE - One of the tappings is the principal tapping, and other tappings are described in relation to the principal tapping by their respective tapping factors. See definitions of these terms below.

3.5.2 principal tapping: The tapping to which the rated quantities are related. [IEV 421-05-02]

3.5.3 tapping factor (corresponding to a given tapping): The ratio:

$$\frac{U_d}{U_r} \text{ (tapping factor) or } \qquad 100\,\frac{U_d}{U_r} \text{ (tapping factor expressed as a percentage).}$$

where

U_r is the rated voltage of the winding (see 3.4.3);

U_d is the voltage which would be developed at no-load at the terminals of the winding, at the tapping concerned, by applying rated voltage to an untapped winding.

NOTE - This definition is not appropriate in relation to a series winding of a booster transformer (see 3.1.3), and in that case the percentage notation would be referred to the voltage of the energizing winding or of the winding of an associated system transformer. [IEV 421-05-03, modified]

3.5.4 plus tapping: A tapping whose tapping factor is higher than 1. [IEV 421-05-04]

3.5.5 minus tapping: A tapping whose tapping factor is lower than 1. [IEV 421-05-05]

3.5.6 tapping step: The difference between the tapping factors, expressed as a percentage, of two adjacent tappings. [IEV 421-05-06]

3.5.7 tapping range: The variation range of the tapping factor, expressed as a percentage, compared with the value '100'.

NOTE - If this factor ranges from 100 + a to 100 – b, the tapping range is said to be: +a %, –b % or ±a %, if a = b. [IEV 421-05-07]

3.5.8 tapping voltage ratio (of a pair of windings): The ratio which is equal to the rated voltage ratio:

- multiplied by the tapping factor of the tapped winding if this is the high-voltage winding;
- divided by the tapping factor of the tapped winding if this is the low-voltage winding. [IEV 421-05-08]

NOTE - While the rated voltage ratio is, by definition, at least equal to 1, the tapping voltage ratio can be lower than 1 for certain tappings when the rated voltage ratio is close to 1.

3.5.9 tapping duty: The numerical values assigned to the quantities, analogous to rated quantities, which refer to tappings other than the principal tapping (see clause 5, and IEC 606). [IEV 421-05-09, modified]

3.5.10 tapping quantities: Those quantities the numerical values of which define the tapping duty of a particular tapping (other than the principal tapping).

NOTE - Tapping quantities exist for any winding in the transformer, not only for the tapped winding, (see 5.2 and 5.3).

The tapping quantities are:

- tapping voltage (analogous to rated voltage, 3.4.3);
- tapping power (analogous to rated power, 3.4.6);
- tapping current (analogous to rated current, 3.4.7). [IEV 421-05-10, modified]

3.5.11 full-power tapping: A tapping whose tapping power is equal to the rated power. [IEV 421-05-14]

3.5.12 reduced-power tapping: A tapping whose tapping power is lower than the rated power. [IEV 421-05-15]

3.5.13 on-load tap-changer: A device for changing the tapping connections of a winding, suitable for operation while the transformer is energized or on load. [IEV 421-11-01]