

Power transformers —

Part 1: General

The European Standard EN 60076-1:1997, with the incorporation of amendments A11:1997, A12:2002 and A1:2000, has the status of a British Standard

ICS 29.180

National foreword

This British Standard is the official English language version of EN 60076-1:1997, including amendments A11:1997, A12:2002 and A1:2000. It is identical with IEC 60076-1:1993, Edition 1:1993, which comprises Edition 2:1993 consolidated by the incorporation of amendment 1:1999.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to text carry the number of the amendment. For example, text altered by CENELEC amendment A1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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English version

Power transformers — Part 1: General

(IEC 60076-1:1993 + A1:1999)

Transformateurs de puissance —
Partie 1: Généralités
(inclut les amendements A11:1997, A12:2002 et
A1:2000)
(CEI 60076-1:1993 + A1:1999)

Leistungstransformatoren —
Teil 1: Allgemeines
(enthält Änderungen A11:1997, A12:2002 und
A1:2000)
(IEC 60076-1:1999 + A1:1999)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword

The text of the International Standard IEC 76-1:1993, prepared by IEC TC 14, Power transformers, together with the common modifications prepared by the Technical Committee CENELEC TC 14 was submitted to the formal vote and was accepted by CENELEC as EN 60076-1 on 1997-03-11.

This European Standard supersedes HD 398.1 S1:1980 and HD 398.4 S1:1980.

Technical differences relate mainly to certain measures (e.g. of flexibility in given circumstances) to bring the standard in line with actual requirements of User's specifications.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-09-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1997-09-01

Annexes designated "normative" are part of the body of the standard. Annexes designated "informative" are given for information only. In this standard Annex A, Annex E and Annex ZA are normative and Annex B, Annex C, Annex D and Annex F are informative.

Annex ZA has been added by CENELEC.

Foreword to amendment A11

This amendment was prepared by the Technical Committee CENELEC TC 14, Power transformers.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as amendment A11 to EN 60076-1:1997 on 1997-10-01.

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Foreword to amendment A12

This amendment to the European Standard EN 60076-1:1997 was prepared by the Technical Committee CENELEC TC 14, Power transformers.

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Annexes designated "normative" are part of the body of the standard. Annexes designated "informative" are given for information only. In this standard, Annex ZB is informative.

Annex ZB has been added by CENELEC.

Foreword to amendment A1

The text of document 14/344FDIS, future amendment 1 to IEC 60076-1:1993, prepared by IEC TC 14, Power transformers, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 60076-1:1997 on 2000-04-01.

NOTE This amendment A1 is identical to EN 60076-1:1997 /A11:1997 except for the reference to CENELEC Report R014-001.

The following dates were fixed:

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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;
- transformers having no windings with rated voltage U_n higher than 1 000 V;
- instrument transformers;
- transformers for static convertors;
- traction transformers mounted on rolling stock;
- starting transformers;
- testing transformers;
- welding transformers.

NOTE 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.¹⁾ 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).

b) Temperature of ambient air and cooling medium

A temperature of ambient air not below $-25\text{ }^{\circ}\text{C}$ and not above $+40\text{ }^{\circ}\text{C}$. For water-cooled transformers, a temperature of cooling water at the inlet not exceeding $+25\text{ }^{\circ}\text{C}$.

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 .)²⁾

¹⁾ Such standards exist for dry-type transformers (IEC 60726), for reactors in general (IEC 60289), for traction transformers and reactors (IEC 60310), and are under preparation for static convertor transformers.

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.

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, Power transformers — Part 5: Ability to withstand short circuit.

IEC 137:1995, 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, 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.

²⁾ See IEC 668-3-3.

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-transformer³⁾

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⁾ 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 IEC 421-01-13).

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]

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 winding⁴⁾

the winding having the highest rated voltage
[IEV 421-03-03]

3.3.5

low-voltage winding⁴⁾

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 winding⁴⁾

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

⁴⁾ 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 IEC 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.

3.3.7**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.

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

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

NOTE 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]

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

NOTE 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 example $U_r = 400/\sqrt{3}\text{kV}$.

NOTE 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 $U_r = 23/\sqrt{3}\text{kV}$.

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

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

NOTE 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]

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

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

NOTE 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

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

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 $\pm a \%$, 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]

3.6 Losses and no-load current

NOTE The values are related to the principal tapping, unless another tapping is specifically stated.

3.6.1**no-load loss**

the active power absorbed when rated voltage (tapping voltage) at rated frequency is applied to the terminals of one of the windings, the other winding or windings being open-circuited

[IEV 421-06-01, modified]

3.6.2**no-load current**

the r.m.s. value of the current flowing through a line terminal of a winding when rated voltage (tapping voltage) is applied at rated frequency, the other winding or windings being open-circuited

NOTE 1 For a three-phase transformer, the value is the arithmetic mean of the values of current in the three phases.

NOTE 2 The no-load current of a winding is often expressed as a percentage of the rated current of that winding. For a multi-winding transformer this percentage is referred to the winding with the highest rated power.

[IEV 421-06-02, modified]

3.6.3**load loss**

the absorbed active power at rated frequency and reference temperature (see **10.1**), associated with a pair of windings when rated current (tapping current) is flowing through the line terminals of one of the windings, and the terminals of the other winding are short-circuited. Further windings, if existing, are open-circuited

NOTE 1 For a two-winding transformer there is only one winding combination and one value of load loss. For a multi-winding transformer there are several values of load loss corresponding to the different two-winding combinations (see clause **6** of IEC 606). A combined load loss figure for the complete transformer is referred to a specified winding load combination. In general, it is usually not accessible for direct measurement in testing.

NOTE 2 When the windings of the pair have different rated power values the load loss is referred to rated current in the winding with the lower rated power and the reference power should be mentioned.

3.6.4**total losses**

the sum of the no-load loss and the load loss

NOTE The power consumption of the auxiliary plant is not included in the total losses and is stated separately.

[IEV 421-06-05, modified]

3.6.5**total harmonic distortion factor:**

$$D = \sqrt{\sum_{h=2}^H U_h^2}$$

where

$$u_h = U_h/U_1;$$

U_h is the rms value of the h^{th} harmonic;

U_1 is the rms value of the fundamental;

H may be taken as 7 in practice for the purposes of this standard.