IEC 60076-15

Edition 2.0 2015-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Power transformers –
Part 15: Gas-filled power transformers

Transformateurs de puissance –
Partie 15: Transformateurs de puissance à isolation gazeuse

IEC 60076-15:2015-04(en-fr)

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INTERNATIONAL
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International Standard IEC 60076-15 has been prepared by IEC technical committee 14: Power transformers.

This second edition of IEC 60076-15 cancels and replaces the first edition published in 2008 and constitutes a technical revision.

The following main technical changes from the first edition are:

– Modified in accordance with the related revised standards of IEC 60076-1, IEC 60076-2, IEC 60076-3 and related items of SF_6 gas in the revised standard of "High-voltage switchgear and controlgear"
– Added the clause "minimum power under alternative cooling modes"
– Added the clause "safety, environmental and other requirements"
– Added the clause "d.c. currents in neutral circuits"
– Added the clause "electromagnetic compatibility (EMC)"
– Added the clause "high frequency switching transients"

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

FDIS	Report on voting
14/811/FDIS	14/818/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60076 series, published under the general title *Power transformers*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

POWER TRANSFORMERS –

Part 15: Gas-filled power transformers

1 Scope

This part of IEC 60076 applies to three-phase and single-phase gas-filled 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, which have no windings with rated voltage higher than 1 000 V;
– instrument transformers;
– traction transformers mounted on rolling stock;
– starting transformers;
– testing transformers;
– welding transformers.

When IEC standards do not exist for such categories of transformers (in particular transformer having no winding exceeding 1 000 V for industrial applications), this part of IEC 60076 may still be applicable either as a whole or in part. This standard does not address the requirements that would make a transformer suitable for mounting in a position accessible to the general public. 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. Such standards exist for:

– reactors in general (IEC 60076-6);
– self-protected transformers (IEC 60076-13);
– transformers for wind turbine applications (IEC 60076-16);
– traction transformers and traction reactors (IEC 60310);
– converter transformers for industrial applications (IEC 61378-1);
– converter transformers for HVDC applications (IEC 61378-2).

At several places in this part it is specified or recommended that an 'agreement' should be reached concerning alternative or additional technical solutions or procedures. Such agreement is 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.

NOTE This standard can be applicable to the gas parts of a transformer in which an insulating gas is used with an insulating liquid.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60076-2:2011, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-10, *Power transformers – Part 10: Determination of sound levels*

IEC 60137, *Insulated bushings for alternating voltages above 1 000 V*

IEC 60376, *Specification of technical grade sulfur hexafluoride (SF6) for use in electrical equipment*

IEC 60480, *Guidelines for the checking and treatment of sulfur hexafluoride (SF6) taken from electrical equipment and specification for its re-use*

IEC 62271-1, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-4:2002, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF6) and its mixtures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Other terms use the meanings ascribed to them in IEC 60076-1, 2, 3, 5 and 10, or in the IEC 60050 series.

3.1
gas-filled power transformer
transformer of which the magnetic circuit and windings are placed in an enclosure filled with an insulating gas

Note 1 to entry: Generally sulfur hexafluoride (SF_6) gas is used, and sometimes this transformer is called a gas-insulated transformer.

3.2
rated gas pressure
gas pressure (gauge pressure) at 20 °C designed for use in a gas-filled power transformer

3.3
guaranteed minimum gas pressure
minimum gas pressure (gauge pressure) at 20 °C, which is able to guarantee the insulation of a gas-filled power transformer

Note 1 to entry: Transformer of which the magnetic circuit and windings are placed in an enclosure or a vessel filled with an insulating liquid such as perfluorocarbon, natural ester, synthetic ester, silicon oil and vegetable oil should be considered a liquid-immersed type transformer.

3.4
design pressure of tanks
relative pressure used to determine the design of the tanks

Note 1 to entry: It is at least equal to the maximum pressure in the tank at the highest temperature that the gas can reach under specified maximum service condition.

3.5 Terms, definitions, symbols and units relating to gas and vacuum tightness

3.5.1
absolute leakage rate
F
amount of gas escaped by time unit at rated filling pressure (or density), expressed in Pa m^3/s

3.5.2
permissible leakage rate
F_p
maximum permissible absolute leakage rate of gas at rated filling pressure (or density) specified by the manufacturer, expressed in Pa m^3/s

3.5.3
relative leakage rate
F_{rel}
absolute leakage rate related to the total amount of gas in the transformer at rated filling pressure (or density)

Note 1 to entry: It is expressed in percentage per year or per day.

4 Service conditions

Service conditions in IEC 60076-1 apply. As far as cooling conditions are concerned, see IEC 60076-2.

5 Rating and general requirements

5.1 Rated power

5.1.1 General

The rated power for each winding shall either be specified by the purchaser or the purchaser shall provide sufficient information to the manufacturer to determine the rated power at the enquiry stage.

The transformer shall have an assigned rated power for each winding which shall be marked on the rating plate. The rated power refers to continuous loading. This is a reference value for guarantees and tests concerning load losses and temperature rises.

If different values of apparent power are assigned under different circumstances, for example, with different methods of cooling, the highest of these values is the rated power.

A two-winding transformer has only one value of rated power, identical for both windings.

For multi-winding transformers, the purchaser shall specify the required power-loading combinations, stating, when necessary, the active and reactive outputs separately.

When the transformer has rated voltage applied to a primary winding, and rated current flows through the terminals of a secondary winding, the transformer receives the relevant rated power for that pair of windings.

The transformer shall be capable of carrying, in continuous service, the rated power (for a multi-winding transformer: the specified combination(s) of winding rated power(s) under conditions listed in Clause 4 of IEC 60076-1:2011 and without exceeding the temperature-rise limitations specified in 5.3.

NOTE 1 The interpretation of rated power according to this subclause implies that it is a value of apparent power input to the transformer – including its own absorption of active and reactive power. The apparent power that the transformer delivers to the circuit connected to the terminals of the secondary winding under rated loading differs from the rated power. The voltage across the secondary terminals differs from rated voltage by the voltage drop (or rise) in the transformer. Allowance for voltage drop, with regard to load power factor, is made in the specification of the rated voltage and the tapping range (see Clause 7 of IEC 60076-8:1997).

National practices can be different.

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.

5.1.2 Preferred values of rated power

Preferred values of rated power in IEC 60076-1 apply.

5.1.3 Minimum power under alternative cooling modes

Where the user has a particular requirement for a minimum power under a particular cooling mode other than the cooling mode for rated power, this shall be stated and subjected to agreement between the supplier and the purchaser in the tender stage.

The transformer shall be capable of carrying, in continuous service, the specified minimum power (for a multi-winding transformer: the specified combination(s) of winding rated power(s) under conditions listed in Clause 4 of IEC 60076-1:2011, and under the specified cooling mode, without exceeding the temperature-rise limitations specified in 5.3.

NOTE An example of this is where the transformer is required to operate at a particular minimum percentage of rated power with the forced cooling out of service (GNAN) to allow for the loss of auxiliary supply and large GNAN rating will be pushed up the transformer cost. A minimum percentage of rated power is determined with consideration of the cost-effectiveness.

5.1.4 Loading beyond rated power

Temporary loading beyond nameplate rating capability is subjected to agreement between the supplier and the purchaser in the tender stage.

NOTE 1 The concept of IEC 60076-7 can be applicable to the consideration of the loading beyond rated power of gas-filled power transformers, but constants and/or factors may not be applicable.

Any specific requirements for loading beyond rated power, operation at higher external cooling medium temperatures or reduced temperature rise limits shall be specified by the purchaser in the enquiry and the contract. Any additional tests or calculations required to verify compliance with these specific requirements shall also be specified.

NOTE 2 This option is intended to be used in particular to give a basis for design and guarantees concerning temporary emergency loading of power transformers.

The bushings, tap-changers, current transformers and other auxiliary equipment shall be selected so as not to restrict the loading capability of the transformer.

NOTE 3 The relevant component standards IEC 60137 for bushings and IEC 60214-1 for tap-changers are consulted for the loading capability of those components.

NOTE 4 These requirements do not apply to transformers for special applications, which do not need a loading capability beyond rated power. For these transformers, if such a capability is required, It is specified.

5.2 Cooling mode

5.2.1 General

The user shall specify the cooling medium (air or water). If the user has particular requirements for the cooling method(s) or cooling equipment, this shall be stated in the enquiry and the contract.

5.2.2 Identification symbols

Transformers shall be identified according to the cooling method employed. For gas-filled power transformers, this identification is expressed by a four-letter code as described below.

First letter: Internal cooling medium:

– G: insulating gas;

Second letter: Circulation mechanism for internal cooling medium:

– N: natural/thermosiphon flow through cooling equipment and in windings;
– F: forced circulation through cooling equipment (e.g., gas blower), thermosiphon flow in windings;
– D: forced circulation through cooling equipment, directed from the cooling equipment into at least the main windings.

Third letter: External cooling medium:

– A: air;
– W: water.

Fourth letter: Circulation mechanism for external cooling medium:

– N: natural convection;
– F: forced circulation (fans, air blowers, water pumps).

5.2.3 Transformers with alternative cooling methods

A transformer may be specified with alternative cooling methods. In this case, the specification and the nameplate shall then carry information about the power values at which the transformer fulfils the temperature rise limitations when these alternatives apply.

The power value for the alternative with the highest cooling capacity is the rated power of the transformer (or of an individual winding of a multi-winding transformer). The alternatives are conventionally listed in rising order of cooling capacity.

EXAMPLE

GNAN/GDAF. The transformer has cooling equipment with blowers and fans but is also specified with a reduced power-carrying under natural cooling.

NOTE The percentage of natural cooling capacity to forced cooling capacity of gas-filled transformers is smaller than that of oil-immersed transformers. It is not difficult generally in oil-immersed transformers to achieve ONAN capacity as 50 % of the OFAF or ODAF capacity. But in gas-filled transformers, it is sometimes difficult and not economical to achieve GNAN capacity as 50 % of the GDAF capacity. The purchaser consults with the manufacturer about natural cooling capacity to forced cooling capacity.

5.3 Temperature-rise limits

5.3.1 Classification and insulation system temperature

Transformers are classified by the insulation systems shown in Table 1.

An approximate value for practical purposes of hot-spot temperature can be calculated by using the concept of Annex B.

The application of insulating materials with different thermal classes leads to unconventional insulation systems (see the examples of unconventional insulation systems as described in Clause 5 of IEC 60076-14:2013).

Table 1 – Classification and insulation system temperature

Letter designation[a]	Thermal class (insulation system temperature °C)
A	105
E	120
B	130
F	155
H	180
N	200
R	220
[a] Temperature classifications are given in IEC 60085.	

5.3.2 Normal temperature-rise limits

The temperature rise of each winding of the transformer, designed for operation at normal service conditions, shall not exceed the corresponding limit specified in Table 2 when tested in accordance with 11.5.

The temperature of the core, metallic parts and adjacent materials shall not reach a value that will cause damage to any part of the transformer.

In most of the gases, the temperature-rise limit of gas is higher than the temperature-rise limit of winding, so that the temperature-rise limit of gas is not necessary to be specified. If necessary, it is subjected to agreement between the supplier and the purchaser.

Table 2 – Winding temperature-rise limits

Thermal class (insulation system temperature °C)	Average winding temperature-rise limits K (see note)
105	60
120	75
130	80
155	100
180	125
200	135
220	150
NOTE Temperature-rise measured in accordance with 11.5.	

5.3.3 Reduced temperature-rises for transformers designed for high cooling air temperatures or special air cooling conditions

Reduced temperature-rises for transformers designed for high cooling air temperatures or special air cooling conditions in IEC 60076-2 apply.

5.3.4 High altitude temperature-rise correction

Unless otherwise agreed between the supplier and the purchaser, for transformers designed for operation at an altitude greater than 1 000 m but tested at normal altitudes, the limits of temperature-rise given in Table 2 shall be reduced by the following amounts for each 500 m by which the intended working altitude exceeds 1 000 m:

– natural-air-cooled transformers: 2 %;
– forced-air-cooled transformers: 3 %.

A corresponding reverse correction may be applied in cases where the altitude of the factory is above 1 000 m and the altitude of the installation site is below 1 000 m.

Any temperature-rise correction in dependence on altitude shall be rounded to the nearest whole number of Kelvin.

The influence of differing ambient temperature or altitude on the air cooling of the tank is disregarded for the water-cooled transformers.

5.3.5 Reduced temperature-rise for transformers designed for high cooling water temperatures

Reduced temperature-rise for transformers designed for high cooling water temperatures in IEC 60076-2 apply.

5.3.6 Temperature rise during specified load cycle

By agreement between manufacturer and purchaser, temperature rise limits can be guaranteed and/or a special test regarding load cycle operation specified (see IEC 60076-7).

5.4 Insulation level

Insulation level described in IEC 60076-3 apply.

5.5 Load rejection on transformers directly connected to a generator

The requirements for transformer connected directly to generators described in IEC 60076-1 apply.

5.6 Rated voltage and rated frequency

Rated voltage and rated frequency in IEC 60076-1 apply.

5.7 Provision for unusual service conditions

Any service conditions not covered by the normal service conditions shall be identified by the purchaser as described in IEC 60076-1.

5.8 Highest voltage for equipment U_m and dielectric tests levels

Highest voltage for equipment U_m and dielectric tests levels in IEC 60076-1 apply.

5.9 Additional information required for enquiry

Additional information required for enquiry that is described in IEC 60076-1 apply.

5.10 Components and materials

All components and materials used in the construction of the transformer shall comply with the requirements of the relevant IEC standards where they exist unless otherwise agreed or specified. In particular bushings shall comply with IEC 60137 and tap-changers shall comply with IEC 60214-1. Insulating gas shall comply with IEC 60376 and 60480 for new and used SF_6 or as agreed for other gases.

5.11 Requirements for gases and gas tightness

5.11.1 Requirements for gases

The manufacturer shall specify the type and the required quantity, quality and density of the gas to be used in a gas-filled power transformer.

The maximum allowable moisture content within gas-filled power transformer filled with gas at rated gas pressure shall be such that the dew-point is not higher than –20 °C for a measurement at 20 °C. Adequate correction shall be made for measurement made at other temperatures.

NOTE 1 A dew point of –5 °C for measurement at 20 °C is acceptable for the gas-filled compartments other than main tank.

NOTE 2 The requirement level for the purity of SF_6 before filling transformers is equal and more than 97 %.

NOTE 3 For the measurement and determination of the dew point, see IEC 60376 and IEC 60480.

5.11.2 Gas tightness

IEC 62271-1 gives general rules to the gas tightness of high-voltage switchgears. This rule can be applicable to the gas-filled power transformers.

The tightness characteristic shall be consistent with a minimum maintenance and inspection philosophy. The tightness for gas is specified by the relative leakage rate F_{rel}.

For SF_6-filled transformers, the relative leakage rate of SF_6 shall not exceed 0,5 percent per year. For transformers filled with the mixture, consisting of SF_6 and other gases, the relative leakage rate of the mixture shall not exceed 0,5 % per year.

6 Requirements for transformers having a tapped winding

Requirements for transformers having a tapped winding in IEC 60076-1 apply.

7 Connection phase displacement symbols

Connection phase displacement symbols in IEC 60076-1 apply.

8 Rating plates

8.1 General

The transformer shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the appropriate items indicated below. The entries on the plate shall be indelibly marked.

8.2 Information to be given in all cases

The information listed below shall be included on the rating plate in all cases.

a) Kind of gas-filled power transformer (for example gas-filled power transformer, gas-filled auto-transformer, gas-filled series transformer, etc.).
b) Number of this standard.
c) Manufacturer's name, country and town where the transformer was assembled.
d) Manufacturer's serial number.
e) Year of manufacture.