IEC 60076-15

Edition 1.0 2008-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Withdrawn

Power transformers – Part 15: Gas-filled power transformers

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

IEC 60076-15:2008

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Part 15: Gas-filled power transformers

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

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POWER TRANSFORMERS –

Part 15: Gas-filled power transformers

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

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

FDIS	Report on voting
14/567/FDIS	14/571/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 the parts in the IEC 60076 series, under the general title *Power transformers*, can be found on the IEC website.

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POWER TRANSFORMERS –

Part 15: Gas-filled power transformers

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1 Scope

This standard applies to gas-filled power transformers (including auto-transformers). The standard applies to all construction technologies.

This standard does not apply to

- single-phase transformers with rated power less than 1 kVA and three-phase transformers less than 5 kVA;
- dry-type transformers (see IEC 60076-11);
- instrument transformers (see IEC 60044);
- starting transformers;
- testing transformers;
- traction transformers mounted on rolling stock;
- welding transformers.

Where IEC standards do not exist for the transformers mentioned above or for other special transformers, this standard may be applicable as a whole or in parts.

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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050, *International Electrotechnical Vocabulary*

IEC 60076-1:1993, *Power transformers – Part 1: General*

IEC 60076-2:1993, *Power transformers – Part 2: Temperature rise*

IEC 60076-3:2000, *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 60085, *Electrical insulation – Thermal classification and designation*

IEC 60376, *Specification of technical grade sulfur hexafluoride SF_6 for use in electrical equipment*

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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*

ISO 9001:2000, *Quality management systems – Requirements*

3 Definitions

For the purpose of this document, the following definitions apply. Other terms used have the meanings ascribed to them in IEC 60076-1, or IEC 60050.

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

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

NOTE A 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 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 Definitions, symbols and units relating to gas and vacuum tightness

3.5.1
absolute leakage rate
F
the 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
the 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}
the absolute leakage rate related to the total amount of gas in the transformer at rated filling pressure (or density). It is expressed in percentage per year or per day.

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4 Service conditions

The requirements in IEC 60076-1 apply. With regard to cooling reference, requirement of IEC 60076-2 apply.

5 Tappings

The requirements in IEC 60076-1 apply.

6 Connections

The requirements in IEC 60076-1 apply.

7 Ability to withstand short circuit

Transformers shall fulfil the requirements in IEC 60076-5. If the purchaser requires a test to demonstrate this fulfilment, this shall be stated in the contract.

8 Rating

8.1 General

The manufacturer shall assign ratings to the transformer, which shall be marked on the rating plate, see Clause 9. These ratings shall be such that the transformer can deliver its rated current under steady loading conditions without exceeding the limits of temperature-rise specified in Clause 11, assuming that the applied primary voltage is equal to the rated voltage, that the supply is at rated frequency and that the transformer is operating at rated gas pressure.

8.2 Rated power

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, temperature-rises and short-circuit impedance.

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.

NOTE A two-winding transformer has only one value of rated power, identical for both windings. When the transformer has rated voltage applied to the primary winding, and rated current flows through the terminals of that winding, the transformer receives the relevant rated power for both 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 powers) under conditions listed in Clause 4 and without exceeding the temperature-rise limitations specified in Clause 11.

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8.3 Loading cycle

If specified in the enquiry or the contract, the transformer may, in addition to its rated power for continuous loading, be assigned a temporary load cycle which it shall be capable of performing under conditions specified in Clause 11.

NOTE This option is to be used in particular to give a basis for design and guarantees concerning short-time emergency loading of large power transformers.

In the absence of such specification, guidance on loading of transformers complying with this part are subjected to agreement between the purchaser and the manufacturer.

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

8.4 Preferred values of rated power

The requirements in IEC 60076-1 apply.

8.5 Operation at higher than rated voltage and/or at disturbed frequency

The requirements in IEC 60076-1 apply.

8.6 Loading beyond nameplate rating

Unless specified in the enquiry or the contract, temporary loading beyond nameplate rating capability is subjected to agreement between the supplier and the purchaser.

NOTE The concept of IEC 60076-7 can be applicable to the consideration of the loading beyond nameplate rating capability of gas-filled transformers, but IEC 60076-7 cannot be applied directly because the cooling characteristics of oil and gas are different.

9 Rating plate

9.1 General

Each transformer shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the items indicated below. The entries on the plate shall be indelibly marked (that is, by etching, engraving, stamping or by a photo-chemical process).

9.2 Information to be given in all cases

a) Kind of transformer (for example gas-filled transformer, gas-filled auto-transformer, etc.).

b) Number and year of this standard.

c) Manufacturer's name.

d) Manufacturer's serial number.

e) Year of manufacture.

f) Number of phases.

g) Rated power (in kVA or MVA). (For multi-winding transformers, the rated power of each winding should be given.)

h) Rated frequency (in Hz).

i) Rated voltages and tapping range (in V or kV).

j) Rated currents (in A or kA).

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k) Connection symbol.

l) Connection diagram.

m) Short-circuit impedance, measured value in percentage. For multi-winding transformers, several impedances for different two-winding combinations are to be given with the respective reference power values. For transformers having a tapped winding, see also IEC 60076-1.

n) Type of cooling. (If the transformer has several assigned cooling methods, the respective power values may be expressed as percentages of rated power, for example GNAN/GDAF 30/100 %.)

o) Insulation system temperature for each winding (for multi-winding transformers, the insulation system temperature of each winding should be given).

p) Temperature-rise limits of windings (only in the case of specifying limits other than the limits in Table 2).

q) Kind of insulating gas.

r) Rated gas pressure (in MPa-gauge).

s) Guaranteed minimum gas pressure (in MPa-gauge).

t) Vacuum withstand capability of the tank.

u) Total mass.

v) Mass of gas.

w) Transportation mass (for transformers exceeding 5 t total mass).

x) Untanking mass (for transformers exceeding 5 t total mass).

y) Insulation levels (the rated withstand voltages for all windings shall appear on the rating plate. The principles of the standard notation are illustrated in IEC 60076-3.).

aa) If the transformer has more than one set of ratings, depending upon different connections of windings which have been specially allowed for in the design, the additional ratings shall all be given on the rating plate, or separate rating plates shall be fitted for each set.

9.3 Additional information to be given when applicable

a) For transformers having one or more windings with 'highest voltage for equipment' U_m equal to or above 3,6 kV:

– short notation of insulation levels (withstand voltages) as described in Clause 3 of IEC 60076-3.

b) For transformers having a tapped winding, particulars about the tappings are as follows:

– for transformers having a tapping range not exceeding ±5 %: tapping voltages on the tapped winding for all tappings. This applies in particular to distribution transformers;

– for transformers having a tapping range exceeding ±5 %: a table stating tapping voltage, tapping current and tapping power for all tappings. In addition the short-circuit impedance values for the principal tapping and at least the extreme tappings shall be given, preferably in ohms per phase referred to a specific winding.

c) Temperature rises of top gas and windings (if not normal values). When a transformer is specified for installation at high altitude, this shall be indicated, together with information on either the reduced temperature-rise figures valid under normal ambient conditions, or the reduced loading which will result in normal temperature-rise at the high altitude (standard transformer with normal cooling capacity).

d) Connection diagram (in cases where the connection symbol will not give complete information regarding the internal connections). If the connections can be changed inside the transformer, this shall be indicated on a separate plate or with duplicate rating plates. The connection fitted at the works shall be indicated.

In addition to the main rating plate with the information listed above, the transformer shall also carry plates with identification and characteristics of auxiliary equipment according to

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international standards for such components (bushings, tap-changer, current transformers, special cooling equipment).

10 Identification according to cooling method

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

First letter: internal cooling medium in contact with the winding:

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, 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).

A transformer may be specified with alternative cooling methods. The specification and the rating plate shall then carry information about the power figures at which the transformer fulfils the temperature-rise limitations when these alternatives apply, see n) of Subclause 9.2. 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. It is recommended for the purchaser to consult with the manufacturer about natural cooling capacity to forced cooling capacity.

11 Temperature-rise limits

11.1 Classification and insulation system temperature

Transformers are classified by the insulation systems shown in Table 1. The maximum temperature occurring in any part of the winding shall not exceed the insulation system temperature in Table 1 continuously.

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

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Components used as insulating material may be used separately or in combination providing that their temperature does not exceed continuously the values given for the appropriate insulation system temperature.

Table 1 – Classification and insulation system temperature

Insulation system (see note)	Insulation system temperature °C
Class 105	105
Class 120	120
Class 130	130
Class 155	155
Class 180	180
Class 200	200
Class 220	220
NOTE Temperature classifications are given in IEC 60085.	

11.2 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 Clause 28.

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

Insulation system (see note 1)	Average winding temperature-rise limits K (see note 2)
Class 105	60
Class 120	75
Class 130	80
Class 155	100
Class 180	125
Class 200	135
Class 220	150
NOTE 1 Temperature classifications are given in IEC 60085. NOTE 2 Temperature-rise measured in accordance with Clause 28.	

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

The requirements in IEC 60076-2 apply.

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11.4 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.

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

The requirements in IEC 60076-2 apply.

11.6 Temperature rise during specified load cycle

If guarantees and/or a special test regarding a load cycle are to be specified, this shall involve the following parameters:

– the initial temperature condition of the transformer, either at ambient temperature or with steady-state temperature-rises corresponding to a specified fraction of rated current (‘preload’);
– the (constant) magnitude of the test current, expressed as a multiple of rated current, and its duration;
– the maximum permissible temperature-rise values for top gas and winding average (by resistance) at the termination of the test. This statement is optional. The test may be executed for information only, without any limits being agreed on beforehand;
– any special observations or measurements to be performed, for example direct hot-spot temperature measurements, thermal imaging of tank-wall heating, and possible limitations in relation to them.

For further recommendations and discussion regarding temperature rise during specified load cycle – particularly measurements and evaluation – temperature rise during specified load cycle is subjected to agreement between the supplier and the purchaser.

12 Insulation levels

The requirements in IEC 60076-3 apply.

13 Requirements for gases and gas tightness

13.1 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 transformer.

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For sulfur hexafluoride-filled transformers, new SF_6 in accordance with IEC 60376 and used SF_6 in accordance with IEC 60480 can be used.

The maximum allowable moisture content within gas-filled 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. For the measurement and determination of the dew point, refer to IEC 60376 and IEC 60480.

NOTE In gas compartments which are separated from transformer winding, a dew point of –5 °C for measurement at 20 °C is acceptable.

13.2 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 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 sulfur hexafluoride-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 percent per year.

14 General requirements for tests

New transformers shall be subjected to tests as specified below.

Tests shall be made at any ambient temperature between 10 °C and 40 °C. For water cooled transformer, tests shall be made at any water temperature not exceeding 25 °C.

Tests shall be made at the manufacturer's works, unless otherwise agreed between the supplier and the purchaser.

All external components and fittings that are likely to affect the performance of the transformer during the test shall be in place.

Tapped windings shall be connected on their principal tapping, unless the relevant test clause requires otherwise or unless the supplier and the purchaser agree otherwise.

The test basis for all characteristics other than insulation is the rated condition, unless the test clause states otherwise. Dielectric tests shall be performed in guaranteed minimum gas pressure.

All measuring systems used for the tests shall have certified, traceable accuracy and be subjected to periodic calibration, according to the rules of 7.6 of ISO 9001.

NOTE Specific requirements on the accuracy and verification of the measuring systems are under consideration (see IEC 60076-8).

If test methods are not prescribed in this standard, or if tests other than those listed in this standard are specified in the contract, such test methods are subjected to agreement between the supplier and the purchaser.

15 Measurement of winding resistance (routine test)

The test described in IEC 60076-1 applies.

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16 Measurement of voltage ratio and check of phase displacement (routine test)

The test described in IEC 60076-1 applies.

17 Measurement of short-circuit impedance and load loss (routine test)

The test described in IEC 60076-1 applies.

The reference temperature of the short-circuit impedance and load loss shall be

– 75 °C for an insulation system temperature of 105 °C;
– average winding temperature-rise plus 20 °C for other average winding temperature-rise.

NOTE Reference temperature with an insulation system of class 200 or above shall be subjected to agreement between the supplier and the purchaser.

When a transformer has windings of different insulation system temperatures, the reference temperature relating to the winding having the higher insulation system temperature shall be used.

18 Measurement of no-load loss and current (routine test)

The test described in IEC 60076-1 applies.

19 Tests on on-load tap-changers (routine test)

The test described in IEC 60076-1 applies.

20 Measurement of zero-sequence impedance(s) on three-phase transformers (special test)

The test described in IEC 60076-1 applies.

21 Measurement of the harmonics of the no-load current (special test)

The test described in IEC 60076-1 applies.

22 Separate-source AC withstand voltage test (routine test)

The test described in IEC 60076-3 applies.

23 Short-duration induced AC voltage test (ACSD) (routine or special test)

The test described in IEC 60076-3 applies. Routine or special test is in accordance with IEC 60076-3.

24 Long-duration induced AC voltage test with partial discharge measurement (ACLD) (routine or special test)

The test described in IEC 60076-3 applies. Routine or special test is in accordance with IEC 60076-3.

Withdrawn

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