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Australian/New Zealand Standard™

Power transformers

Part 11: Dry-type transformers



AS/NZS IEC 60076.11:2024

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- CIGRE Australia
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- Electricity Engineers Association of New Zealand
- Energy Efficiency & Conservation Authority of New Zealand
- Energy Networks Australia
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Australian/New Zealand Standard™

Power transformers

Part 11: Dry-type transformers

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-008, Power Transformers, to supersede AS 60076.11—2006.

The objective of this document is to give guidance to dry-type power transformers (including auto-transformers) having values of highest voltage for equipment up to and including 72,5 kV and at least one winding operating at greater than 1,1 kV.

This document does not apply to:

- (a) gas-filled dry-type transformers where the gas is not air;
- (b) single-phase transformers rated at less than 5 kVA;
- (c) polyphase transformers rated at less than 15 kVA;
- (d) instrument transformers;
- (e) starting transformers;
- (f) testing transformers;
- (g) traction transformers mounted on rolling stock;
- (h) flameproof and mining transformers;
- (i) welding transformers;
- (j) voltage regulating transformers; and
- (k) small power transformers in which safety is a special consideration.

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

This document is identical with, and has been reproduced from, IEC 60076-11:2018, *Power transformers — Part 11: Dry-type transformers* and its Interpretation Sheet No. 1 (2020) which has been added at the end of the source text.

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- (i) In the source text “this part of IEC 60076” should read “this document”.
- (ii) A full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). 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. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60076-11 has been prepared by IEC technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 2004 and constitutes a technical revision.

The main changes with regard to the previous edition are as follows:

- Extension of the scope up to 72,5kV
- Enclosure management in regards of the performance
- Management of the dielectric and thermal features with altitude

- New climatic classes for a better adaptation of customers' need
- Establishment of the relation between location and environmental classes
- For fire behaviour classes, limitation at 1 000 kVA and process of test more robust
- Introduction of Seismic class
- Recommendations for amorphous transformers

The text of this International Standard is based on the following documents:

FDIS	Report on voting
14/964/FDIS	14/972/RVD

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

This document 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 document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

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NOTES

Australian/New Zealand Standard

Power transformers

Part 11: Dry-type transformers

1 Scope

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- single-phase transformers rated at less than 5 kVA;
- polyphase transformers rated at less than 15 kVA;
- instrument transformers;
- starting transformers;
- testing transformers;
- traction transformers mounted on rolling stock;
- flameproof and mining transformers;
- welding transformers;
- voltage regulating transformers;
- small power transformers in which safety is a special consideration.

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60068-3-3, *Environmental testing – Part 3-3: Guidance – Seismic test methods for equipments*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2, *Insulation co-ordination – Part 2: Application guidelines*

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

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

IEC 60076-3:2013, *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 60076-12:2008, *Power transformers – Part 12: Loading guide for dry-type power transformers*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60332-3-10, *Tests on electric cables under fire conditions – Part 3-10: Test for vertical flame spread of vertically-mounted bunched wires or cables – Apparatus*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60721-3-4, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weatherprotected locations*

IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC 61378-1, *Converter transformers – Part 1: Transformers for industrial applications*

IEC 62271-202, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

ISO 12944-6, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 6: Laboratory performance test methods*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

dry-type transformer

transformer of which the magnetic circuit and windings are not immersed in an insulating liquid

3.2

totally enclosed dry-type transformer

transformer in an un-pressurised enclosure cooled by the circulation of the internal air having no intentional exchange with external air

3.3

enclosed dry-type transformer

transformer in a ventilated enclosure cooled by the circulation of the external air

3.4

non-enclosed dry-type transformer

transformer supplied without a protective enclosure cooled by natural or forced air ventilation

4 Service conditions

4.1 General

The requirements of IEC 60076-1 apply to dry-type transformers only in so far as they are referred to in this document.

4.2 Normal service conditions

a) Altitude:

See IEC 60076-1.

b) Temperature of cooling air and water:

See IEC 60076-1.

For water cooled transformers, specification of the water (temperature, water flow, etc.) has to be defined by agreement between manufacturer and purchaser if the temperature of the water is different from that specified in IEC 60076-1 and IEC 60076-2

NOTE Liquids other than water can be used as a cooling medium then all technical data of the liquid has to be defined by agreement between manufacturer and purchaser

c) Wave-shape of supply voltage:

A sinusoidal supply voltage with a total harmonic content not exceeding 5 % and an even harmonic content not exceeding 1 %.

The purchaser shall specify the magnitude and frequency of any harmonic voltages present in the supply that exceed these limits.

The manufacturer should take into account these harmonics in determination of additional core losses and also regarding the saturation of the core.

d) Load current harmonic content:

At the enquiry stage the purchaser shall specify the magnitude and frequency of each of the harmonic current components generated by the load.

The manufacturer shall consider the additional losses caused by harmonic currents in calculating the temperature rise of the windings and the effects on the other metallic parts of the transformer.

The manufacturer shall calculate the additional loss by using the method of IEC 61378-1 or by using a method like finite element by agreement between manufacturer and purchaser.

If the total harmonic content of the load current exceeds 5 %, then the extra losses due to these harmonic currents shall be taken into account by increasing the test current for the temperature rise test. The temperature rise with these losses shall not exceed the corresponding limit specified in [Table 2](#) when tested in accordance with [14.3.2](#).

e) Symmetry of three-phase supply voltages:

See IEC 60076-1.

f) Installation environment:

This standard defines specific classes for environment:

- 1) for climatic conditions;
- 2) for humidity and pollution;
- 3) for fire behaviour;
- 4) for seismic disturbance;

- 5) environmental conditions within the following definitions according to IEC 60721-3-4:
- i) biological conditions 4B1;
 - ii) chemically active substances 4C2;
 - iii) mechanically active substances 4S3;
 - iv) mechanical conditions 4M4.
- g) For transformers intended to be installed indoors, some of these environmental conditions might not be applicable.
- h) Inrush current:
- System inrush current limitations, if any, (maximum value, duration) shall be given at the enquiry stage by the purchaser.
- i) Frequency of energization:
- If frequency of energization is greater than 24 times a year, then purchaser shall specify the number of energizations per year at the enquiry stage.
- j) Protection from water and liquids:
- The transformer shall be protected against dripping water or flooding by water and other liquids.
- k) Special electrical and environmental conditions around the transformer:
- IEC 60076-3 recommends general minimum clearances between transformer live parts and conductive parts in the installation.
- Any part of the installation made of insulation material becomes conductive when moistened with rain water, salt water or other conductive liquids. Partial discharges in the surroundings of the transformer can decrease the dielectric strength of the air.
- Therefore the clearances between these installations parts and the live parts of the transformer shall meet the clearances recommended in IEC 60076-3.
- NOTE An agreement between purchaser and manufacturer is needed to reduce the clearances between transformer live parts and conductive parts in the installation.
- l) Level of vibration:
- Vibrations of the structure where the transformer is to be installed shall be taken into account when designing the transformer and special consideration shall be given in the stress transferred to connection terminals.
- The purchaser shall specify vibration spectrum at the enquiry stage. The procedure of vibration test, if any, should be agreed at enquiry stage between purchaser and manufacturer.
- m) Corrosion protection:
- Depending on the type of the installation, the purchaser should choose a protection class defined in ISO 12944 or as agreed between purchaser and manufacturer.
- n) Maintenance
- The user shall follow the manufacturer guide line for maintenance and specially avoid an accumulation of dust or pollution on the transformer by a regular cleaning.

4.3 Electromagnetic compatibility (EMC)

Transformers shall be considered as passive elements in respect to emission and immunity to electromagnetic disturbances.

5 Rating and general requirements

5.1 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 10](#), assuming that the applied primary voltage is equal to the rated voltage and that the supply is at rated frequency.

5.2 Rated power

5.2.1 General

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.

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 rated power corresponds to continuous duty; nevertheless, dry-type transformers complying with this standard can be overloaded and guidance on overloads is given in IEC 60076-12.

5.2.2 Definition of the rated power with fans cooling or heat exchangers

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.

When additional cooling by means of fans is provided, the rated power without fans shall be subject to agreement between purchaser and supplier.

5.2.3 Transformer IP00 (without enclosure)

The transformer shall have an assigned rated power for each winding which shall be marked on the rating plate.

5.2.4 Transformer with enclosure

This subclause defines rated power and the distance between enclosures and live parts when the transformer is equipped with an enclosure.

Two cases are defined:

- a) The transformer in an enclosure is manufactured, tested in the enclosure and then delivered on site:
 - The clearances between the live parts and the enclosure shall be defined by the manufacturer. The dielectric tests shall be performed with the enclosure as a routine test.

- If the clearance between the live part and the enclosure meets the requirement of IEC 60076-3 the dielectric routine test shall be performed either with enclosure or without enclosure.
- It is permitted to disassemble the enclosure for transportation reasons. In this case the dis-assembled clearances between the live parts and the enclosure shall meet the requirements of IEC 60076-3.
- There shall be no reduction (de-rating) of the rated power.

b) Transformer and enclosure are delivered on site separately, or later:

- There are two methods to determine the thermal performance of enclosure:
 - The de-rating of the rated power is determined by IEC 62271-202. Then the thermal class of enclosure shall be declared by the manufacturer of the enclosure (seller of the package).
 - The enclosure is calculated using [Annex C](#) of this document.
- The clearance between the live part and the enclosure shall meet the requirement of IEC 60076-3.
- Enclosure shall have a rating plate and the manufacturer of the enclosure or seller of the package is responsible for determining the rated power of the transformer with the enclosure.

5.2.5 Preferred values of rated power

The preferred values shall be in accordance with IEC 60076-1 starting from 50 kVA.

5.2.6 Loading beyond rated power

The loading guides for dry-type transformers in IEC 60076-12 and the requirements in IEC 60076-1 shall apply.

5.3 Provision for unusual service conditions

The purchaser shall identify in his enquiry any service conditions not covered by the normal service conditions in [4.2](#). Examples of such conditions are:

- high or low ambient temperature outside the limits prescribed in [4.2](#);
- restricted ventilation;
- altitude in excess of the limit prescribed in [4.2](#);
- damaging fumes and vapours;
- steam;
- humidity in excess of the limit prescribed in [4.2](#);
- dripping water;
- salt spray;
- conductive pollution;
- excessive and abrasive dust;
- high harmonic content of the load current prescribed in [4.2](#);

- distortion of the supply voltage waveform prescribed in [4.2](#);
- fast transient overvoltage over the limits prescribed in [11.1](#);
- associated power factor correction and method of capacitor switching to limit inrush current;
- superimposed DC current;
- seismic qualification which would otherwise require special considerations in the design;
- extreme mechanical shock and vibrations;
- transport and storage conditions not covered by the normal condition described in [5.7](#);
- solar radiation;
- regular frequent energization in excess of 24 times per year;
- regular frequent short-circuits;
- V/Hz in excess of IEC 60076-1;
- if a generator step-up transformer is intended to be used in back-feed mode when not connected to the generator without protection on the lower voltage side;
- corrosion protection, according to the type of installation;
- environment (see [4.2](#)), the purchaser should choose classes of protection in ISO12944 or by agreement between purchaser and manufacturer;
- load rejection conditions for generator transformers more severe than those given in IEC 60076-1.

Transformer specification for operation under such abnormal conditions shall be subject to agreement between the manufacturer and purchaser.

Supplementary requirements, within defined limits, for the rating and testing of transformers designed for other than normal service conditions listed in [4.2](#), such as high temperature of cooling air or altitude above 1 000 m, are given in [10.2](#) and [10.3](#).

5.4 Transportation and storage

5.4.1 Transport limitation

If transport size or weight limits apply, these shall be stated in the enquiry.

If any other special conditions apply during transportation, they shall be stated in the enquiry.

5.4.2 Transport acceleration

The transformer shall be designed and manufactured to withstand a constant acceleration of at least 10 m/s^2 in all directions (in addition to the acceleration due to gravity in the vertical direction) without any damage. (See [4.2.f.5](#))

If the transport is not the responsibility of the manufacturer and an acceleration in excess of 10 m/s^2 is expected during transport, the accelerations and frequencies shall be defined at the enquiry stage. If higher accelerations are specified by the purchaser, the manufacturer should take them into account in the design and should give some advice for the transportation and packaging.

If the transformer is intended to be used as a mobile transformer, this shall be stated in the enquiry.

NOTE The use of impact or shock recorders during transportation for large transformers is common practice.

5.4.3 Temperature and environment conditions for transport and storage

All transformers shall be suitable for transportation and storage at ambient temperatures down to -25°C .

For storage and transportation with other ambient temperature see [12.1](#).

Transformers shall be protected during transportation and storage against contamination, water, etc.

5.5 Rated voltage and rated frequency

5.5.1 Rated voltage

The requirements in IEC 60076-1 apply.

5.5.2 Rated frequency

The requirements in IEC 60076-1 apply.

5.6 Operation at higher than rated voltage

The requirements in IEC 60076-1 apply.

NOTE 1 This requirement is not meant to be systematically utilised in normal service. The consequential increase in iron losses under these conditions will have adverse effects unless such operation is of limited duration. This condition is reserved for relatively rare cases of service under limited periods of time, for example emergency service or extreme peak loading.

NOTE 2 Under-fluxing will not increase the rated current.

5.7 Highest voltage for equipment U_m and dielectric tests levels

For line terminals, unless otherwise specified by the purchaser, U_m (highest voltage for equipment) shall be taken to be the lowest value that exceeds the rated voltage of each winding given in [Table 3](#).

Unless otherwise specified by the purchaser, dielectric test levels shall be taken to be the highest applicable value corresponding to U_m , given in [Table 3](#).

The purchaser can choose in alignment with insulation coordination one of the values of [Table 3](#) or select higher value listed in IEC 60076-3.

5.8 Identification according to cooling method

5.8.1 General

The purchaser shall specify the cooling medium (air or water).

If the purchaser has particular requirements for cooling method(s) or cooling equipment, this shall be stated in the enquiry.

5.8.2 Identification symbols

Transformers shall be identified according to the cooling method employed. Letter symbols for use in connection with each cooling method shall be as given in [Table 1](#).

Table 1 — Letter symbols

		Symbol
Type of cooling medium	Air	A
	Water	W
Type of circulation	Natural	N
	Forced	F

5.8.3 Arrangement of symbols

Transformers shall be identified by two symbols for each cooling method for which a rating is assigned by the manufacturer, typically as follows:

- A transformer designed for natural air ventilation is designated AN.
- A transformer designed for natural air ventilation up to specified rating and with forced cooling to a higher rating is designated AN/AF.
- A transformer designed with forced cooling with a water heat exchanger is designated AFWF.
- A transformer designed with forced cooling water inside the coil is designated WF.

5.9 Guaranteed temperature rise at rated conditions

The design of the transformer shall be in accordance with the operating conditions (harmonic contents, ambient temperature etc.) stated by the purchaser at the enquiry stage.

The guaranteed temperature rise shall take into account the additional losses due to harmonics if specified, which increase eddy losses and stray losses in the windings and structural/frame parts.

If no harmonics are specified at the design stage but the real load current in service contains harmonics, the load on the transformer may need to be reduced or the cooling improved, to prevent the transformer temperature rise from exceeding the guaranteed limits.

5.10 Additional information required for enquiry

The type of transformer, for example, separate winding transformer, auto-transformer or series transformer shall be specified by the purchaser.

5.11 Sound level

See IEC 60076-1.

5.12 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.

6 Tappings

The requirements in IEC 60076-1 apply for de-energized tap changers (DETC) as well as on load tap changers (OLTC).

The preferred tapping range for DETC is either:

±5 % in steps of 2,5 % (5 tap positions);

or

$\pm 5\%$ (3 tap positions).

Tapping selection shall be made with de-energised transformers by the use of bolted links or DETC.

7 Connections

Unless otherwise specified by the purchaser, transformer connections shall be Dyn11 or Dyn5 in accordance with IEC 60076-1. The neutral connection shall be capable of carrying full rated phase current.

8 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.

9 Rating plate

9.1 Rating plate fitted to the transformer

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):

- a) dry-type transformer;
- b) number and year of this part of IEC 60076;
- c) manufacturer's name, country and town where the transformer was assembled;
- d) manufacturer's serial number;
- e) year of manufacture;
- f) thermal class of insulation system for each winding (either by temperature, letter or both – refer to IEC 60085). The first thermal class shall refer to the high voltage winding, the second thermal class shall refer to the low voltage winding. When more than two windings are present, the thermal classes shall be placed in the order of the windings from the high voltage to the low voltage;
- g) number of phases;
- h) rated power;
- i) apparent power for each cooling system;
- j) rated frequency;
- k) rated voltages, including tapping voltages, if any;
- l) rated currents for each kind of cooling;
- m) connection symbol;
- n) short-circuit impedance at rated current and at the appropriate reference temperature;
- o) type of cooling;
- p) total mass;

- q) insulation levels for each winding according to IEC 60076-3 standard notation;
- r) degree of protection;
- s) environmental class;
- t) climatic class;
- u) fire behaviour class;
- v) seismic class or floor accelerations if any;
- w) maximum altitude if exceeds 1 000 m;
- x) winding temperature rise for each winding if guaranteed values differ from [Table 2](#).

9.2 Rating plate fitted to the transformer enclosure

Each transformer enclosure shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the items indicated in [9.1](#). The entries on the plate shall be indelibly marked (that is, by etching, engraving, stamping or by a photo-chemical process).

10 Temperature-rise limits

10.1 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 [14.3.2](#).

The average temperature rise of the winding is defined as the difference between the average temperature of the winding and the temperature of the cooling air or of the water at the intake of the cooling equipment, for air-cooled or water-cooled transformers.

The maximum temperature occurring in any part of the winding insulation system is called the hot-spot temperature. The hot spot temperature shall not exceed the rated value of the hot-spot winding temperature specified in Table 2 of IEC 60076-12:2008. This temperature could be measured, however an approximate value for practical purposes can be calculated by using equation 9 in 5.8 of IEC 60076-12:2008 with the values for Z and q given in equation 9 of IEC 60076-12:2008.

Components used as insulating material may be used separately or in combination, providing that their temperature does not exceed the values given for the appropriate insulation system temperature in accordance with the requirements as prescribed in the left hand column of [Table 2](#).

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.

Table 2 — Winding temperature-rise limits

Insulation system thermal class (see Note 1)	Average winding temperature rise limits at rated current (see Note 2)
°C	K
105 (A)	60
120 (E)	75
130 (B)	80
155 (F)	100
180 (H)	125