



SLOVENSKI STANDARD
oSIST prEN IEC 60076-2:2026

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Močnostni transformatorji - 2. del: Segretek transformatorjev, potopljenih v tekočino

Power transformers - Part 2: Temperature rise for liquid-immersed transformers

Leistungstransformatoren - Teil 2: Übertemperaturen für flüssigkeitsgefüllte Transformatoren

Transformateurs de puissance - Partie 2: Echauffement des transformateurs immergés dans le liquide

Ta slovenski standard je istoveten z: prEN IEC 60076-2:2026

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14/1220/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

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OF INTEREST TO THE FOLLOWING COMMITTEES:

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☒ SUBMITTED FOR CENELEC PARALLEL VOTING☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING**Attention IEC-CENELEC parallel voting**

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting.

The CENELEC members are invited to vote through the CENELEC online voting system.

This document is still under study and subject to change. It should not be used for reference purposes.

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TITLE:

Power transformers - Part 2: Temperature rise for liquid-immersed transformers

PROPOSED STABILITY DATE: 2031

NOTE FROM TC/SC OFFICERS:

National committees are requested to read the INF cover letter (14/1218/INF) on the submission of IEC 60076-2 when conditioning the CDV of IEC 60076-2

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 2: Thermal performance measurement and test procedures for liquid-immersed transformers

FOREWORD

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International Standard IEC 60076-2 has been prepared by IEC technical committee 14: Power transformers.

This first edition cancels and replaces the third edition published in 2011. It is a technical revision.

This edition includes the following significant technical changes with respect to the previous edition based on guidance provided by IEC TC 14 AHG 36:

- a) the title is changed to: Thermal performance measurement and test procedures for liquid-immersed transformers;
- b) the scope is changed to: This part of IEC 60076 applies to liquid-immersed transformers, verifies compliance with temperature requirements and gives the methods for temperature rise tests;
- c) the clauses 4, 5, and 6 are moved from edition 2011 to IEC 60076-1 revised document including the temperature rise limits and ambient temperature reference values;

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- d) the procedures for the temperature rise test were improved in relation to the new thermal requirements;
- e) the core temperature test and corresponding temperature rise determination is introduced;
- f) annexes B, D and E are modified, and three informative annexes F, G, H and I are added in order to facilitate the standard application.

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

FDIS	Report on voting

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 of the IEC 60076 series can be found, under the general title *Power transformers*, 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 web site 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

POWER TRANSFORMERS –

Part 2: Thermal performance measurement and test procedures for liquid-immersed transformers

1 Scope

This part of IEC 60076 applies to liquid-immersed transformers, verifies compliance with temperature requirements and gives the methods for temperature rise tests.

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

IEC 60076-7, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60076-8, *Power transformers – Part 8: Application guide*

IEC 61181, *Mineral oil-filled electrical equipment – Application of dissolved gas analysis (DGA) to factory tests on electrical equipment*

IEC Guide 115, *Application of measurement uncertainty to conformity assessment activities in the electrotechnical sector*

IEC 60076-19-1, *Power transformers - Part 19 - 1: Rules for the determination of uncertainties in the measurement of the losses of power transformers*

IEC 60076-22-2, *Power transformers - Part 22-2: Power transformer and reactor fittings - Removable radiators*

IEC 60076-22-3, *Power transformers - Part 22-2: Power transformer and reactor fittings - Insulating liquid to air heat exchangers*

IEC 60076-22-6, *Power transformers - Part 22-6: Power transformer and reactor fittings - Electric fans for transformers*

ISO 10880, *Non-destructive testing — Infrared thermographic testing — General principles*

IEC 60567, *Oil-filled electrical equipment - Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids – Guidance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60076-1 and the following apply.

3.1

bottom liquid temperature

θ_b

temperature of the liquid entering the bottom winding

3.2

bottom liquid temperature rise

$\Delta\theta_b$

difference between the bottom liquid temperature and the external cooling medium temperature

3.3

external cooling medium

fluid (air or water) external to the transformer cooling system (air or water) into which the heat produced by the transformer losses is transferred

3.4

θ_a

temperature of the external cooling medium

temperature of the external cooling medium outside the influence from the transformer

3.5

top liquid temperature

θ_o

the temperature of the liquid at the top of the tank, representative of top liquid in the cooling flow stream

3.6

top liquid temperature rise

$\Delta\theta_o$

difference between the top liquid temperature and the external cooling medium temperature

3.7

average liquid temperature

θ_{om}

average temperature of the top liquid and bottom liquid temperatures

3.8

average liquid temperature rise

$\Delta\theta_{om}$

difference between the average liquid temperature and the external cooling medium temperature

3.9

average liquid temperature rise at shut down

$\Delta\theta'_{om}$

difference between the average liquid temperature and the external cooling medium temperature at shut down

3.10

winding temperature determined from resistance measurement

θ_2

winding temperature determined from resistance measurements at shut down

- 301 **3.11**
 302 **average liquid temperature at shut down**
 303 θ'_{om}
 304 average temperature of the top liquid and bottom liquid temperatures at shut down
- 305 **3.12**
 306 **average winding temperature**
 307 θ_w
 308 winding temperature determined at the end of temperature rise test from the measurement of
 309 winding d.c. resistance
- 310 **3.13**
 311 **average winding temperature rise**
 312 $\Delta\theta_w$
 313 difference between the average winding temperature and the external cooling medium
 314 temperature
- 315 **3.14**
 316 **average winding gradient**
 317 g
 318 difference between the average winding temperature and the average liquid temperature
- 319 **3.15**
 320 **winding hotspot to top liquid temperature gradient**
 321 $\Delta\theta_{h-o}$
 322 difference between the winding hotspot temperature and the top liquid temperature
- 323 **3.16**
 324 **winding hottest temperature reading at shut down**
 325 θ'_h
 326 hottest measured winding temperature of winding conductors in contact with solid insulation or
 327 liquid at shut down
- 328 **3.17**
 329 **top liquid temperature at shut down**
 330 θ'_o
 331 temperature of the insulating liquid at the top of the tank at shut down, representative of top
 332 liquid in the cooling flow stream
- 333 **3.18**
 334 **hotspot factor**
 335 H
 336 dimensionless factor to estimate the local increase of the average winding gradient due to the
 337 additional loss and variation in the liquid flow stream
- 338 **3.19**
 339 **winding hotspot temperature rise**
 340 $\Delta\theta_h$
 341 difference between the winding hotspot temperature and the external cooling medium
 342 temperature
- 343 **3.20**
 344 **no-load top liquid temperature**
 345 θ_{co}
 346 temperature of the top liquid at the end of the no-load temperature rise test at the same tank
 347 location as the top liquid temperature defined in 3.5

- 348 **3.21**
349 **no-load bottom liquid temperature**
350 θ_{cb}
351 temperature of the bottom liquid at the end of the no-load temperature rise test at the same
352 tank location as the bottom liquid temperature defined in 3.1.
- 353 **3.22**
354 **internal core hotspot temperature**
355 θ_c
356 hottest core internal temperature determined from the no load temperature rise at highest core
357 excitation and the liquid temperatures relevant to the operating condition
- 358 **3.23**
359 **internal core hotspot temperature rise**
360 $\Delta\theta_c$
361 the difference between the internal core hotspot temperature and the external cooling medium
362 temperature
- 363 **3.24**
364 **shut down**
365 instant when the power supply is switched off
- 366 **3.25**
367 **cooling method**
368 cooling media type and flow principles, coded by capital letters

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4 Thermal performance measurement

4.1 General

The following subclauses describe the procedures for the determination of temperature and temperature rise values during factory testing and also the methods for substituting service loading conditions by equivalent test procedures.

The thermal performance measurement is carried out to verify the guaranteed temperature rises in insulation liquid and windings as given in Clause 5.4.3 of IEC 60076-1.

NOTE Altitude correction of cooling conditions is given in Clause 5.5 of IEC 60076-1

The temperature rise test can also reveal overheating within the transformer due to conditions such as stray flux heating and poor connections. The transformer loading capability can be verified by direct measurement or by application of corresponding thermal models using the data from the test.

During a temperature rise test various temperatures may be measured or derived, including:

- External cooling medium temperature
- Top liquid temperature
- Bottom liquid temperature
- Average liquid temperature
- Average winding temperatures
- Internal structural part temperatures
- Tank temperature
- Internal core hotspot temperature
- Winding hotspot temperature

NOTE Some of these measurements depend on the presence of temperature sensors

During the temperature rise test, the transformer shall be equipped with any relevant protective devices that would be present in service and are within the scope of the contract between customer and manufacturer. Any indication from these devices during the test shall be noted and the case investigated.

For transformers designed with alternative cooling method ratings, a temperature rise test shall be performed for each cooling method rating to determine the corresponding temperature rises and thermal parameters. By agreement between manufacturer and customer, the testing may be reduced to the test at the nominal power of the transformer if customer accepts to use the calculated parameters for the other cooling method power ratings.

4.2 Temperature of the external cooling media (air or water)

The external cooling medium is defined by the third letter code in the cooling method (see IEC 60076-1, Clause 5.2.2)

4.2.1 Air temperature

For the temperature rise test, the external cooling medium temperature shall be between 10 °C and the maximum external cooling medium temperature at which the winding hotspot temperature shall not exceed the long-time emergency loading temperature limit specified in IEC 60076-7, or the limit specified by the customer, at any point during the test.

Where direct winding hotspot measurement is not provided, compliance with this limit shall be assessed by calculation using the measured external cooling medium temperature, the measured liquid temperature, and the calculated winding hotspot-to-top-liquid temperature gradient. The calculation basis shall be documented in the test report.

Precautions shall be taken to minimize variations of cooling-air temperature, during the whole test period. Rapid variations in readings shall be prevented by using heat sinks or ambient cans for the temperature sensors. The thermal time constant of the heat sinks shall be approximately 2,5 h, suitable for all transformer designs. A report stating the heat-sink thermal time constant shall be provided by the manufacturer. Informative Annex H provides an example of a heat-sink design that fulfils the time-constant requirement.

NOTE. The time constant of a container (heat sink or ambient can) shall be taken as the time necessary for its temperature to change 6,3 K when the ambient temperature is abruptly changed 10 K.

An alternative is to use an ambient temperature sensor with a time constant less than that of the transformer but not less than 30 min and the ambient temperature sampling interval is less than 10% of the sensor time constant. Then any variations may be smoothed by applying a moving-average filter over the period of 2,5 h in the real time.

The sensors should be protected from direct heat radiation from the tank and other heat sources.

Readings should be taken at regular intervals not exceeding 5 min or at shorter intervals if agreed between customer and manufacturer. These readings should be synchronized with other temperature measurements and recorded automatically and continuously.

The temperature rise test shall be done as in service with a stable environment regulated by the airflow management, e.g. by positioning the transformer away from open doors, ports or ventilation outlets, and by balancing ventilation to ensure that the air exchange rate is sufficient for fresh air without affecting temperature stability. Temporary use of doors or ports shall be permitted only where it does not affect the readings of the temperature sensors. During the last four hours of the test, any change in test-bay ventilation and any use of doors or ports shall not be permitted.

The distance between the tank including cooling equipment and any object including the laboratory walls, (excluding testing equipment), shall be more than 3 m.

In the case of separate cooling equipment placed at a distance greater than 3 m from the transformer tank, the ambient temperature shall be measured around the cooling equipment applying the same rules given below. When the separate cooling equipment is placed at a distance of less than 3 m, the ambient temperature shall be measured as defined below for the cooling equipment mounted on the tank.

The transformer shall be positioned so as to minimise obstructions to the airflow and local recirculation of hot air, and to ensure stable and evenly distributed ambient conditions.

In case of cooling equipment mounted on the tank, it is not allowed to install any ambient temperature sensor between the tank and the cooling equipment.

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448 The position of the ambient temperature sensors shall be selected in accordance with the
449 applicable cooling method for transformers with multiple cooling methods.

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