



**NSAI**  
Standards

Irish Standard  
I.S. EN 60076-14:2013

Power transformers -- Part 14: Liquid-immersed power transformers using high-temperature insulation materials (IEC 60076-14:2013 (EQV))

## I.S. EN 60076-14:2013

*Incorporating amendments/corrigenda issued since publication:*

The National Standards Authority of Ireland (NSAI) produces the following categories of formal documents:

I.S. xxx: Irish Standard – national specification based on the consensus of an expert panel and subject to public consultation.

S.R. xxx: Standard Recommendation - recommendation based on the consensus of an expert panel and subject to public consultation.

SWiFT xxx: A rapidly developed recommendatory document based on the consensus of the participants of an NSAI workshop.

<i>This document replaces:</i>	<i>This document is based on:</i> EN 60076-14:2013	<i>Published:</i> 25 October, 2013
This document was published under the authority of the NSAI and comes into effect on:  31 October, 2013		ICS number: 29.180
<b>NSAI</b> 1 Swift Square, Northwood, Santry Dublin 9	T +353 1 807 3800 F +353 1 807 3838 E standards@nsai.ie  W NSAI.ie	<b>Sales:</b> T +353 1 857 6730 F +353 1 857 6729 W standards.ie
Údarás um Chaighdeáin Náisiúnta na hÉireann		

ICS 29.180

English version

**Power transformers -  
Part 14: Liquid-immersed power transformers  
using high-temperature insulation materials  
(IEC 60076-14:2013)**

Transformateurs de puissance -  
Partie 14: Transformateurs de puissance  
immergés dans du liquide utilisant des  
matériaux d'isolation haute température  
(CEI 60076-14:2013)

Leistungstransformatoren -  
Teil 14: Flüssigkeitsgefüllte  
Leistungstransformatoren mit  
Hochtemperatur-Isolierstoffen  
(IEC 60076-14:2013)

This European Standard was approved by CENELEC on 2013-10-21. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

**CENELEC**

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

**CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels**

---

## Foreword

The text of document 14/755/FDIS, future edition 1 of IEC 60076-14, prepared by IEC/TC 14 "Power transformers" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60076-14:2013.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2014-07-21
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2016-10-21

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

## Endorsement notice

The text of the International Standard IEC 60076-14:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60076-4	NOTE	Harmonized in EN 60076-4.
IEC 60216-1	NOTE	Harmonized as EN 60216-1.
IEC 60317	NOTE	Harmonized in EN 60317 series.
IEC 60422	NOTE	Harmonized as EN 60422.
IEC 60505	NOTE	Harmonized as EN 60505.
IEC 60567	NOTE	Harmonized as EN 60567.
IEC 60599	NOTE	Harmonized as EN 60599.
IEC 60641-3	NOTE	Harmonized in EN 60641-3 series.
IEC 60674-3	NOTE	Harmonized in EN 60674-3 series.
IEC 60819-3	NOTE	Harmonized in EN 60819-3 series.
IEC 60851-4	NOTE	Harmonized as EN 60851-4.
IEC 60867	NOTE	Harmonized as EN 60867.
IEC 60893-3	NOTE	Harmonized in EN 60893-3 series.

IEC 60970	NOTE	Harmonized as EN 60970.
IEC 61039	NOTE	Harmonized as EN 61039.
IEC 61100	NOTE	Harmonized as EN 61100.
IEC 61203	NOTE	Harmonized as EN 61203.
IEC 61212-3	NOTE	Harmonized in EN 61212-3 series.
IEC 61629-1	NOTE	Harmonized as EN 61629-1.

## Annex ZA (normative)

### Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60076-1	-	Power transformers - Part 1: General	EN 60076-1	-
IEC 60076-2	-	Power transformers - Part 2: Temperature rise for liquid- immersed transformers	EN 60076-2	-
IEC 60076-5	-	Power transformers - Part 5: Ability to withstand short circuit	EN 60076-5	-
IEC 60076-7	-	Power transformers - Part 7: Loading guide for oil-immersed power transformers	-	-
IEC 60076-16	-	Power transformers - Part 16: Transformers for wind turbines applications	EN 60076-16	-
IEC 60085	-	Electrical insulation - Thermal evaluation and designation	EN 60085	-
IEC 60137	-	Insulated bushings for alternating voltages above 1 000 V	EN 60137	-
IEC 60214-1	-	Tap-changers - Part 1: Performance requirements and test methods	EN 60214-1	-
IEC 60296	-	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear	EN 60296	-
IEC 60836	-	Specifications for unused silicone insulating liquids for electrotechnical purposes	EN 60836	-
IEC 61099	-	Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes	EN 61099	-
IEC 61378-1	-	Convertor transformers - Part 1: Transformers for industrial applications	EN 61378-1	-
IEC 61378-2	-	Convertor transformers - Part 2: Transformers for HVDC applications	EN 61378-2	-

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references .....	8
3 Terms and definitions .....	9
4 Insulation systems.....	11
4.1 General.....	11
4.2 Winding insulation types .....	12
4.2.1 General .....	12
4.2.2 Summary of winding/system insulation types .....	13
4.2.3 Hybrid winding types .....	13
4.2.4 High-temperature insulation winding .....	16
5 Temperature rise limits .....	17
5.1 General.....	17
5.2 Thermally upgraded paper (TUP) .....	19
5.3 Cellulose used in ester liquid .....	19
6 Components and materials .....	19
6.1 General.....	19
6.2 Leads and cables.....	19
7 Special design considerations .....	20
7.1 Short-circuit considerations.....	20
7.2 Dielectric requirements .....	20
7.3 Temperature requirements.....	20
7.4 Overload.....	22
8 Required information .....	23
8.1 Information to be provided by the purchaser .....	23
8.1.1 Ambient temperatures and loading cycle.....	23
8.1.2 Other unusual service conditions .....	23
8.2 Information to be provided by the manufacturer .....	23
8.2.1 Thermal characteristics.....	23
8.2.2 Guarantees.....	23
9 Rating plate and additional information.....	23
9.1 Rating plate .....	23
9.2 Transformer manual.....	24
10 Test requirements.....	24
10.1 Routine, type and special tests .....	24
10.2 Dissolved gas analysis.....	24
10.3 OD cooled compact transformers .....	24
10.4 Evaluation of temperature-rise tests for windings with multiple hot-spots .....	24
10.5 Dielectric type tests .....	26
11 Supervision, diagnostics, and maintenance .....	27
11.1 General.....	27
11.2 Transformers filled with mineral insulating oil.....	27
11.3 Transformers filled with high-temperature insulating liquids .....	27
Annex A (informative) Insulation materials .....	28

Annex B (informative) Rapid temperature increase and bubble generation .....	35
Annex C (informative) Ester liquid and cellulose .....	38
Annex D (normative) Insulation system coding .....	52
Bibliography.....	55
Figure 1 – Example of semi-hybrid insulation windings .....	14
Figure 2 – Example of a mixed hybrid insulation winding .....	15
Figure 3 – Example of full hybrid insulation windings .....	16
Figure 4 – Example of high-temperature insulation system .....	17
Figure 5 – Temperature gradient conductor to liquid .....	21
Figure 6 – Modified temperature diagram for windings with mixed hybrid insulation system .....	26
Figure A.1 – Example of a thermal endurance graph.....	29
Figure B.1 – Bubble evolution temperature chart.....	36
Figure C.1 – Tensile strength ageing results of TUP in mineral oil and natural ester liquid.....	39
Figure C.2 – Composite tensile strength ageing results of TUP in mineral oil and natural ester liquid .....	40
Figure C.3 – DP ageing results of TUP in mineral oil and natural ester liquid .....	41
Figure C.4 – Composite DP ageing results of TUP in mineral oil and natural ester liquid.....	42
Figure C.5 – Tensile strength ageing results of kraft paper in mineral oil and natural ester liquid.....	42
Figure C.6 – Composite tensile strength ageing results of kraft paper in mineral oil and natural ester liquid .....	43
Figure C.7 – DP ageing results of kraft paper in mineral oil and natural ester liquid .....	43
Figure C.8 – Composite DP ageing results of kraft paper in mineral oil and natural ester liquid.....	44
Figure C.9 – Infrared spectra of kraft paper aged in liquid at 110 °C for 175 days .....	46
Figure C.10 – Unit life versus temperature of TUP ageing data (least squares fit).....	48
Figure C.11 – Unit life versus temperature of kraft paper ageing data (least squares fit) .....	48
Table 1 – Preferred insulation system thermal classes .....	12
Table 2 – Winding/system insulation comparison .....	13
Table 3 – Maximum continuous temperature rise limits for transformers with hybrid insulation systems .....	18
Table 4 – Maximum continuous temperature rise limits for transformers with high-temperature insulation systems.....	19
Table 5 – Suggested maximum overload temperature limits for transformers with hybrid insulation systems.....	22
Table 6 – Suggested maximum overload temperature limits for transformers with high-temperature insulation systems.....	22
Table A.1 – Typical properties of solid insulation materials .....	32
Table A.2 – Typical enamels for wire insulation .....	33
Table A.3 – Typical performance characteristics of unused insulating liquids .....	34
Table C.1 – Effect of moisture solubility limits on cellulose moisture reduction.....	46
Table C.2 – Comparison of ageing results.....	47



Table C.3 – Maximum temperature rise for ester liquid/cellulose insulation systems .....	49
Table C.4 – Suggested maximum overload temperature limits for ester liquid/cellulose insulation systems .....	49

INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

**POWER TRANSFORMERS –**

**Part 14: Liquid-immersed power transformers  
using high-temperature insulation materials**

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

This first edition of IEC 60076-14 is an International Standard which cancels and replaces the second edition of the Technical Specification IEC/TS 60076-14 published in 2009. It constitutes a technical revision.

This International Standard includes the following significant technical changes with respect to the Technical Specification:

- a) the hot-spot relationship to thermal class is now defined;
- b) a new 140 thermal class is defined;
- c) the number of insulation systems is reduced to only three: conventional, hybrid and high-temperature;

- d) homogeneous high-temperature insulation system has been changed to just high-temperature insulation system;
- e) winding definitions were introduced to define variations in the hybrid insulation system;
- f) the system example drawings have been revised for clarity;
- g) all suggested limits corresponding to Part 7 loading guide have been defined in a similar format;
- h) moisture equilibrium curves for high-temperature materials have been added to the moisture and bubble generation annex;
- i) an annex has been added to introduce the concept of thermal enhancement of cellulose by ester;
- j) some guide information, such as overload temperature limit suggestions was retained, but most of the other informative text was moved into informative annexes.

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

FDIS	Report on voting
14/755/FDIS	14/759/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 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.

## INTRODUCTION

This part of IEC 60076 standardizes liquid-immersed transformers that use high-temperature insulation. As a system, the solid insulation may encompass a broad range of materials with varying degrees of thermal capability. The insulating and cooling liquids also vary substantially, ranging from mineral oil to a number of liquids that also have a range of thermal capability.

This international standard is not intended to stand alone, but rather builds on the information and guidelines documented in other parts of the IEC 60076 series. Accordingly, this document follows two guiding principles. The first principle is that liquid-immersed transformers are well known and are well defined in other parts of this series and therefore, the details of these transformers are not repeated in this international standard, except where reference has value, or where repetition is considered appropriate for purposes of emphasis or comparison.

The second principle is that the materials used in normal liquid-immersed transformers, typically kraft paper, pressboard, wood, mineral oil, paint and varnish, which operate within temperature limits given in IEC 60076-2, are well known and are considered normal or conventional. All other insulation materials, either solid or liquid that have a thermal capability higher than the materials used in this well-known system of insulation materials are considered high-temperature. Consequently, this standard or normal insulation system is defined as the “conventional” insulation system for comparison purposes and these normal thermal limits are presented for reference to illustrate the differences between other higher-temperature systems.

This international standard addresses loading, overloading, testing and accessories in the same manner. Only selected information for the “conventional” transformers is included for comparison purposes or for emphasis. All other references are directed to the appropriate IEC document.

## POWER TRANSFORMERS –

### Part 14: Liquid-immersed power transformers using high-temperature insulation materials

#### 1 Scope

This part of IEC 60076 applies to liquid-immersed power transformers employing either high-temperature insulation or combinations of high-temperature and conventional insulation, operating at temperatures above conventional limits.

It is applicable to:

- power transformers in accordance with IEC 60076-1;
- convertor transformers according to IEC 61378 series;
- transformers for wind turbine applications in accordance with IEC 60076-16;
- arc furnace transformers;
- reactors in accordance with IEC 60076-6.

This part of IEC 60076 may be applicable as a reference for the use of high-temperature insulation materials in other types of transformers and reactors.

#### 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, *Power transformers – Part 1: General*

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

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

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

IEC 60076-16, *Power transformers – Part 16: Transformers for wind turbine applications*

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

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

IEC 60214-1, *Tap-changers – Part 1: Performance requirements and test methods*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60836, *Specifications for unused silicone insulating liquids for electrotechnical purposes*

This is a free preview. Purchase the entire publication at the link below:

[Product Page](#)

- 
- [Looking for additional Standards? Visit Intertek Inform Infostore](#)
  - [Learn about LexConnect, All Jurisdictions, Standards referenced in Australian legislation](#)
-