



**NSAI**  
Standards

Irish Standard  
I.S. EN 61378-1:2011

# Convertor transformers -- Part 1: Transformers for industrial applications (IEC 61378-1:2011 (EQV))

## I.S. EN 61378-1:2011

*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> EN 61378-1:1998 + corr Nov 1998	<i>This document is based on:</i> EN 61378-1:2011	<i>Published:</i> 11 November, 2011
This document was published under the authority of the NSAI and comes into effect on:  22 November, 2011		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		

**EUROPEAN STANDARD**  
**NORME EUROPÉENNE**  
**EUROPÄISCHE NORM**

**EN 61378-1**

November 2011

ICS 29.180

Supersedes EN 61378-1:1998 + corr. Nov.1998

English version

**Convertor transformers -**  
**Part 1: Transformers for industrial applications**  
**(IEC 61378-1:2011)**

Transformateurs de conversion -  
Partie 1: Transformateurs pour  
applications industrielles  
(CEI 61378-1:2011)

Stromrichtertransformatoren -  
Teil 1: Transformatoren für industrielle  
Anwendungen  
(IEC 61378-1:2011)

This European Standard was approved by CENELEC on 2011-08-30. 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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

**CENELEC**

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

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

## Foreword

The text of document 14/686/FDIS, future edition 2 of IEC 61378-1, prepared by IEC/TC 14, "Power transformers", was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61378-1:2011.

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) 2012-05-30
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2014-08-30

This document supersedes EN 61378-1:1998 + corr. Nov.1998.

EN 61378-1:2011 includes the following significant technical changes with respect to EN 61378-1:1998 + corr. Nov.1998:

- addition of winding connections (zig-zag, extended delta, etc.) with phase displacement ( $<30^\circ$ );
- addition of transformers with more than one active part in the same tank;
- change of reference power definition (it is now based on fundamental component of the current);
- addition of considerations for guidelines for OLTC selection;
- addition of regulating transformer feeding converter transformer;
- addition of considerations about current sharing and hot spot temperature in high current windings for various winding arrangements;
- addition of transducers used for d.c. voltage regulation together with diode rectifiers;
- improved old annexes with several calculation examples;
- addition of new annexes for special measurements setups.

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 61378-1:2011 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 60076-4:2002	NOTE Harmonized as EN 60076-4:2002 (not modified).
IEC 60076-5:2006	NOTE Harmonized as EN 60076-5:2006 (not modified).
IEC 60076-10:2001	NOTE Harmonized as EN 60076-10:2001 (not modified).
IEC 60146-1-3:1991	NOTE Harmonized as EN 60146-1-3:1993 (not modified).
IEC 61378-2:2001	NOTE Harmonized as EN 61378-2:2001 (not modified).

---

## Annex ZA (normative)

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

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.

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 60050-421	1990	International electrotechnical vocabulary (IEV) - Chapter 421: Power transformers and reactors	-	-
IEC 60076	Series	Power transformers	EN 60076	Series
IEC 60076-1	2011	Power transformers - Part 1: General	EN 60076-1	2011
IEC 60076-2	2011	Power transformers - Part 2: Temperature rise for liquid-immersed transformers	EN 60076-2	2011
IEC 60076-3 + corr. December	2000 2000	Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air	EN 60076-3	2001
IEC 60076-6	2007	Power transformers - Part 6: Reactors	EN 60076-6	2008
IEC 60076-8	1997	Power transformers - Part 8: Application guide	-	-
IEC 60076-11	2004	Power transformers - Part 11: Dry-type transformers	EN 60076-11	2004
IEC 60146	Series	Semiconductor converters - General requirements and line commutated converters	EN 60146	Series
IEC 60146-1-1	2009	Semiconductor converters - General requirements and line commutated converters - Part 1-1: Specification of basic requirements	EN 60146-1-1	2010
IEC/TR 60146-1-2	2011	Semiconductor converters - General requirements and line commutated converters - Part 1-2: Application guide	-	-
IEC/TR 60616	1978	Terminal and tapping markings for power transformers	-	-

*This page is intentionally left BLANK.*

## CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references.....	9
3 Terms, definitions and acronyms.....	9
3.1 Terms and definitions .....	9
3.2 Acronyms .....	10
4 Classification .....	11
4.1 General .....	11
4.2 Normal service conditions .....	11
4.3 Provision for unusual service conditions .....	12
5 Ratings.....	12
5.1 General .....	12
5.2 Rated power at rated frequency and load capability .....	12
5.3 Rated and service voltages .....	13
5.3.1 Transformer energized from an a.c. power system .....	13
5.3.2 Transformer energized from a converter/inverter with or without variable frequency .....	13
5.4 Rated current .....	13
5.5 Phase displacement and terminal identification for three-phase transformer .....	13
5.6 Rating plate .....	14
5.7 Units with tertiary windings loaded with filter and compensation.....	14
5.8 On load tap-changers .....	15
6 Load loss and voltage drop in transformers and reactors .....	15
6.1 General .....	15
6.2 Determination of transformer load loss under distorted current loading .....	15
6.3 Current sharing, losses and hot spot in high current windings.....	19
6.4 Effect of geometrical winding arrangement and magnetic coupling between windings on their eddy current losses due to harmonics in transformers with three or more windings wound on the same core limb .....	20
6.5 Losses in interphase transformers, current-balancing reactors, series- smoothing reactors and transductors .....	26
6.5.1 General .....	26
6.5.2 Interphase transformers.....	26
6.5.3 Current-balancing reactors.....	26
6.5.4 Series-smoothing reactors .....	26
6.5.5 Transductors .....	26
6.6 Voltage drops in transformers and reactors .....	27
6.6.1 General .....	27
6.6.2 Transductors .....	28
7 Tests for converter transformers .....	29
7.1 General .....	29
7.2 Measurement of commutating reactance and determination of the inductive voltage drop .....	30
7.2.1 Commutating reactance .....	30
7.2.2 Inductive voltage regulation.....	30
7.3 Measurement of voltage ratio and phase displacement.....	31
7.4 Dielectric tests.....	31

7.4.1	General .....	31
7.4.2	Dielectric test between interleaved valve windings .....	31
7.5	Load loss test .....	32
7.5.1	General .....	32
7.5.2	Load loss measurement in rectifier transformers with transducers in the same tank .....	32
7.5.3	Test bus bars configuration for short circuit of high current valve windings .....	32
7.6	Temperature rise tests .....	32
7.6.1	General .....	32
7.6.2	Total loss injection .....	33
7.6.3	Rated load loss injection .....	33
7.6.4	Test of temperature rise on dry-type transformers .....	35
8	On load noise level with transducers and/or IPT .....	35
Annex A (informative)	Determination of transformer service load loss at rated non-sinusoidal converter current from measurements with rated transformer current of fundamental frequency .....	38
Annex B (informative)	Short-circuit test currents and load losses in transformers for single-way converters (total loss injection) .....	56
Annex C (informative)	Current sharing measurement in high current valve windings .....	57
Annex D (informative)	Examples of duty cycles .....	66
Annex E (informative)	Guidelines for design review .....	67
Annex F (informative)	Determination of loss in transformer tank due to magnetic field. 3D simulation and guidelines for tank losses evaluation and tank hotspot calculation .....	70
Annex G (informative)	Short-circuit measurements of rectifier transformers equipped with built in transducers .....	71
Annex H (informative)	Determination of the transformer voltage ratio and phase displacement by the turn ratio measurements .....	73
Annex I (informative)	Phase displacement connections and terminal indications of converter transformers .....	78
Annex J (normative)	Correlation between IEC 61378-1 and IEC 60146-1-1 ratings .....	83
Bibliography	.....	90
Figure 1	– B6U or DB 6 pulse double bridge connection .....	10
Figure 2	– DSS 6 pulse connection .....	11
Figure 3	– Leakage fields for a three-winding transformer with closely coupled valve windings .....	22
Figure 4	– Leakage fields for a three-winding transformer with decoupled valve windings .....	23
Figure 5	– Leakage fields for a three winding transformer with loosely coupled double concentric valve windings .....	24
Figure 6	– Leakage fields for a three winding transformer with loosely coupled double-tier valve windings .....	25
Figure 7	– Typical transducer regulating curve (with max voltage drop at zero control current) and tolerance band .....	28
Figure A.1	– Cross-section of a winding strand .....	40
Figure A.2	– Terminal identification for winding connection Y y0y6 .....	43
Figure A.3	– Terminal identification for winding connection D d0y1 .....	46



Figure A.4 – Valve current DB connection rectangular shape positive shape .....	47
Figure A.5 – Valve current DB connection rectangular shape positive and negative shape.....	48
Figure A.6 – Valve current DSS connection rectangular shape .....	52
Figure C.1 – Example of valve high current winding and measurement equipment disposition .....	58
Figure C.2 – Transformer windings arrangement .....	59
Figure C.3 – Measurement circuit for the in-phase measurement.....	60
Figure C.4 – Measurement circuit for the in-opposition measurement.....	61
Figure C.5 – Measurements and comparison with the simulations made by finite element method software for the in-phase current distribution.....	63
Figure C.6 – Measurements and comparison with the simulations made by finite element method software for the in-opposition current distribution .....	65
Figure H.1 – Yd1 connection .....	74
Figure H.2 – Yd11 connection .....	74
Figure H.3 – Pd0+7,5 connection.....	75
Figure H.4 – Oscilloscope connection.....	76
Figure H.5 – Oscilloscope with phase B + 7,5° lag referring to phase A.....	76
Figure H.6 – Oscilloscope with phase B – 7,5° lead referring to phase A.....	77
Figure I.1 – Counterclockwise phase displacement.....	78
Figure I.2 – Yd11 connection.....	78
Figure I.3 – Yd1 connection.....	78
Figure I.4 – Example I.1 phase displacement.....	79
Figure I.5 – Example I.2 phase displacement.....	79
Figure J.1 – DB connection ideal rectangular current blocks .....	83
Figure J.2 – DSS Connection rectangular current blocks.....	84
Table 1 – Connections and calculation factors .....	36
Table A.1 – Specified harmonic currents and phase displacement in the valve windings.....	41
Table A.2 – Resistance measurements at 20 °C winding temperature .....	42
Table A.3 – Specified harmonic currents and phase displacement in the line and valve windings.....	45
Table A.4 – Measurements from test report .....	46
Table A.5 – Resulting current harmonics .....	48
Table A.6 – Resulting current harmonics .....	49
Table A.7 – Resulting current harmonics .....	50
Table A.8 – Detailed transformer load losses at rated tap position, with tertiary unloaded.....	51
Table A.9 – Resulting current harmonics .....	52
Table A.10 – Specified harmonic currents and phase displacement in the line and valve windings.....	53
Table A.11 – Resulting current harmonics .....	54
Table A.12 – Detailed transformer load losses at rated tap position, with tertiary unloaded.....	55
Table C.1 – Measurements and comparison with the simulations made by finite element method software for the in-phase current distribution.....	62

Table C.2 – Measurements and comparison with the simulations made by finite element method software for the in-opposition current distribution .....	64
Table D.1 – Examples of duty cycles for different applications .....	66
Table H.1 – Single phase ratio measurements.....	73
Table J.1 – Harmonics content up to 25 <sup>th</sup> in DB 6 pulse connection (ideal rectangular current waveshape).....	84
Table J.2 – Harmonics content up to 25 <sup>th</sup> in DSS 6 pulse connection (ideal rectangular current waveshape).....	85
Table J.3 – Calculation factor comparison example .....	86
Table J.4 – Calculation factor comparison general factors .....	87

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

### **CONVERTER TRANSFORMERS –**

#### **Part 1: Transformers for industrial applications**

### **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 61378-1 has been prepared by IEC technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 1997. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- addition of winding connections (zig-zag, extended delta, etc.) with phase displacement ( $<30^\circ$ );
- addition of transformers with more than one active part in the same tank;
- change of reference power definition (it is now based on fundamental component of the current);
- addition of considerations for guidelines for OLTC selection;
- addition of regulating transformer feeding converter transformer;

**I.S. EN 61378-1:2011**

61378-1 © IEC:2011(E)

– 7 –

- addition of considerations about current sharing and hot spot temperature in high current windings for various winding arrangements;
- addition of transducers used for d.c. voltage regulation together with diode rectifiers;
- improved old annexes with several calculation examples;
- addition of new annexes for special measurements setups.

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

FDIS	Report on voting
14/686/FDIS	14/695/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 61378 series can be found, under the general title *Converter 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.

A bilingual version of this standard may be issued at a later date.

**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.**

## CONVERTER TRANSFORMERS –

### Part 1: Transformers for industrial applications

#### 1 Scope

This Part of IEC 61378 deals with the specification, design and testing of power transformers and reactors which are intended for integration within semiconductor converter plants; it is not applicable to transformers designed for industrial or public distribution of a.c. power in general.

The scope of this International Standard is limited to application of power converters of any power rating. Typical applications are: thyristor rectifiers for electrolysis; diode rectifiers for electrolysis; thyristor rectifiers for large drives; thyristor rectifiers for scrap melting furnaces, and diode rectifiers feeding inverters for variable speed drives. The standard also covers the regulating unit utilized in such application as step down regulating transformers or autotransformers. The valve winding highest voltage for equipment is limited to 36 kV.

This standard is not applicable to transformers for HVDC power transmission. These are high-voltage transformers, and they are subjected to d.c. voltage tests.

The standards for the complete converter plant (IEC 60146 series, or other publications dedicated to particular fields of application) may contain requirements of guarantees and tests (such as insulation and power loss) for the whole plant, including the converter transformer and possibly auxiliary transformers and reactor equipment. This does not relieve the application of the requirements of this standard concerning the guarantees and tests applicable to the converter transformer itself as a separate component before being assembled with the remainder of the converter plant.

The guarantees, service and type tests defined in this standard apply equally to transformers supplied as part of an overall converter package, or to those transformers ordered separately but for use with converter equipment. Any supplementary guarantee or special verification has to be specifically agreed in the transformer contract.

The converter transformers covered by this standard may be of the oil-immersed or dry-type design. Unless specific exceptions are stated in this standard, the transformers comply with IEC 60076 series for oil-immersed transformers, and with IEC 60076-11 for dry-type transformers.

**NOTE** For some converter applications, it is possible to use common distribution transformers of standard design. The use of such standard transformers in the special converter applications may require a certain derating. This matter is not specifically covered in this standard, which deals with the requirements to be placed on specially designed units. It is possible to estimate this derating from the formulae given in 5.1, and also from Clause 9 of IEC 60076-8:1997.

This standard deals with transformers with one or more active parts installed in the same tank like regulating (auto)transformer and one or two rectifier transformers. It also covers transformers with transducers and/or one or more interphase transformers.

For any combination not listed above an agreement between the purchaser and manufacturer is necessary regarding the determination and the measurement of the total losses.

This standard deals with transformers star Y and delta D and any other phase shifting connections (like zig-zag, extended delta, polygon etc.). Phase shifting windings can be placed on either the regulating or rectifier transformer.

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
-