

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Converter transformers –
Part 1: Transformers for industrial applications**

**Transformateurs de conversion -
Partie 1: Transformateurs pour applications industrielles**

This is a preview. [Click here to purchase the full publication.](#)



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2011 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Converter transformers –
Part 1: Transformers for industrial applications**

**Transformateurs de conversion -
Partie 1: Transformateurs pour applications industrielles**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XC

ICS 29.180

ISBN 978-2-8322-1698-9

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

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 th in DB 6 pulse connection (ideal rectangular current waveshape).....	84
Table J.2 – Harmonics content up to 25 th 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 bilingual version (2014-07) corresponds to the English version, published in 2011-07.

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;
- 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.

The French version of this standard has not been voted upon.

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.

The contents of the corrigendum of January 2012 have been included in this copy.

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.