



IEEE

IEC/IEEE 60076-57-129

Edition 1.0 2017-11

INTERNATIONAL STANDARD

**Power transformers –
Part 57-129: Transformers for HVDC applications**





THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2017 IEC, Geneva, Switzerland
Copyright © 2017 IEEE

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 being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

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

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue
New York, NY 10016-5997
United States of America
stds.ipr@ieee.org
www.ieee.org

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 the IEEE

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

About IEC/IEEE publications

The technical content of IEC/IEEE publications is kept under constant review by the IEC and IEEE. Please make sure that you have the latest edition, a corrigendum 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 It also gives information on projects, replaced and withdrawn publications.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 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 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.



IEEE

IEC/IEEE 60076-57-129

Edition 1.0 2017-11

INTERNATIONAL STANDARD

**Power transformers –
Part 57-129: Transformers for HVDC applications**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.180

ISBN 978-2-8322-4447-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
2.1 IEC references.....	8
2.2 IEEE references.....	9
3 Terms, definitions and symbols.....	9
3.1 Terms and definitions.....	9
3.2 Symbols.....	10
4 Use of normative references.....	11
5 General requirements	11
5.1 General.....	11
5.2 Service conditions.....	11
5.2.1 General	11
5.2.2 Temperature.....	11
5.2.3 Load current	11
5.2.4 AC voltage.....	11
5.2.5 Direction of power flow	11
5.3 Unusual service conditions	12
5.4 Loading of transformer above rating.....	12
6 Rating data.....	12
6.1 General.....	12
6.2 Rated voltage	12
6.3 Rated current.....	12
6.4 Rated frequency	12
6.5 Rated power	12
7 Losses.....	13
7.1 General.....	13
7.2 No-load loss.....	13
7.3 Load loss under rated frequency conditions	13
7.4 Load loss under service conditions	13
7.5 Determination of hot-spot temperature	14
8 Test requirements	15
8.1 General.....	15
8.1.1 Routine tests	15
8.1.2 Type tests.....	15
8.1.3 Special tests.....	15
8.1.4 Commissioning tests.....	15
8.2 Test applicability.....	16
8.2.1 General	16
8.2.2 DC withstand voltage test.....	16
8.2.3 Polarity reversal test.....	16
8.2.4 AC applied withstand test for valve side winding(s).....	16
8.3 Dielectric test voltage levels	17
8.3.1 Line windings.....	17
8.3.2 Valve windings	17
8.4 Induced voltage level with partial discharge measurement	18

9	Tests	18
9.1	General	18
9.1.1	Applicable tests	18
9.1.2	Test sequence	18
9.1.3	Ambient temperature	18
9.1.4	Assembly	18
9.1.5	Converter transformers for connection to gas-insulated equipment	19
9.2	Load loss and impedance measurements	19
9.2.1	General	19
9.2.2	Calculation procedure	19
9.3	Switching impulse test	20
9.4	Applied switching impulse test on the valve side winding	20
9.5	Lightning impulse tests	20
9.6	DC withstand voltage test	20
9.6.1	Applicability	20
9.6.2	Transformer test temperature	20
9.6.3	Polarity	20
9.6.4	Test procedure	21
9.6.5	Acceptance criteria	21
9.7	Polarity reversal test	21
9.7.1	Applicability	21
9.7.2	Transformer test temperature	21
9.7.3	Test procedure	21
9.7.4	Acceptance criteria	22
9.8	Extended polarity-reversal test	23
9.8.1	Applicability	23
9.8.2	Transformer test temperature	23
9.8.3	Test procedure	23
9.8.4	Acceptance criteria	25
9.9	AC applied voltage test for valve side winding(s)	25
9.9.1	Test procedure	25
9.9.2	Acceptance criteria	25
9.10	AC applied voltage test on line side winding(s)	25
9.11	AC induced voltage test with partial discharge measurement	26
9.11.1	General	26
9.11.2	Acceptance criteria	26
9.12	Induced voltage test including running of oil pumps	26
9.13	Temperature-rise test	26
9.13.1	General	26
9.13.2	Test procedure	27
9.13.3	Tank surface temperature rise measurement	28
9.14	Load current test	28
9.15	Sound level measurement	28
9.16	Insulation power-factor test	29
9.17	Winding insulation resistance test	29
9.18	Core insulation resistance test	29
9.19	Short-circuit test	29
9.20	Frequency Response Analysis (FRA) measurements	29
9.21	Over-excitation test	29

10	Dielectric tests on transformers that have been in service	29
11	Sound levels.....	30
11.1	General.....	30
11.2	Determination of service sound levels	30
11.3	Guaranteed sound levels	30
12	Bushings	30
12.1	General.....	30
12.2	Line side winding bushings	31
12.3	Valve side winding bushings	31
13	Tap-changer.....	31
13.1	General.....	31
13.2	Current wave shape.....	31
13.3	Consecutive operation of tap-changers	31
14	High-frequency modelling	31
15	Tolerances	32
15.1	General.....	32
15.2	Short-circuit impedance tolerances	32
16	Rating plate.....	32
	Annex A (informative) In service overloading of HVDC converter transformers used with current commutated valves (either mercury arc valves or thyristors).....	34
A.1	General.....	34
A.2	Overloading in service	34
A.3	Temperature rise test for demonstrating normal loading condition.....	36
A.4	Temperature rise test for demonstrating planned overload conditions	36
	Annex B (informative) HVDC converter transformers for use with voltage source converters	38
B.1	General.....	38
B.2	Converter transformer stressed with only fundamental voltage and current.....	38
B.3	Converter transformer stressed with direct voltage, fundamental voltage and fundamental current	39
B.4	Converter transformer stressed with the valves connected directly to the converter transformer.....	40
B.5	Summary of stresses	41
	Annex C (informative) Design review	42
C.1	General.....	42
C.2	Topics.....	42
	Annex D (informative) Transformer specification content	44
D.1	General.....	44
D.2	Data to be provided by the purchaser.....	44
D.3	Data to be provided by the manufacturer.....	45
	Annex E (informative) Audible sound of converter transformers	47
E.1	General.....	47
E.2	Technical reference	47
E.3	Current harmonics	47
E.4	Voltage harmonics	47
E.5	DC bias current.....	48
E.6	Derivation of service sound power levels	48
E.7	Sound level guarantee	48

Annex F (informative) Determination of transformer service load loss at rated non-sinusoidal converter current from measurements with rated transformer current of fundamental frequency	49
F.1 General.....	49
F.2 Alternative method for calculation of the winding eddy loss enhancement factor	50
Bibliography.....	52
Figure 1 – Double reversal test voltage profile	22
Figure 2 – Extended polarity reversal test alternative 1	24
Figure 3 – Extended polarity reversal test alternative 2.....	4
Figure A.1 – Example of an overload diagram.....	36
Figure B.1 – Configuration with no additional stresses on the converter transformer	39
Figure B.2 – Configuration with multi-level VSC HVDC converter station applied in a monopolar scheme with DC overhead line transmission	40
Figure B.3 – Configuration with VSC valves connected directly to the converter transformer	41
Figure F.1 – Cross-section of a winding strand	51
Table 1 – Routine, type and special tests.....	15
Table A.1 – Example of an overload table	35

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 57-129: Transformers for HVDC 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.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).*

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions 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. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in recommending the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in this sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE 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 (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are 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 IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, 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/IEEE Publication or any other IEC or IEEE 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 implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC/IEEE 60076-57-129 has been prepared by IEC technical committee 14: Power transformers, in cooperation with the Transformers Committee of the IEEE Power & Energy Society¹, under the IEC/IEEE Dual Logo Agreement.

This publication cancels and replaces the first edition of IEC 61378-2 published in 2001 and IEEE Std C57.129™ published in 2007.

This publication is published as an IEC/IEEE Dual Logo standard.

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

FDIS	Report on voting
14/904/FDIS	14/907/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.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of parts of the 60076 International Standard, published under the general title *Power transformers*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the sustaining date indicated on the IEC website 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 publication may be issued at a later date.

¹ A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/60076/60076-57-129-2017/60076-57-129-2017_wg-participants.pdf

POWER TRANSFORMERS –

Part 57-129: Transformers for HVDC applications

1 Scope

This part of 60076 International Standard specifies requirements of liquid-immersed three-phase and single-phase converter transformers for use in high voltage direct current (HVDC) power transmission systems including back-to-back applications. It applies to transformers having two, three or multiple windings.

This document does not apply to

- converter transformers for industrial applications (see IEC 61378-1 or IEEE Std C57.18.10);
- converter transformers for traction applications (see IEC 60310).

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.

2.1 IEC references

IEC 60050-421, *International Electrotechnical Vocabulary – Chapter 421: Power transformers and reactors* (available at <http://www.electropedia.org>)

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 60076-18, *Power transformers – Part 18: Measurement of frequency response*

IEC 60076-10, *Power transformers – Part 10: Determination of sound levels*

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

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

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

IEC/IEEE 65700-19-03, *Bushings for DC application*