

This is a preview - click here to buy the full publication



IEEE

IEC/IEEE 60076-16

Edition 2.0 2018-09
REDLINE VERSION

INTERNATIONAL STANDARD



**Power transformers –
Part 16: Transformers for wind turbine applications**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.180; 29.180

ISBN 978-2-8322-6094-4

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

CONTENTS

FOREWORD.....	4
INTRODUCTION.....
1 Scope.....	8
2 Normative references.....	8
2.1 IEC references.....	8
2.2 IEEE references.....	9
2.3 ISO references.....	9
2.4 CENELEC references.....	9
3 Terms and definitions.....	9
4 Use of normative references.....	10
5 Rating.....	10
6 Service conditions.....	11
6.1 Normal service conditions.....	11
6.1.1 General.....	11
Altitude.....
6.1.2 Temperature of external cooling- air medium.....	11
6.2 Particular service conditions for transformers installed in a tower or nacelle.....	11
6.2.1 General.....	11
6.2.2 Temperature rise correction.....	12
6.3 Content of harmonic currents in the transformer.....	13
Wave-shape of supply voltage.....
6.4 Over-excitation.....	14
6.5 Harmonic distortion of voltage.....	14
6.6 Transient- over and under voltages.....	14
6.7 Humidity and salinity.....	15
Special electrical and environmental conditions around the transformer.....	0
6.8 Level of vibration.....	16
Provision for unusual service conditions for transformers for wind turbine applications.....
Transportation and storage conditions.....
6.9 Corrosion protection.....	17
6.10 Consideration for hermetically sealed transformers.....	17
6.11 Flammability issues with transformers mounted in the tower or nacelle.....	17
6.12 Thermal cycling of transformer.....	17
7 Electrical characteristics.....	17
Rated power.....
7.1 Highest voltage for equipment.....	18
7.2 Tappings (tap-changer).....	18
7.3 Connection group.....	18
7.4 Dimensioning of neutral- terminal connection.....	18
7.5 Short-circuit impedance.....	18
7.6 Insulation levels for high- voltage and low voltage windings.....	19
Temperature rise guaranteed at rated conditions.....
7.7 Overload capability.....	19
7.8 Inrush current.....	20

7.9	Frequency of energization	20
7.10	Ability to withstand short circuit	20
7.11	Operation with forced cooling	20
7.12	Over-temperature protection	21
8	Rating plate	21
9	Tests	21
9.1	List and classification of tests (routine, type and special tests)	21
	Routine tests	
	Type tests	
	Special tests	
	 General	
	 Chopped wave test	
	 Electrical resonance frequency test	
	 Climatic tests	
	 Environmental test E3	
	 Fire behavior test	
9.2	Additional tests for wind turbine transformers	23
9.2.1	General	23
9.2.2	Lightning impulse type tests	23
9.2.3	Lightning impulse routine sample tests	23
9.2.4	Partial discharge test for liquid-immersed transformers	23
9.2.5	Climatic and environmental tests for dry-type transformers	23
	Annex A (informative) Calculation method and tables	
	Annex A (informative) Effects of voltage harmonics	44
A.1	Design and specification considerations	44
A.2	Effects of voltage harmonics	44
	Bibliography	47
	Figure – Heat dissipation in a natural ventilated room	
	Figure – Schematic diagram of power frequency current injection apparatus	
	Figure – Switched transformer winding voltage responses with capacitor injection	
	Figure – HV Injection test figure	
	Figure – Example of measurement device	
	Table – Insulation levels	
	Table 1 – Recommended minimum values of short-circuit impedance for transformers with two separate windings	19
	Table – Impact of harmonics content on liquid-immersed transformer losses	
	Table – Impact of harmonics content on dry type transformers losses	
	Table A.1 – Example of voltage harmonic order	45

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 16: Transformers for wind turbine 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 reviewing 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 that 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.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC/IEEE 60076-16 has been prepared by IEC technical committee 14: Power transformers, in cooperation with Performance Characteristics Subcommittee of the IEEE Power and Energy Society ¹, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

This second edition of IEC/IEEE 60076-16 cancels and replaces IEC 60076-16:2011, and constitutes a technical revision.

The main changes with respect to the previous edition are as follows:

- 1) relationship between transformer rated power and the output current from the associated generator is introduced;
- 2) thermal correction of the effective cooling medium has been introduced;
- 3) testing regime has been strengthened to ensure transformers are suitable for the harsh electrical environment to which they are subjected.

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
14/959/FDIS	14/965/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 all parts in the IEC/IEEE 60076 series, published under the general title *Power transformers*, can be found on the IEC website.

¹ A list of IEEE participants can be found at the following URL: <https://standards.ieee.org/project/60076-16.html>

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability 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.

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 publication using a colour printer.

INTRODUCTION

~~This part of IEC 60076 is intended to specify the additional requirements for the transformers for installation in wind turbine applications.~~

~~Wind turbines use generator step-up transformers to connect the turbines to a network. These transformers can be installed in the nacelle or in the tower or outside close to the wind turbine.~~

~~This standard covers transformers for wind turbine applications or wind farms where the constraints on transformers exceed the requirement of the present IEC 60076 series. The constraints are not often known or recognized by the transformer manufacturers, wind turbine manufacturers and operators and as a result the level of reliability of these transformers can be lower than those used for conventional applications.~~

~~The transformers for wind turbine applications are not included in the present list of IEC 60076 standard series.~~

~~The purpose of this standard is help to obtain the same level of reliability as transformers for more common applications.~~

~~This standard deals particularly with the effects of repeated high frequency transient over-voltages, electrical, environmental, thermal, loading, installation and maintenance conditions that are specific for wind turbines or wind farms.~~

~~On site measurements, investigations and observations in wind turbines have detected risks for some different kind of installations:~~

- ~~— repeated high frequency transient over or under voltages in the range of kHz;~~
- ~~— over and under frequency due to turbine control;~~
- ~~— values of over voltage;~~
- ~~— over voltage or under voltage coming from LV side;~~
- ~~— high level of transient over voltages due to switching;~~
- ~~— presence of partial discharge around the transformer;~~
- ~~— harmonic contents current and voltage;~~
- ~~— overloading under ambient conditions;~~
- ~~— fast transient overload;~~
- ~~— clearances not in compliance with the minimum prescribed;~~
- ~~— installation conditions and connections;~~
- ~~— restricted conditions of cooling;~~
- ~~— water droplets;~~
- ~~— humidity levels that exceed the maximum permissible values;~~
- ~~— salt and dust pollution and extreme climatic conditions;~~
- ~~— high levels of vibration;~~
- ~~— mechanical stresses.~~

~~Therefore it is necessary to take into account in the design of the transformer the constraints of this application, or to define some protective devices to protect the transformer. Additional or improved routine, type or special tests for these transformers have to be specified to be in compliance with the constraints on the network.~~

POWER TRANSFORMERS –

Part 16: Transformers for wind turbine applications

1 Scope

This part of IEC 60076 applies to dry-type and liquid-immersed transformers for ~~rated power 100 kVA up to 10 000 kVA for~~ wind turbine step-up applications having a winding with highest voltage for equipment up to and including ~~36 72,5 kV and at least one winding operating at a voltage greater than 1,1 kV~~. This document applies to the transformer used to connect the wind turbine generator to the wind farm power collection system or adjacent distribution network and not the transformer used to connect several wind turbines to a distribution or transmission network.

Transformers covered by this document comply with the relevant requirements prescribed in the IEC 60076 standards or IEEE C57 standards.

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 60076-1:~~2011~~, *Power transformers – Part 1: General*

IEC 60076-2:~~2011~~, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3:~~2000~~, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5:~~2006~~, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-7:~~2005~~, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

~~IEC 60076-8:1997, Power transformers – Application guide~~

IEC 60076-11:~~2004~~, *Power transformers – Part 11: Dry-type transformers*

IEC 60076-12:~~2008~~, *Power transformers – Part 12: Loading guide for dry-type power transformers*

~~IEC 60076-13:2006, Power transformers – Part 13: Self-protected liquid-filled transformers~~

IEC 60076-14, *Power transformers – Part 14: Liquid-immersed power transformers using high-temperature insulating materials*

~~IEC 61100, Classification of insulating liquids according to fire-point and net calorific value~~

IEC 61378-1:2014, *Converter transformers – Part 1: Transformers for industrial applications*

~~IEC 61378-3:2006, *Converter transformers – Part 3: Application guide*~~

~~IEC 61400-1:2005, *Wind turbines – Part 1: Design requirements*~~

2.2 IEEE references

IEEE Std C57.12.00™, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.01™, *IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers*

IEEE Std C57.12.80™, *IEEE Standard Terminology for Power and Distribution Transformers*

IEEE Std C57.91™, *IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators*

IEEE Std C57.96™, *IEEE Guide for Loading Dry-Type Distribution and Power Transformers*

IEEE Std C57.110™, *IEEE Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*

IEEE Std C57.154™, *IEEE Standard for the Design, Testing, and Application of Liquid-Immersed Distribution, Power, and Regulating Transformers Using High-Temperature Insulation Systems and Operating at Elevated Temperatures*

ANSI C84.1, *Electric Power Systems and Equipment – Voltage Ratings (60 Hz)*

2.3 ISO references

ISO 12944 (all parts), *Paints and varnishes – Corrosion protection of steel structures by protective paint systems*

ISO 12944-4, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 4: Types of surface and surface preparation*

2.4 CENELEC references

EN 50588-1:2015, *Medium power transformers 50 Hz, with highest voltage for equipment not exceeding 36 kV – Part 1: General requirements*

This is a preview - click here to buy the full publication



IEEE

IEC/IEEE 60076-16

Edition 2.0 2018-09

INTERNATIONAL STANDARD

**Power transformers –
Part 16: Transformers for wind turbine applications**



CONTENTS

FOREWORD.....	4
1 Scope.....	6
2 Normative references	6
2.1 IEC references.....	6
2.2 IEEE references.....	6
2.3 ISO references.....	7
2.4 CENELEC references	7
3 Terms and definitions	7
4 Use of normative references	8
5 Rating.....	8
6 Service conditions	8
6.1 Normal service conditions	8
6.1.1 General	8
6.1.2 Temperature of external cooling medium	8
6.2 Particular service conditions for transformers installed in a tower or nacelle	9
6.2.1 General	9
6.2.2 Temperature rise correction.....	9
6.3 Content of harmonic currents in the transformer.....	10
6.4 Over-excitation	11
6.5 Harmonic distortion of voltage.....	11
6.6 Transient voltages	11
6.7 Humidity and salinity.....	11
6.8 Level of vibration	12
6.9 Corrosion protection	12
6.10 Consideration for hermetically sealed transformers	12
6.11 Flammability issues with transformers mounted in the tower or nacelle	12
6.12 Thermal cycling of transformer.....	12
7 Electrical characteristics.....	12
7.1 Highest voltage for equipment.....	12
7.2 Tappings (tap-changer).....	12
7.3 Connection group.....	13
7.4 Dimensioning of neutral connection	13
7.5 Short-circuit impedance	13
7.6 Insulation levels for high and low voltage windings	13
7.7 Overload capability	13
7.8 Inrush current	14
7.9 Frequency of energization.....	14
7.10 Ability to withstand short circuit.....	14
7.11 Operation with forced cooling.....	14
7.12 Over-temperature protection	14
8 Rating plate.....	14
9 Tests	15
9.1 List and classification of tests (routine, type and special tests).....	15
9.2 Additional tests for wind turbine transformers.....	15

9.2.1	General	15
9.2.2	Lightning impulse type tests.....	15
9.2.3	Lightning impulse routine sample tests	15
9.2.4	Partial discharge test for liquid-immersed transformers.....	15
9.2.5	Climatic and environmental tests for dry-type transformers	15
Annex A (informative) Effects of voltage harmonics		16
A.1	Design and specification considerations.....	16
A.2	Effects of voltage harmonics	16
Bibliography.....		19

Table 1 – Recommended minimum values of short-circuit impedance for transformers with two separate windings	13
---	----

Table A.1 – Example of voltage harmonic order	17
---	----

INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER TRANSFORMERS –

Part 16: Transformers for wind turbine 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 reviewing 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 that 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 60076-16 has been prepared by IEC technical committee 14: Power transformers, in cooperation with Performance Characteristics Subcommittee of the IEEE Power and Energy Society ¹, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

This second edition of IEC/IEEE 60076-16 cancels and replaces IEC 60076-16:2011, and constitutes a technical revision.

The main changes with respect to the previous edition are as follows:

- 1) relationship between transformer rated power and the output current from the associated generator is introduced;
- 2) thermal correction of the effective cooling medium has been introduced;
- 3) testing regime has been strengthened to ensure transformers are suitable for the harsh electrical environment to which they are subjected.

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
14/959/FDIS	14/965/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 all parts in the IEC/IEEE 60076 series, 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 stability 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: <https://standards.ieee.org/project/60076-16.html>

POWER TRANSFORMERS –

Part 16: Transformers for wind turbine applications

1 Scope

This part of IEC 60076 applies to dry-type and liquid-immersed transformers for wind turbine step-up applications having a winding with highest voltage for equipment up to and including 72,5 kV. This document applies to the transformer used to connect the wind turbine generator to the wind farm power collection system or adjacent distribution network and not the transformer used to connect several wind turbines to a distribution or transmission network.

Transformers covered by this document comply with the relevant requirements prescribed in the IEC 60076 standards or IEEE C57 standards.

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

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

IEC 60076-3, *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 60076-7, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60076-12, *Power transformers – Part 12: Loading guide for dry-type power transformers*

IEC 60076-14, *Power transformers – Part 14: Liquid-immersed power transformers using high-temperature insulating materials*

IEC 61378-1, *Converter transformers – Part 1: Transformers for industrial applications*

2.2 IEEE references

IEEE Std C57.12.00™, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.01™, *IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers*

IEC/IEEE 60076-16:2018

– 7 –

© IEC/IEEE 2018

IEEE Std C57.12.80™, *IEEE Standard Terminology for Power and Distribution Transformers*

IEEE Std C57.91™, *IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators*

IEEE Std C57.96™, *IEEE Guide for Loading Dry-Type Distribution and Power Transformers*

IEEE Std C57.110™, *IEEE Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*

IEEE Std C57.154™, *IEEE Standard for the Design, Testing, and Application of Liquid-Immersed Distribution, Power, and Regulating Transformers Using High-Temperature Insulation Systems and Operating at Elevated Temperatures*

ANSI C84.1, *Electric Power Systems and Equipment – Voltage Ratings (60 Hz)*

2.3 ISO references

ISO 12944 (all parts), *Paints and varnishes – Corrosion protection of steel structures by protective paint systems*

ISO 12944-4, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 4: Types of surface and surface preparation*

2.4 CENELEC references

EN 50588-1:2015, *Medium power transformers 50 Hz, with highest voltage for equipment not exceeding 36 kV – Part 1: General requirements*