IEC/IEEE 60076-16

Edition 2.0 2018-09

INTERNATIONAL STANDARD

Power transformers –
Part 16: Transformers for wind turbine applications

iTeh STANDARD PREVIEW
(standards.iteh.ai)

IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

IEC/IEEE 60076-16:2018-09(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2018 IEC, Geneva, Switzerland
Copyright © 2018 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 Varembé
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
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 - webstore.iec.ch/advsearchform
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 It also gives information on projects, replaced and withdrawn publications.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 21 000 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
67 000 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: sales@iec.ch.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1e51ae0c-6d37-4b91-b82b-b08d02e262ad/iec-ieee-60076-16-2018

IEC/IEEE 60076-16

Edition 2.0 2018-09

INTERNATIONAL STANDARD

Power transformers –
Part 16: Transformers for wind turbine applications

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.180; 29.180

ISBN 978-2-8322-5807-1

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

® Registered trademark of the International Electrotechnical Commission

CONTENTS

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ee1ac6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/10d7b6b6-0cd7-4b63-9b2b-b98d02e26ed4/iec-ieee-60076-16-2018

© IEC/IEEE 2018

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)

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.

IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

2.1 IEC references

IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

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*

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*

iTeh STANDARD PREVIEW
(standards.iteh.ai)

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*

IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
wind turbine transformer
generator step up transformer connecting the wind turbine to the power collection system of the wind farm or the adjacent distribution network for single turbine installations

3.2
tower
supporting structure of the wind turbine on top of which the nacelle with generator and other equipment is located

3.3
nacelle
housing that contains the drive-train and other elements on top of a horizontal-axis wind turbine tower

[SOURCE: IEC 60050-415:1999, 415-01-07]

3.4
effective cooling medium
ambient air, either internal or external to the tower or nacelle, or cooling water that comes into contact with the cooling surface of the transformer

3.5
compartmentalized type transformer
transformer with integral enclosure comprised of multiple independent compartments, usually with separate entrances into the HV and LV termination compartments

3.6
sealed transformer
transformer which is so constructed that the external atmosphere is not intended to gain access to the interior

3.7
routine sample test
test which is usually defined as a type test or special test but carried out as an additional routine test on a random sample of transformers

4 Use of normative references

This standard can be used with either the IEC or IEEE normative references but the references shall not be mixed. The purchaser shall include in the enquiry and order which normative references are to be used. If the choice of normative references is not specified, then IEC standards shall be used except for wind turbine transformers intended for installation in North America where IEEE standards shall be used.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/1ce1ae6c-6d57-4b63-b82b-b08d02e262ed/iec-ieee-60076-16-2018

5 Rating

The transformer rating specified by the purchaser shall take into account the maximum current delivered to the transformer by the associated wind turbine generator system irrespective of the operating voltage and power factor.

6 Service conditions

6.1 Normal service conditions

6.1.1 General

The normal service conditions detailed in IEC 60076-1 or IEEE Std C57.12.00 for liquid-immersed transformers or the normal service conditions in IEC 60076-11 or IEEE Std C57.12.01 for dry-type transformers shall apply unless otherwise stated in this document or specified by the purchaser.

6.1.2 Temperature of external cooling medium

If the transformer is installed external to the tower or nacelle, the normal conditions specified in IEC 60076-1 or IEEE Std C57.12.00 for liquid-immersed transformers and IEC 60076-11 or IEEE Std C57.12.01 for dry-type transformers shall apply, unless otherwise specified. If the transformer is installed within the tower or nacelle then particular conditions apply as shown in 6.2.

6.2 Particular service conditions for transformers installed in a tower or nacelle

6.2.1 General

Where the transformer is installed in a tower or nacelle then higher temperatures of the cooling medium local to the transformer may be expected.

6.2.2 Temperature rise correction

Based on the ambient conditions of the installation, the purchaser shall specify the yearly average and maximum temperature of the effective cooling medium (e.g. air or water). If the yearly average or maximum temperature of the cooling medium exceeds the relevant value in the respective standard, the difference between the values and the "normal service conditions" values shall be subtracted from the temperature rise limits specified in IEC 60076-2, IEC 60076-11 or IEEE Std C57.12.00 as follows:

$$K_{\text{max}} = T_{\text{max ecm}} - T_{\text{max std}}$$

$$K_{\text{av}} = T_{\text{av ecm}} - T_{\text{av std}}$$

where

K_{max} is the temperature correction for the maximum ambient temperature;

K_{av} is the temperature correction for the yearly average ambient temperature;

$T_{\text{max ecm}}$ is the maximum temperature of the effective cooling medium;

$T_{\text{max std}}$ is the maximum ambient temperature of the effective cooling medium according to the relevant standard;

$T_{\text{av ecm}}$ is the average temperature of the effective cooling medium;

$T_{\text{av std}}$ is the yearly average ambient temperature of the effective cooling medium according to the relevant standard.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC/IEEE 60076-16:2018
https://standards.iteh.ai/catalog/standards/sist/fcc1ae6c-6457-4b63-b82b-b08d02c262ed/iec-ieee-60076-16-2018

K_{av} can be used in determining the temperature rise limit of average winding and winding hot-spot temperatures in all transformers. In liquid-immersed transformers K_{max} can be used in determining the temperature rise limit for the top liquid temperature.

If the only available information is the maximum ambient temperature, the increase of the yearly average ambient temperature can be assumed to be the same as the increase of the maximum ambient temperature, making K_{av} and K_{max} equal.

For example, for a transformer using insulation material of thermal class 105 (regular kraft paper immersed in mineral oil) installed in an environment where the average temperature is 32 °C and the maximum ambient temperature is 48 °C, the corrected temperature rise limits based on IEC 60076-2 would be:

$$K_{\text{av}} = (32 - 20) = 12 \text{ K}$$

$$\Delta\theta_{\text{w}} = 65 - K_{\text{av}} = 65 - 12 = 53 \text{ K}$$

$$\Delta\theta_{\text{h}} = 78 - K_{\text{av}} = 78 - 12 = 66 \text{ K}$$

For liquid-immersed transformers K_{max} can be applied:

$$K_{\text{max}} = (48 - 40) = 8 \text{ K}$$