IEEE STANDARDS ASSOCIATION

IEEE Guide for Determination of Hottest-Spot Temperature in Dry-Type Transformers

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C57.134™-2013
(Revision of
IEEE Std C57.134-2000)

IEEE Std C57.134™-2013
(Revision of
IEEE Std C57.134-2000)

IEEE Guide for Determination of Hottest-Spot Temperature in Dry-Type Transformers

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

Approved 11 December 2013

IEEE-SA Standards Board

Abstract: Methodologies for determination of the steady-state winding hottest-spot temperature in dry-type distribution and power transformers with ventilated, sealed, solid cast, and encapsulated windings built in accordance with IEEE Std C57.12.01™ and IEC 60726 are described in this guide. Converter transformers are not included in this guide.

Keywords: ambient temperature, average winding temperature rise, dry-type transformer, IEEE C57.134, production transformer, prototype transformer, temperature measurement, temperature sensors, transformer model, winding hottest-spot temperature

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-7381-8868-3 STD98506
Print: ISBN 978-0-7381-8869-0 STDPD98506

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. 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 or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON, ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at http://ieeexplore.ieee.org/xpl/standards.jsp or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents 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. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this IEEE guide was completed, the Dry-Type Transformer Hottest-Spot Temperature Working Group had the following membership:

Paulette Payne Powell, *Chair*

Timothy Holdway	Charles Johnson, Jr.	Richard Marek

The following members of the individual balloting committee voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

Samuel Aguirre	Gary Hoffman	Dhiru Patel
I. Antweiler	Timothy Holdway	Wesley Patterson
Javier Arteaga	Philip Hopkinson	Paulette Payne Powell
Robert Ballard	Charles Johnson, Jr.	Brian Penny
Peter Balma	Lars Juhlin	Alvaro Portillo
Barry Beaster	Laszlo Kadar	Lewis Powell
Steven Bezner	John Kay	Iulian Profir
Wallace Binder	Sheldon Kennedy	Jonathan Rickmann
Thomas Bishop	Joseph L. Koepfinger	Pierre Riffon
Thomas Blackburn	Jim Kulchisky	Michael Roberts
Carl Bush	Saumen Kundu	Charles Rogers
Thomas Callsen	John Lackey	Oleg Roizman
Paul Cardinal	Chung-Yiu Lam	John Rossetti
Gary Donner	Aleksandr Levin	Marnie Roussell
Randall Dotson	Richard Marek	Thomas Rozek
Jorge Fernandez Daher	William McBride	Bartien Sayogo
Joseph Foldi	Daniel Mulkey	James Smith
Marcel Fortin	Jerry Murphy	Jerry Smith
Derek Foster	Ryan Musgrave	David Stankes
Frank Gerleve	K. R. M. Nair	Gary Stoedter
Jalal Gohari	Michael Newman	Robert Thompson
Randall Groves	Raymond Nicholas	John Vergis
Ajit Gwal	Lorraine Padden	Tony Weekes
David Harris	Vlad Papp	Matthew Wilkowski
Roger Hayes	Bansi Patel	Jian Yu
Gary Heuston		Waldemar Ziomek

When the IEEE-SA Standards Board approved this guide on 11 December 2013, it had the following membership:

John Kulick, *Chair*
David J. Law, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi	Mark Halpin	Ron Petersen
Peter Balma	Gary Hoffman	Gary Robinson
Farooq Bari	Paul Houzé	Jon Walter Rosdahl
Ted Burse	Jim Hughes	Adrian Stephens
Wael William Diab	Michael Janezic	Peter Sutherland
Stephen Dukes	Joseph L. Koepfinger*	Yatin Trivedi
Jean-Philippe Faure	Oleg Logvinov	Phil Winston
Alexander Gelman		Yu Yuan

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Julie Alessi
IEEE-SA Content Publishing

Erin Spiewak
IEEE-SA Technical Community Programs

Introduction

This introduction is not part of IEEE Std C57.134-2013, IEEE Guide for Determination of Hottest-Spot Temperature in Dry-Type Transformers.

The hottest-spot allowance is a number used in industry standards to establish the average temperature rise for rating purposes. The rated ambient temperature and hottest-spot allowance are subtracted from the rated insulation temperature class to determine the average temperature rise to be confirmed by thermal testing.

IEEE Std 1™ states that the value of the hottest-spot allowance is arbitrary, difficult to determine, and depends on many factors, such as size and design of the equipment. Based on the 1944 experimental work of Stewart and Whitman, and Satterlee, standards used a hottest-spot allowance of 30 ºC for 80 ºC average temperature rise. The 30 ºC hottest-spot temperature allowance established in 1944 for 80 ºC average temperature rise was approximately correct for ventilated dry-type transformers produced at that time.

The 220 ºC insulation temperature class, 150 ºC average temperature rise, was initially used in sealed units. For these units, the 30 ºC hottest-spot temperature allowance was probably correct due to operation in the hotter inside gas. The 1959 Loading Guide, ANSI Appendix C57.96, used rated load limiting hottest-spot temperatures to 150 ºC for ventilated units and 220 ºC for sealed units. In 1965, NEMA Standard TR 27 extended the 220 ºC insulation temperature class to ventilated units. In 1974, IEEE Std C57.12.01™ also adopted the 220 ºC insulation temperature class for ventilated units. In both these documents, the 30 ºC hottest-spot allowance for the 220 ºC insulation temperature class was retained. In 1989, IEEE Std C57.12.01™ and the Loading Guide IEEE Std C57.96™ used a constant 30 ºC hottest-spot allowance for all insulation temperature classes and all size transformers. By comparison, IEC 60726 (1982-01) used a variable hottest-spot allowance ranging from 5 ºC to 30 ºC.

The winding hottest-spot temperature rise and average winding temperature rise are related by a ratio that is dependent upon such factors as the following:

a) Turn insulation
b) Winding height
c) Radial build
d) Ventilating ducts

From this relation, it is apparent that no single winding hottest-spot temperature allowance is applicable to all types and ratings of transformers due to the variability of factors affecting the winding hottest-spot temperature. Laboratory test results reported by Pierce in 1993 validate this finding.

As a step to establishing appropriate temperature limits, the Dry-Type Hot-Spot Methodology Working Group members were encouraged to report their findings on winding hottest-spot temperature measurements. The report has confirmed the variability of the winding hottest-spot temperature ratio; however, the quantity of data compiled is insufficient for validation of winding hottest-spot temperature allowance. To aid consistency and repeatability of results, the working group decided to establish a methodology for determination of winding hottest-spot temperature by testing for qualification of a design family or mathematical model, and by testing or calculation for validation of production units.

The working group deemed it impractical to detail winding configurations and possible hottest-spot locations. The manufacturer has the detailed design knowledge and the responsibility for determining the winding hottest-spot rise. When additional information is available, it will be incorporated into future revisions of this guide.

Contents

IEEE Guide for Determination of Hottest-Spot Temperature in Dry-Type Transformers

1. Overview

1.1 Scope

This guide describes methodologies for determination of the steady-state winding hottest-spot temperature in dry-type distribution and power transformers with ventilated, sealed, solid cast, and encapsulated windings built in accordance with IEEE Std C57.12.01™ and IEC 60076-11. Converter transformers are not included in this guide.[1]

1.2 Purpose

Assumptions regarding the relation of winding hottest-spot temperature rise to average winding temperature rise are not representative of all dry-type transformer constructions and winding size. A uniform methodology for determination of winding hottest-spot temperature will provide consistency in testing and calculations for manufacturers' verification of the winding hottest-spot temperature to the user, and for validation and review of winding hottest-spot temperature limits.

[1] Information on references can be found in Clause 2.