

IEEE Guide for Transformers Directly Connected to Generators

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

IEEE Std C57.116™-2014

(Revision of
IEEE Std C57.116-1989)

IEEE Guide for Transformers Directly Connected to Generators

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

Approved 27 March 2014

IEEE-SA Standards Board

Abstract: Information on the selection and application considerations for the unit power transformer and unit auxiliaries power transformer is provided in this guide. Consideration is given to connections that include direct connection and connections through generator circuit breakers and load-break switches. The considerations referred to in this guide apply to hydroelectric and thermal electric generating stations. Various power transformer connections and possible operating problems under normal and abnormal conditions are treated. Phasing procedures, basic impulse insulation level selection, and loading practices are not covered.

Keywords: back-feed, electrical parameters, generator bus, IEEE C57.116™, load tap changing, overcurrent, overexcitation, transformer connections, transmission system, unit auxiliaries, unit power transformer

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

Copyright © 2014 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 27 May 2014. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-0-7381-9098-3 STD98640
Print: ISBN 978-0-7381-9099-0 STDPD98640

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

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 Power Transformers-Directly Connected GSU Working Group had the following membership:

Gary Hoffman, *Chair*
William Griesacker, *Vice Chair*
Randall Kyle, *Secretary*

Mark Baldwin
Peter Balma
Wallace Binder
Michael Botti
James Campbell
John Crouse
Ramsis Girgis
David Harris
Jose Izquierdo
John John

Wayne Johnson
Krzystof Kulasek
Jeffrey LaMarca
John Lackey
Emilio Morales Cruz
Jeffrey Nazarko
Bipin Patel
Jeffrey Ray
Dinesh Sankarakurup

Roderick Sauls
Stephen Schroeder
Ewald Schweiger
Hemchandra Shertukde
Jin H. Sim
Eduardo Tolachir
David Wallach
Joe Watson
Kipp Yule
Richard vonGemmingen

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

Mohamed Abdel Khalek
William Ackerman
Emmanuel Agamloh
Saleman Alibhay
Stephen Antosz
Carlo Arpino
Senthil Kumar Asok Kumar
Peter Balma
Thomas Barnes
Barry Beaster
Robert Beavers
Jeffrey Benach
W. J. (Bill) Bergman
Steven Bezner
Wallace Binder
Thomas Blackburn
W. Boettger
Paul Boman
Kenneth Bow
Derek Brown
Gustavo Brunello
Zeeky Bukhala
Carl Bush
William Byrd
Paul Cardinal
Robert Christman
Craig Colopy
Stephen Conrad
Randall Crellin
John Crouse
Willaim Darovny
Alan Darwin
Glenn Davis

Matthew Davis
Davide De Luca
Scott Digby
Gary Donner
Ahmed Elneweihi
Ahmed ElSerafi
Dan Evans
Jorge Fernandez Daher
Sudath Fernando
Joseph Foldi
Marcel Fortin
Rostyslaw Fostiak
Fredric Friend
Doaa Galal
Robert Ganser
Frank Gerleve
Ali Ghafourian
Alexander Glaninger-Katschnig
James Graham
Stephen Grier
William Griesacker
J. Travis Griffith
Randall Groves
Ajit Gwal
David Harris
Roger Hayes
Lee Herron
Gary Heuston
Werner Hoelzl
Robert Hoerauf
Gary Hoffman
Jill Holmes
Philip Hopkinson

David Horvath
Andrew Jones
Laszlo Kadar
C. Kalra
Gael Kennedy
Sheldon Kennedy
Yuri Khersonsky
James Kinney
Joseph L. Koepfinger
Boris Kogan
Jim Kulchisky
Saumen Kundu
John Lackey
Chung-Yiu Lam
Jeffrey LaMarca
Thomas La Rose
Raluca Lascu
Aleksandr Levin
Albert Livshitz
Thomas Lundquist
Greg Luri
Richard Marek
J. Dennis Marlow
William McBride
William McCown
Michael McDonald
James Mciver
Joseph Melanson
James Michalec
John Miller
T. David Mills
Daniel Mulkey
Jerry Murphy

R. Murphy
Ryan Musgrove
K. R. M. Nair
Michael Newman
Charles Ngethe
Lorraine Padden
Mirko Palazzo
Bansi Patel
Dhiru Patel
Shawn Patterson
Paulette Payne Powell
Brian Penny
Christopher Petrola
Alvaro Portillo
Iulian Profir
John Roach
Michael Roberts
Charles Rogers
Oleg Roizman

John Rossetti
Thomas Rozek
Dinesh Sankarakurup
Steven Sano
Roderick Sauls
Bartien Sayogo
Stephen Schroeder
Robert Seitz
Devki Sharma
Veselin Skendzic
James Smith
Jerry Smith
John Spare
Brian Sparling
Gary Stoedter
James Swank
Michael Thompson
Robert Thornton-Jones
James Timperley
Eduardo Tolcachir

Demetrios Tziouvaras
Joe Uchiyama
Eric Udren
Gerald Vaughn
John Vergis
Jane Verner
David Wallach
William Walter
Barry Ward
Daniel Ward
Joe Watson
Kenneth White
James Wilson
Larry Yonce
Richard Young
Jian Yu
Kipp Yule
Luis Zambrano
Waldemar Ziomek

When the IEEE-SA Standards Board approved this guide on 27 March 2014, it had the following membership:

John Kulick, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Peter Balma
Farooq Bari
Ted Burse
Clint Chaplin
Stephen Dukes
Jean-Philippe Faure
Gary Hoffman

Michael Janezic
Jeffrey Katz
Joseph L. Koepfinger*
David J. Law
Hung Ling
Oleg Logvinov
Ted Olsen
Glenn Parsons

Ron Petersen
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Don Wright
Yu Yuan

*Member Emeritus

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

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

Michelle Turner
IEEE Standards Program Manager, Document Development

Erin Spiewak
IEEE Standards Program Manager, Technical Program Manager

Introduction

This introduction is not part of IEEE Std C57.116™-2014, IEEE Guide for Transformers Directly Connected to Generators.

Transformers, directly connected to generators, experience excitation and short-circuit duties beyond those covered in other power transformer standards. Therefore, in 1979, the IEEE Transformers Committee decided that an application guide for such transformers was needed. In 1989, the IEEE Std C57.116 was approved and describes the selection, application, and specification considerations for the unit and unit auxiliaries transformers taking into account their connections, voltage and kilovolt ampere ratings; and excitation and through-fault capabilities during possible operating conditions, both normal and abnormal. Also included are load-tap changing and isolated phase-bus duct heating considerations. This guide does not address phasing procedures, basic impulse level selection, or loading practices.

In 2011, the IEEE Transformers Committee decided to revise this guide. Therefore, this guide is based on the latest knowledge, design, and application experience of the industry including:

- An updated Equation (1)
- New material on unit auxiliaries transformer faults and calculations
- Expanded guidance on use of isolated phase-bus
- A new clause on unit transformer operation in back-feed configuration
- A new bibliography
- General updates to match the current IEEE Style Manual

This standard is intended to provide guidance to application and specification engineers and therefore its use is strictly voluntary. Its use may become mandatory only when required by a duly constituted legal authority or when specified in a contractual relationship.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
2. Normative references.....	2
3. Definitions	2
4. Background	3
5. Transformer connections	5
5.1 Unit transformer connections	5
5.2 Unit auxiliaries transformer connection.....	5
5.3 Unit transformer and unit auxiliaries transformer external connections	6
6. Selection of parameters of unit transformer	6
6.1 Generator bus electrical characteristics	6
6.2 Transmission system electrical characteristics	10
6.3 Evaluation of parameters for unit transformers	10
6.4 Summary of parameter selection	18
6.5 Spare, leased or alternative unit transformer	19
7. Selection of parameters of unit auxiliaries transformer	20
7.1 DETC voltage rating and tap range	21
7.2 Impedance.....	21
7.3 Megavoltampere rating.....	21
7.4 Phase relationship	21
7.5 Unit auxiliaries transformer loading.....	22
8. Transformer overcurrent considerations	22
8.1 Unit transformer faults.....	22
8.2 Unit auxiliaries transformer faults	22
8.3 Fast load transfer—mechanical considerations.....	25
9. Load tap changing considerations	29
9.1 Load tap changing equipment.....	29
9.2 Duty considerations	30
9.3 Specifications.....	30
10. Transformers with isolated phase-bus duct connections	30
11. UT transformers operated in back-feed configuration	31
11.1 Special transformer considerations.....	32
11.2 Protective relaying considerations	33
11.3 Surge protection considerations	34
Annex A (informative) Bibliography	35

IEEE Guide for Transformers Directly Connected to Generators

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Overview

1.1 Scope

This guide describes selection and application considerations for the unit power transformer and unit auxiliaries power transformer. Consideration is given to connections that include direct connection and connections through generator circuit breakers and load-break switches. The considerations referred to in this guide apply to hydroelectric and thermal electric generating stations. Various power transformer connections and possible operating problems under normal and abnormal conditions are treated. Phasing procedures, basic impulse insulation level selection, and loading practices are not covered.

1.2 Purpose

The terminology, function, application, theory of operation and protection, and design of unit power transformers and unit auxiliaries power transformers are not covered by existing transformer standards and guides. The purpose of this document is to provide guidance for specifying, designing, and applying these types of power transformers.