

IEEE 3000
STANDARDS COLLECTION™

**IEEE 3001 STANDARDS:
POWER SYSTEMS DESIGN**

IEEE Std 3001.5™-2013

IEEE Recommended Practice for the
Application of Power Distribution
Apparatus in Industrial and
Commercial Power Systems



IEEE STANDARDS ASSOCIATION



IEEE Recommended Practice for the Application of Power Distribution Apparatus in Industrial and Commercial Power Systems

Sponsor

**Technical Books Coordinating Committee
of the
IEEE Industry Applications Society**

Approved 11 December 2013

IEEE-SA Standards Board

Abstract: The selection and application of power distribution apparatus used in industrial and commercial power systems are covered in this recommended practice. It is likely to be of greatest value to the power-oriented engineer with limited experience with this equipment. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

Keywords: apparatus, busway, cable systems, circuit breakers, conductors, fuses, IEEE 3001.5™, panelboards, separable insulated connectors, switchboards, switches, switchgear, transformers

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 25 April 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.
National Electrical Safety Code and NESC are both registered trademarks and service marks of The Institute of Electrical and Electronics Engineers, Inc.
National Electrical Code, NEC, and NFPA 70 are registered trademarks of the National Fire Protection Association, Inc.
Teflon, Tefzel, and Hypalon are registered trademarks of DuPont.

PDF: ISBN 978-0-7381-8874-4 STD98509
Print: ISBN 978-0-7381-8875-1 STDPD98509

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 recommended practice was completed, the Power System Design Working Group had the following membership:

Peter Sutherland, *Chair*

Gary H. Fox, *Vice Chair*

Tom Baldwin
Kurt Clemente
Alireza Daneshpooy
Russell Gentile
Manjinder Gill
Alok Gupta
Jim Harvey
Adrienne Hendrickson
Barry Homberger

John Kay
Tanuj Khandelwal
Dave Korpers
Wei-Jen Lee
T. David Mills
Daniel Neeser
Lorraine Padden
Dev Paul

Abraham Pichardo
Louie Powell
Kent Saylor
Shelli Sedlak
Sonny Sengupta
James Smith
Jerry Smith
David Tepen
Steven Townsend

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

William Ackerman
Frederick Brockhurst
William Bush
William Byrd
Paul Cardinal
Kurt Clemente
Larry Conrad
Carey Cook
Glenn Davis
Neal Dowling
Donald Dunn
Dan Evans
Gary H. Fox
Randall Groves
David Harris
Timothy Hayden

Robert Hoerauf
Piotr Karocki
Gael Kennedy
Yuri Khersonsky
Joseph L. Koepfinger
Jim Kulchisky
Saumen Kundu
Ed Larsen
Wei-Jen Lee
Duane Leschert
Omar Mazzoni
William McBride
Donald McCullough
Daniel Neeser
Dennis Neitzel
T. Olsen

Lorraine Padden
Bansi Patel
Howard Penrose
Iulian Profir
Daniel Leland Ransom
Charles Rogers
Bartien Sayogo
Robert Schuerger
Gil Shultz
James Smith
Jerry Smith
Peter Sutherland
David Tepen
John Vergis
Kenneth White
Jian Yu

When the IEEE-SA Standards Board approved this recommended practice 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
Peter Balma
Farooq Bari
Ted Burse
Stephen Dukes
Jean-Philippe Faure
Alexander Gelman

Mark Halpin
Gary Hoffman
Paul Houzé
Jim Hughes
Michael Janezic
Joseph L. Koepfinger*
Oleg Logvinov
Ron Petersen

Gary Robinson
Jon Walter Rosdahl
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
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
Program Manager, IEEE Standards Technical Community Content Publishing

Lisa Perry
Program Manager, IEEE Standards Technical Community

Introduction

This introduction is not part of IEEE Std 3001.5™-2013, IEEE Recommended Practice for the Application of Power Distribution Apparatus in Industrial and Commercial Power Systems.

IEEE 3000 Standards Collection™

This recommended practice was developed by the Technical Books Coordinating Committee of the Industrial and Commercial Power Systems Department of the Industry Applications Society as part of a project to repackage the popular IEEE Color Books®. The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate use of modern publishing and distribution technologies.

When this project is completed, the technical material in the thirteen IEEE Color Books will be included in a series of new standards—the most significant of which will be a new standard, IEEE Std 3000™, IEEE Recommended Practice for the Engineering of Industrial and Commercial Power Systems. The new standard will cover the fundamentals of planning, design, analysis, construction, installation, startup, operation, and maintenance of electrical systems in industrial and commercial facilities. Approximately 60 additional dot standards, organized into the following categories, will provide in-depth treatment of many of the topics introduced by IEEE Std 3000™:

- Power Systems Design (3001 series)
- Power Systems Analysis (3002 series)
- Power Systems Grounding (3003 series)
- Protection and Coordination (3004 series)
- Emergency, Standby Power, and Energy Management Systems (3005 series)
- Power Systems Reliability (3006 series)
- Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a dot standard comes from a particular chapter of a particular IEEE Color Book. In other cases, material from several IEEE Color Books has been combined into a new dot standard.

The material in this recommended practice largely comes from Chapter 10, Chapter 12, and Chapter 13 of IEEE Std 141™ (*IEEE Red Book™*), Chapter 5 of IEEE Std 241™ (*IEEE Gray Book™*), and Chapter 4 of IEEE Std 1100™ (*IEEE Emerald Book™*).

IEEE Std 3001.5™

This publication provides a recommended practice for the electrical design of commercial and industrial facilities. It is likely to be of greatest value to the power-oriented engineer with limited commercial or industrial plant experience. It can also be an aid to all engineers responsible for the electrical design of commercial and industrial facilities. However, it is not intended as a replacement for the many excellent engineering texts and handbooks commonly in use, nor is it detailed enough to be a design manual. It should be considered a guide and general reference on electrical design for commercial and industrial facilities.

Tables, charts, and other information that have been extracted from codes, standards, and other technical literature are included in this publication. Their inclusion is for illustrative purposes; where technical accuracy is important, the latest version of the referenced document should be consulted to assure use of complete, up-to-date, and accurate information.

Contents

1. Overview	1
1.1 Scope	1
2. Normative references.....	1
3. Introduction	5
3.1 Equipment installation	5
3.2 Maintenance, testing, and safety.....	6
3.3 Heat losses	6
4. Switching apparatus for power circuits	8
4.1 Classifications.....	8
4.2 Switches.....	8
4.3 Transfer switches.....	10
4.4 Fuses.....	11
4.5 Circuit breakers.....	12
4.6 Service protectors	24
5. Switchgear and switchboards	24
5.1 General discussion	24
5.2 Classifications.....	24
5.3 Types of metal-enclosed switchgear.....	25
5.4 Switchgear design features	31
5.5 Ratings.....	33
5.6 Application guides.....	35
5.7 Control power	36
6. Panelboards	39
6.1 Classifications.....	40
6.2 Ratings.....	41
7. Busways.....	41
7.1 Origin.....	41
7.2 Busway construction.....	42
7.3 Feeder busway	43
7.4 Plug-in busway	44
7.5 Lighting busway	45
7.6 Trolley busway	46
7.7 Standards	47
7.8 Selection and application of busways.....	47
7.9 Layout.....	53
7.10 Installation	53
7.11 Field testing	55
7.12 Busways over 600 V (metal-enclosed bus).....	55
8. Transformers	57
8.1 General	57
8.2 Transformer construction.....	57
8.3 Classifications.....	58
8.4 Specifications.....	67
8.5 Transformer power ratings	69

8.6 Transformer voltage ratings.....	72
8.7 Connections.....	77
8.8 Impedance.....	78
8.9 Insulation.....	80
8.10 Accessories.....	82
8.11 Termination facilities.....	82
8.12 Sound levels.....	83
8.13 Transformer heating due to harmonic currents.....	83
9. Cable systems.....	85
9.1 Cable construction.....	86
9.2 Cable outer finishes.....	96
9.3 Cable ratings.....	101
9.4 Installation.....	107
9.5 Connectors.....	113
9.6 Terminations.....	117
9.7 Splicing devices and techniques.....	128
9.8 Grounding of cable systems.....	130
9.9 Protection from transient overvoltage.....	131
9.10 Testing.....	132
9.11 Cable specification.....	133
Annex A (informative) Bibliography.....	135

IEEE Recommended Practice for the Application of Power Distribution Apparatus in Industrial and Commercial Power Systems

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 recommended practice covers the selection and application of power distribution apparatus used in industrial and commercial power systems. It is likely to be of greatest value to the power-oriented engineer with limited experience with this equipment. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.