

IEEE 3000
STANDARDS COLLECTION®

IEEE 3003 STANDARDS:
POWER SYSTEMS
GROUNDING

IEEE Std 3003.2™-2014

Recommended Practice for
Equipment Grounding and Bonding
in Industrial and Commercial Power
Systems

IEEE STANDARDS ASSOCIATION



IEEE Recommended Practice for Equipment Grounding and Bonding in Industrial and Commercial Power Systems

Sponsor

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

Approved 21 August 2014

IEEE-SA Standards Board

Abstract: The grounding and bonding of equipment in industrial and commercial power systems is covered in this recommended practice. The interconnection and grounding of the non-electrical metallic elements of a system is covered first. This is followed by a discussion of the objectives of equipment grounding and bonding, including minimizing electric shock hazard to personnel, providing adequate current carrying capability for ground faults, and ensuring the timely operation of overcurrent protection.

Keywords: bond, electrode, ground, grounded, grounding, IEEE 3003.2™

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 10 October 2014. Printed in the United States of America.

National Electrical Code, NEC, and NFPA 70 are registered trademarks of the National Fire Protection Association, Inc.

National Electrical Safety Code and NESC are both registered trademarks and service marks of The Institute of Electrical and Electronics Engineers, Inc.

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

PDF: ISBN 978-0-7381-9261-1 STD98755
Print: ISBN 978-0-7381-9262-8 STDPD98755

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 Systems Grounding Working Group had the following membership:

Massimo Mitolo, Chair

Thomas Baldwin
William Bush
Paul Cardinal
Carolyn Cooper

Carey Cook
Douglas Dorr
Tony Locker
Dalleep Mohla
Sergio Panetta

Elliot Rappaport
Robert Schuerger
David Shipp
Michael Simon

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

William Ackerman
Michael Adams
Gabriele F. D. Alleva
Roger M. Avery
Thomas Baldwin
Michael Bayer
W. J. (Bill) Bergman
Steven Bezner
Wallace Binder
Thomas Bishop
John Bonner
Roger Boyell
Frederick Brockhurst
Derek Brown
William Brumsickle
Gustavo Brunello
William Byrd
Paul Cardinal
Keith Chow
Donald Colaberardino
Terry Conrad
Carey Cook
Glenn Davis
Carlo Donati
Gary Donner
Douglas Dorr
Randall Dotson
Neal Dowling
Marcus Durham
Robert Durham
Dan Evans
Keith Flowers
Marcel Fortin
Gary Fox
Doaa Galal
Frank Gerleve
Kenneth Gettman
David Gilmer
Randall Groves
Thomas Gruz
Ajit Gwal

James Harvey
Timothy Hayden
Lee Herron
Scott Hietpas
Werner Hoelzl
Robert Hoerauf
Ronald Hotchkiss
John Houdek
John Kay
Chad Kennedy
Gael Kennedy
Yuri Khersonsky
Chad Kiger
Jim Kulchisky
Saumen Kundu
Thomas La Rose
Michael Lauxman
Wei-Jen Lee
Duane Leschert
Albert Livshitz
Greg Luri
Ahmad Mahinfallah
Michael Maytum
John McAlhaney, Jr.
William McBride
William McCoy
Donald McCullough
William Moncrief
Kimberly Mosley
David Mueller
Jerry Murphy
Paul Myers
Dennis Neitzel
Arthur Neubauer
Michael Newman
Joe Nims
Gearold O. H. Eidhin
Lorraine Padden
Mirko Palazzo
Sergio Panetta
Antony Parsons

K. James Phillips
Percy Pool
Louie Powell
Iuliam Profir
Moises Ramos
Daniel Leland Ransom
Elliot Rappaport
Johannes Rickmann
John Roach
Michael Roberts
Charles Rogers
Jesse Rorabaugh
Thomas Rozek
Steven Sano
Vincent Saporita
Bartien Sayogo
Robert Schuerger
Robert Schuermann
Kenneth Sedziol
Robert Seitz
Gil Shultz
Michael Simon
David Singleton
James Smith
Jeremy Smith
Jerry Smith
Gary Stoedter
Eugene Stoudenmire
Raymond Strittmatter
Peter Sutherland
David Tepen
Marcelo Valdes
John Vergis
Peter Walsh
Kenneth White
Kenneth White
Wayne Williams
James Wilson
Larry Young
Jian Yu
Daidi Zhong

When the IEEE-SA Standards Board approved this recommended practice on 21 August 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
T. W. 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*

Julie Alessi
IEEE-SA Content Publishing

Lisa Perry
IEEE-SA Technical Community Programs

Introduction

This introduction is not part of IEEE Std 3003.2™-2014, IEEE Recommended Practice for Equipment Grounding and Bonding 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 and Bonding (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 2 of IEEE Std 142™-2007 (*IEEE Green Book™*).

IEEE Std 3003.2™

This recommended practice provides fundamental concepts and recommended procedures for equipment grounding of power apparatus, wiring systems, interior and exterior substations, and utilization equipment.

Contents

1. Overview	1
1.1 Scope	1
1.2 General	1
1.3 Covered—equipment grounding and bonding	2
1.4 Not covered—system grounding	3
1.5 General	3
1.6 Objectives	3
1.7 Electric shock exposure	4
1.8 Thermal capability	4
1.9 Overcurrent protection operation	4
2. Normative references	5
3. Definitions, acronyms, and pictorial guide	6
3.1 Grounding and bonding terminology	6
3.2 Acronyms not defined in definitions section	7
3.3 Terminology pictorial guide	8
4. Fundamental concepts	9
4.1 Cabling of conductors	14
4.2 Enclosing metal shell	15
4.3 Electromagnetic interference suppression	17
4.4 Bonding of metal sleeves enclosing a protective conductor	17
4.5 Protective connections associated with steep wave front voltage protection equipment	18
4.6 Connection to earth	20
5. Equipment grounding and bonding as influenced by type of use	21
6. Outdoor open-frame substations	23
6.1 General	23
6.2 Design of paths for power frequency ground-fault current flow	23
6.3 Design of earthing connections	24
6.4 Surge voltage protective equipment	25
6.5 Control of surface voltage gradient	25
6.6 Voltage gradients external to, but adjacent to, the boundary fence	25
7. Unit substations	26
8. Interior wiring systems	27
8.1 General	27
8.2 Service equipment	27
8.3 Interior electric circuits	27
8.4 Thermal withstand	28
9. Interior unit substations and switching centers	30
9.1 Switching centers	30
9.2 Unit substations	31
10. Utilization equipment	31
Annex A (informative) Bibliography	34

IEEE Recommended Practice for Equipment Grounding and Bonding 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 grounding and bonding of equipment in industrial and commercial power systems. The interconnection and grounding of the non-electrical metallic elements of a system is covered first. This is followed by a discussion of the objectives of equipment grounding, including minimizing electric shock hazard to personnel, providing adequate current carrying capability for ground faults, and ensuring the timely operation of overcurrent protection.

1.2 General

The practices set forth herein are primarily applicable to industrial, institutional, or commercial power systems.

Where distances or power levels may dictate circuitry and equipment similar to a utility, consideration of utility practices is warranted. In addition to the general technical considerations in the practice of grounding as discussed in this recommended practice, as well as pertinent codes or standards imposed by local