

IEEE Trial-Use Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V

IEEE Industry Applications Society

Sponsored by the
Power Systems Engineering Committee

IEEE Trial-Use Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V

Sponsor

**Power Systems Engineering Committee
of the
IEEE Industry Applications Society**

Approved 21 August 2014

IEEE-SA Standards Board

Grateful Acknowledgment

The following material from CIGRE Working Group C4.1 10 Final Report, Voltage Dip Immunity of Equipment and Installations, April 2010 is reprinted with permission:

Table 7, adapted from Table 6-5 page 185 of CIGRE report

Figure 19, adapted from 6-6 page 145 and Fig 6-35 page 160 of CIGRE report

Table 8, adapted from Fig 2-17 page 40, and from Table 4.1 page IO1 of CIGRE report

Table 9, from un-numbered table on page 35 of CIGRE report

Figure 20 adapted from Table 4.2, Page 102 of CIGRE report

Figure 21 adapted from Table 4.1 on page 101 of CIGRE report and Table 4.2 and Table 4.3 on page 104 of CIGRE report

Table A.1 adapted from Table 4.1 on page 101 of CIGRE report and Table 4.2 and Table 4.3 on page 104 of CIGRE report

Abstract: A trial-use, non-industry-specific recommended practice for voltage sag and short interruption ride-through performance and compliance testing for all electrical and electronic equipment connected to low-voltage power systems that can experience malfunction or shutdown as a result of reductions in supply voltage lasting less than one minute is detailed in this document. Testing procedures and requirements for test equipment are clearly defined within this document to reflect this electrical environment, including single-phase, two-phase, and three-phase balanced and unbalanced voltage sags. Requirements for certification and test reporting, including characterization of voltage-sag ride-through equipment are also defined.

Keywords: equipment testing, IEEE 1668™, immunity, power quality, ride-through, voltage dip, voltage sag, voltage-sag characteristics

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 22 September 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 978-0-7381-9279-6 STD98768
Print: ISBN 978-0-7381-9280-2 STDPD98768

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.

Publication of this trial-use standard for comment and criticism has been approved by the Institute of Electrical and Electronics Engineers, Inc. Trial-use standards are effective for 24 months from the date of publication. Comments for revision will be accepted for 18 months after publication. Suggestions for revision should be directed to the Secretary, IEEE-SA Standards Board, 445 Hoes Lane, Piscataway, NJ 08855. It is expected that following the 24-month period, this trial-use standard, revised as necessary, shall be submitted to the IEEE-SA Standards Board for approval as a full-use standard.

Participants

At the time this IEEE trial-use recommended practice was completed, the Voltage Sag Ride-through Working Group had the following membership:

Doug Dorr, *Chair*

Scott Anderson, *Vice Chair*

Yves Allard
William Brumsickle
Math Bollen
Jack Caufield
John Coffman
Sasa Djokic
Brian Fortenbery

Robert Gettier
Gary Malhoit
Brad Martin
John Mentzer
Mark Minzlaff
Melinda Norris
Gregory Olson
Greg Rieder

James Rossman
Mark Rucker
Salman Sabbah
Mark Stephens
Rick Temple
Chuck Thomas
John-Carl Zarella

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

William Ackerman
Emmanuel Agamloh
Ali Al Awazi
Mihaela Albu
Steven Alexanderson
Saleman Alibhay
Gabriele F. D. Alleva
Curtis Ashton
George Ballassi
G. Bartok
Steven Bezner
Thomas Bishop
William Bloethe
Math Bollen
Kenneth Bow
William Brumsickle
Gustavo Brunello
William Bush
Paul Cardinal
Keith Chow
Stephen Conrad
Jerry Corkran
Luis Coronado
Randall Cunico
Chuanyou Dai
James Daley
Glenn Davis
Sasa Djokic
Dieter Dohnal
Gary Donner
Doug Dorr
Neal Dowling
Gearold O. H. Eidhin
Ahmed El Serafi
Alexander Emanuel
Dan Evans
Keith Flowers
Rostyslaw Fostiak

Carl Fredericks
Frank Gerleve
Robert Gettier
Mietek Glinkowski
Jalal Gohari
Stephen Grier
J. Travis Griffith
Randall Groves
Thomas Gruzs
Ajit Gwal
Paul Hamer
Jerry Harness
Richard Harp
Charles Henville
Gary Heuston
Werner Hoelzl
Soonwook Hong
Philip Hopkinson
Ronald Jarrett
Charles Jensen
Andrew Jones
Laszlo Kadar
Yuri Khersonsky
Jim Kulchisky
Saumen Kundu
Thomas Ladson
Chung-Yiu Lam
Thomas La Rose
Ed Larsen
Raluca Lascu
Theo Laughner
William Lockley
Russell Lowe
Bruce Mackie
Gary Malhoit
John McAlhaney, Jr.
Walter McCannon
Peter Megna
James Michalec

T. David Mills
Sujeet Mishra
Jerry Murphy
R. Murphy
Bruce Muschlitz
Michael Newman
Gregory Olson
Lorraine Padden
Bansi Patel
Christopher Petrola
Henry Pinto
Ulrich Pohl
Iulian Profir
Michael Roberts
Charles Rogers
John Rossetti
James Rossman
Bob Saint
Bartien Sayogo
Robert Schuerger
Kenneth Sedziol
Michael Simon
Veselin Skendzic
Jerry Smith
John Spare
Mark Stephens
Gary Stoedter
Peter Sutherland
James Swank
Peter Tirinzoni
Joe Uchiyama
Eric Udren
John Vergis
Matthew Wakeham
Daniel Ward
Kenneth White
Matthew Wilkowski
Jian Yu

When the IEEE-SA Standards Board approved this trial-use 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
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*

Patrick Gibbons
IEEE-SA Content Publishing

Lisa Perry
IEEE-SA Technical Community Programs

Introduction

This introduction is not part of IEEE Std 1668™-2014, IEEE Trial-Use Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V.

IEEE Std 1668-2014 is a non-industry specific trial use recommended practice for voltage-sag ride-through performance and compliance testing for all electrical and electronic equipment connected to low-voltage power systems that can experience malfunction or shutdown as a result of reductions in supply voltage lasting less than one minute. The recommended practice includes defining minimum voltage-sag immunity requirements based on actual voltage-sag data. A clause dedicated to the detailed analysis of voltage sags experienced by end users provides insight into real-world voltage sags. Testing procedures and test equipment requirements are clearly defined within this document to reflect this electrical environment, including single-phase, two-phase, and three-phase balanced and unbalanced voltage sags. This recommended practice also defines certification and test reporting requirements, including voltage-sag ride-through equipment characterization.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	2
1.3 Limitations	2
2. Normative references	2
3. Definitions and acronyms	3
3.1 Definitions	3
3.2 Acronyms	5
4. A primer on voltage sags	5
4.1 Background on voltage sags	5
4.2 The basics of voltage sags	6
4.3 Other key voltage-sag characteristics	9
4.4 Faults and voltage sags	13
4.5 Voltage sags and current relationships	24
4.6 How common are voltage sags?	24
4.7 Other causes and effects of voltage sags	33
5. Recommended voltage-sag test requirements	34
5.1 Background on test requirements	34
5.2 Classification of voltage-sag types in three-phase systems	34
5.3 Recommended voltage-sag immunity levels	37
Annex A (informative) Test procedures and guidelines	44
A.1 Considerations and guidance on test vector	44
A.2 Safety precautions for voltage-sag testing	46
A.3 Test setup	47
A.4 Compliance test procedures	50
A.5 Voltage-sag immunity characterization test procedures	54
Annex B (normative) Test equipment requirements	75
Annex C (normative) Certification and test reports	76
C.1 Certificates	76
C.2 Test reports	76
Annex D (informative) Bibliography	78

IEEE Trial-Use Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V

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 document is a non-industry-specific recommended practice for voltage-sag ride-through performance and compliance testing for all electrical and electronic equipment connected to low-voltage power systems (with nominal/rated voltage less than 1000 V) that can experience malfunction or shutdown as a result of reductions in supply voltage lasting less than one minute. The recommended practice includes defining minimum voltage-sag immunity requirements based on actual voltage-sag data. A clause dedicated to the detailed analysis of voltage sags experienced by end users provides insight into real-world voltage sags. Testing procedures and requirements for test equipment are clearly defined within this document to reflect the electrical environment, including single-phase, two-phase, and three-phase, balanced and unbalanced voltage sags. The recommended practice also defines requirements for certification and test reporting, including characterization of voltage-sag ride-through equipment.