

IEEE Recommended Practice for Monitoring Electric Power Quality

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

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

IEEE Std 1159™-2019
(Revision of IEEE Std 1159-2009)

IEEE Recommended Practice for Monitoring Electric Power Quality

Developed by

Transmission and Distribution Committee
of the
IEEE Power and Energy Society

Approved 13 June 2019

IEEE-SA Standards Board

Abstract: The monitoring of electrical characteristics of single-phase and polyphase ac power systems is encompassed in this recommended practice. It includes consistent descriptions of conducted electromagnetic phenomena occurring on power systems. This recommended practice describes nominal conditions and deviations from these nominal conditions that may originate within the source of supply or load equipment or may originate from interactions between the source and the load. Also, this recommended practice discusses power quality monitoring devices, application techniques, and the interpretation of monitoring results.

Keywords: assessment, compatibility, dip, distortion, electromagnetic phenomena, harmonics, IEEE 1159, imbalance, instruments, interference, monitoring, noise, power quality, rms variation, sag, susceptibility, swell, transient, unbalance

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

Copyright © 2019 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 13 August 2019. 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 Code, NEC, and Standard for Electrical Safety in the Workplace are registered trademarks of the National Fire Protection Association, Inc.

PDF: ISBN 978-1-5044-5928-0 STD23741
Print: ISBN 978-1-5044-5929-7 STDPD23741

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 Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

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. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups 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 Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users 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.

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 Xplore at <http://ieeexplore.ieee.org/> 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 & Energy Working Group had the following membership:

Steven Johnston, *Chair*
Timothy D. Unruh, *Vice Chair*

Reza Arghaneleh
Richard P. Bingham
Thomas Cooke
Joseph Grappe

Bill Howe
Kevin Kittredge
Theo Laughner
Matt Norwalk
Scott Peele

Kenn Sedziol
Nicholas Zagrodnik
Francisc Zavoda
David Zech

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

William Ackerman
Robert Arno
Curtis Ashton
Thomas Barnes
Frank Basciano
Richard P. Bingham
William Bloethe
Jeffrey Brogdon
Gustavo Brunello
Demetrio Bucaneg
William Bush
William Byrd
Mario Manana Canteli
Sean Carr
Wen-Kung Chang
Michael Chirico
Glenn Davis
Davide De Luca
Gary Donner
Michael Dood
Neal Dowling
Donald Dunn
Zakia El Omari
Jorge Fernandez Daher
Waymon Goch
Joseph Grappe
Randall Groves
Jeffrey Helzer
Lee Herron
Werner Hoelzl
John Houdek
Sangkwon Jeong
Steven Johnston
Geza Joos

Laszlo Kadar
Innocent Kamwa
John Kay
Peter Kelly
Yuri Khersonsky
James Kinney
Gary Kobet
Jim Kulchisky
Mikhail Lagoda
Benjamin Lanz
Michael Lauxman
Lawrence Long
William McBride
Thomas McCarthy
John McDaniel
Jerry Murphy
Bruce Muschlitz
Ali Naderian Jahromi
Alexandre Nassif
Joe Nims
Matthew Norwalk
Gearold O. H. Eidhin
Gregory Olson
Lorraine Padden
Marty Page
Bansi Patel
Dhiru Patel
Marc Patterson
Gary Peele
Howard Penrose
Christopher Petrola
Prasad Pmsvsv
Craig Preuss

Iulian Profir
Reynaldo Ramos
Lakshman Raut
John Roach
Charles Rogers
Oleg Roizman
Ryandi Ryandi
Daniel Sabin
Steven Sano
Sergio Santos
Bartien Sayogo
Thomas Schossig
Kenn Sedziol
Nikunj Shah
Devki Sharma
Harish Sharma
Hyeong Sim
Jerry Smith
Gary Smullin
Wayne Stec
Gary Stoedter
K. Stump
David Tepen
Timothy D. Unruh
John Vergis
Roel Vries
Reigh Walling
William Walter
Daniel Ward
Kenneth White
James Wikston
Jian Yu
Nicholas Zagrodnik
David Zech

When the IEEE-SA Standards Board approved this recommended practice on 13 June 2019, it had the following membership:

Gary Hoffman, *Chair*
Ted Burse, *Vice Chair*
Jean-Philippe Faure, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Stephen D. Dukes
J. Travis Griffith
Guido Hiertz
Christel Hunter
Thomas Koshy
Joseph L. Koepfinger*
Thomas Koshy

John D. Kulick
David J. Law
Joseph Levy
Howard Li
Xiaohui Liu
Kevin Lu
Daleep Mohla
Andrew Myles

Annette D. Reilly
Dorothy Stanley
Sha Wei
Phil Wennblom
Philip Winston
Howard Wolfman
Feng Wu
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 1159-2019, IEEE Recommended Practice for Monitoring Electric Power Quality.

This recommended practice provides useful information for individuals interested in power quality monitoring projects. It provides definitions, summaries, and characterizations of typical power quality phenomena that lead to power quality problems. There is discussion on monitoring instruments and selecting the appropriate instrument for the task followed by information on the application of the monitors is provided, including: safety, locations to monitor, sensing inputs, and measurement thresholds. After the monitoring period is completed, there is information on validating the data, extracting the critical data, and interpreting both summaries and critical events.

Contents

1. Overview	10
1.1 Scope	10
1.2 Purpose	10
2. Normative references.....	10
3. Definitions	11
4. Power quality phenomena	12
4.1 Introduction	12
4.2 Electromagnetic compatibility	12
4.3 General classification of phenomena	12
4.4 Detailed descriptions of phenomena.....	14
5. Monitoring objectives.....	34
5.1 Introduction	34
5.2 Need for monitoring power quality	34
5.3 Equipment tolerances and effects of disturbances on equipment	35
5.4 Equipment types	35
6. Measurement instruments.....	35
6.1 Introduction	35
6.2 History: four generations	35
6.3 Reasons to monitor versus type of monitor	36
6.4 Parameters to be measured	36
6.5 Monitoring instruments	39
6.6 Pitfalls/Cautions.....	44
7. Application techniques	46
7.1 Introduction	46
7.2 Safety	47
7.3 Monitoring location	51
7.4 Equipment connection	54
7.5 Measurement thresholds	59
8. Interpreting power monitoring results	63
8.1 Introduction	63
8.2 Interpreting data summaries	64
8.3 Critical data extraction.....	65
8.4 Interpreting critical events	70
8.5 Verifying data interpretation.....	79
Annex A (informative) Calibration and self-testing	80
A.1 Introduction	80
A.2 Calibration issues.....	81
Annex B (informative) We need a title.....	83
Annex C (informative) Glossary	90
Annex D (informative) Bibliography	94

IEEE Recommended Practice for Monitoring Electric Power Quality

1. Overview

1.1 Scope

This recommended practice encompasses the monitoring of characteristics of electric power systems. It includes consistent descriptions of conducted electromagnetic phenomena occurring on power systems. This recommended practice presents definitions of nominal conditions and deviations from these nominal conditions that may originate within the source of supply or load equipment or may originate from interactions between the source and the load. This recommended practice also discusses measurement techniques, application techniques, and the interpretation of monitoring results.

1.2 Purpose

This recommended practice provides users with a consistent set of terms and definitions for describing power quality phenomena. An understanding of how power quality phenomena affects the power system and end-use equipment is required in order to make monitoring useful. Proper measuring techniques are required to safely obtain useful, accurate data. Appropriate location of monitors, systematic studies, and interpretation of results will enhance the value of power quality monitoring. The purpose of this recommended practice is to assist users as well as equipment and software manufacturers and vendors by describing techniques for defining, measuring, quantifying, and interpreting electromagnetic phenomena on the power system.

2. Normative references

No normative references apply to this recommended practice. Bibliographical references can be found in [Annex D](#).