



IEEE Guide for the Electrical Measurement of Partial Discharges in High Voltage Bushings and Instrument Transformers

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.160™-2023

STANDARDS

IEEE Guide for the Electrical Measurement of Partial Discharges in High Voltage Bushings and Instrument Transformers

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 6 December 2023

IEEE-SA Standards Board

Abstract: The test procedure for electrical measurement of partial discharge (PD) in bushings and instrument transformers using wide-band measuring instruments for the evaluation of the apparent charge level of PD occurring under ac and dc test voltages is described in this guide.

Keywords: apparent charge, bushing, calibrating charge, calibrating circuit, current transformer, IEEE C57.160™, partial discharge, voltage transformer

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

Copyright © 2024 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 7 August 2024. 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 979-8-8557-0703-8 STD26927
Print: ISBN 979-8-8557-0704-5 STDPD26927

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <https://www.ieee.org/about/corporate/governance/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 Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers>), appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents are developed within IEEE Societies and subcommittees of IEEE Standards Association (IEEE SA) Board of Governors. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers are not necessarily members of IEEE or IEEE SA 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 makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning this standard, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. IEEE Standards documents do not guarantee safety, security, health, or environmental protection, or guarantee against interference with or from other devices or networks. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. 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 their 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: THE NEED TO PROCURE 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 balloting 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 is 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, nor 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 the presenter's views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group. Statements made by volunteers may not represent the formal position of their employer(s) or affiliation(s).

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, 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 subcommittees of the IEEE SA Board of Governors 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 evaluating comments or in revisions to an IEEE standard is welcome to join the relevant IEEE working group. You can indicate interest in a working group using the Interests tab in the Manage Profile and Interests area of the [IEEE SA myProject system](#).¹ An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.²

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 constitute 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.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

¹Available at: <https://development.standards.ieee.org/myproject-web/public/view.html>.

²Available at: <https://standards.ieee.org/about/contact/>.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US 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, neither IEEE nor its licensors waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate licensing fees, 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; <https://www.copyright.com/>. 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 10 years. When a document is more than 10 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 [IEEE Xplore](#) or [contact IEEE](#).³ For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#).⁴ Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE standards are developed in compliance with the [IEEE SA Patent Policy](#).⁵

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

³Available at: <https://standards.ieee.org/about/contact>.

⁴Available at: <https://standards.ieee.org/standard/>

⁵Available at: <https://standards.ieee.org/about/sasb/patcom/materials>.

filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <https://standards.ieee.org/about/sasb/patcom/patents>. 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.

IMPORTANT NOTICE

Technologies, application of technologies, and recommended procedures in various industries evolve over time. The IEEE standards development process allows participants to review developments in industries, technologies, and practices, and to determine what, if any, updates should be made to the IEEE standard. During this evolution, the technologies and recommendations in IEEE standards may be implemented in ways not foreseen during the standard's development. IEEE standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. 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.

Participants

At the time this guide was completed, the PD in Bushings & PT/CTs Working Group had the following membership:

Thang Hochanh, *Chair*
Thang Hochanh, *Secretary*

Lee Bigham	Robert Middleton	Januz Szczechowski
Dominique Bollgier	Stephen Oakes	Jacques Vanier
Jonathan Cheatham	Juan Jose Ramirez	David Wallace
Reto Fausch	Gomez	Eric Weatherbee
Marcos Ferreira	Pierre Riffon	Daniel Weyer
Marek Kornowski	Zoltan Roman	Bill Whitehead
Deepak Kumaria	Thomas Sizemore	Shibao Zhang
	Steve Snyder	

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

Donald Ayers	Sheldon Kennedy	Timothy Charles
Peter Balma	Vladimir Khalin	Raymond
Martin Baur	James Kinney	Samala Santosh Reddy
Barry Beaster	Hermann Koch	Johannes Rickmann
Jason Bellamy	Boris Kogan	Pierre Riffon
Emil Bercea	Axel Kraemer	Sebastien Riopel
Enrique Betancourt	Jim Kulchisky	Diego Robalino
Thomas Blackburn	Raja Kuppaswamy	Richard Rohr
J. Brafa	John Lackey	Zoltan Roman
Jeffrey Britton	Chung-Yiu Lam	Rodrigo Ronchi
Demetro Jr. Bucaneg	David Larochelle	Ryandi Ryandi
Arvind Chaudhary	Nigel Macdonald	Mathieu Sauzay
C. Clair Claiborne	Darrell Mangubat	Bartien Sayogo
Ray Davis	James McBride	Stephen Shull
J. Arturo Del Rio	William McDermid	Hyeong Sim
John Densley	Susan McNelly	Thomas Sizemore
Donald Dunn	Andrew McNulty	Jerry Smith
Jorge Fernandez Daher	Ross McTaggart	Gary Smullin
Namal Fernando	Vinay Mehrotra	Steve Snyder
Fredric Friend	Charles Morgan	Sanjib Som
Eduardo Garcia	Thomas Mulcahy	Robert Stinson
Edwin Goodwin	Daniel Mulkey	Gary Stoedter
Detlev Gross	Jerry Murphy	Juan Thierry
Randall Groves	K. R. M. Nair	Mark Tostrud
Bal Gupta	Rudolf Ogajanov	Marco Tozzi
Said Hachichi	Bansi Patel	James Van De Ligt
John Harley	Dhiru Patel	Ajith Varghese
Werner Hoelzl	Howard Penrose	Jason Varnell
Gary Hoffman	Charles Pestell	Roger Verdolin
Philip Hopkinson	Christopher Petrola	John Vergis
Daniel Huenger	Donald Platts	Yves Vermette
Mohammad Iman	Alvaro Portillo	David Wallace
Richard Jackson	Iulian Profir	David Wallach
Nathan Jacob	Ulf Radbrandt	Eric Weatherbee
John John	Farnoosh Rahmatian	Jonathan Woodworth
Laszlo Kadar	Lakshman Raut	Jian Yu
John Kay		Shibao Zhang
Thomas Keels		Igor Ziger

When the IEEE SA Standards Board approved this guide on 6 December 2023, it had the following membership:

David J. Law, *Chair*
Ted Burse, *Vice Chair*
Gary Hoffman, *Past Chair*
Konstantinos Karachalios, *Secretary*

Sara R. Biyabani
Doug Edwards
Ramy Ahmed Fathy
Guido R. Hiertz
Yousef Kimiagar
Joseph L. Koepfinger*
Thomas Koshy
John D. Kulick

Joseph S. Levy
Howard Li
Gui Lin
Johnny Daozhuang Lin
Xiaohui Liu
Kevin W. Lu
Daleep C. Mohla
Andrew Myles

Paul Nikolich
Annette D. Reilly
Robby Robson
Lei Wang
F. Keith Waters
Karl Weber
Philip B. Winston
Don Wright

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C57.160–2023, IEEE Guide for the Electrical Measurement of Partial Discharge in High Voltage bushings and Instrument Transformers.

This is a new guide which describes the test procedure for the electrical measurement of partial discharge (PD) occurring in bushings and instrument transformers during ac and dc dielectric tests. General principles of PD measurement, including the narrowband method, are covered in IEC 60270.

Contents

1. Overview	14
1.1 Scope	14
1.2 Purpose	14
1.3 Word usage	14
2. Normative references	15
3. Definitions, acronyms, and abbreviations	15
3.1 Definitions	15
3.2 Acronyms and abbreviations	16
4. Specification of PD measuring circuits.....	16
4.1 General	16
4.2 Test circuit and measuring system for alternating voltage	16
5. PD Calibration.....	21
5.1 Typical PD limit and scale factor	21
5.2 Calibration.....	21
5.3 Calibrator capacitor C_0	21
6. Bushing PD test	21
6.1 Test requirements.....	21
6.2 Preparation of the bushing for test	22
6.3 Test circuit	22
6.4 PD test, ac applications.....	27
6.5 PD Test, dc applications.....	29
7. Instrument transformer PD test	30
7.1 Preparation of the test object.....	30
7.2 Instrument transformer test circuits	31
7.3 Calibration.....	31
7.4 PD Test	36
Annex A (informative) PD Patterns and Recognition.....	38
Annex B (informative) Calibrator apparent charge verification	47
Annex C (informative) Test room and circuit conditions for sensitive PD testing.....	49

List of Figures

Figure 1—Example of a PRPD pattern display	19
Figure 2—Second example of a PRPD pattern display	19
Figure 3—Bushing with voltage or test tap	23
Figure 4—Test circuit with coupling device in series with test object	24
Figure 5—Test with coupling device in series with coupling capacitor	24
Figure 6—Test circuit with bushing flange that cannot be isolated from ground	25
Figure 7—Balanced test circuit	26
Figure 8—Alternative balanced test circuit	26
Figure 9—Unbalanced test circuit: Typical calibration connections	27
Figure 10—Balanced test circuit: Typical calibration connections	28
Figure 11—Voltage transformer: Test circuit for PD measurement	32
Figure 12—Voltage transformer: Alternative test circuit for PD measurement	32
Figure 13—Voltage transformer: Calibration connections for PD measurement	33
Figure 14—Voltage transformer: Balanced circuit for PD measurement	33
Figure 15—Voltage transformer: Alternative balanced test circuit for PD measurement	33
Figure 16—Voltage transformer: Calibration connections for PD measurement	34
Figure 17—Current transformer: Unbalanced test circuit for PD measurement	34
Figure 18—Current transformer: Unbalanced test circuit for PD measurement calibration connections for PD measurement	35
Figure 19—Current transformer: Alternative test circuit for PD measurement	35
Figure 20—Current Transformer: Balanced test circuit for PD measurement	35
Figure 21—Current Transformer: Alternative balanced test circuit for PD measurement	36
Figure 22—Current transformer: Calibration connections for PD measurement	36
Figure A.1—Crane hook, close to the high voltage bushing: Sharp edge on a grounded point	38
Figure A.2—Corona sphere not correctly installed on the high voltage bushing: Sharp edge on a high voltage electrode	39
Figure A.3—Sharp edge on a grounded point	39
Figure A.4—Sharp edge on a high voltage electrode	40
Figure A.5—Floating conductive part	40
Figure A.6—Single void in epoxy resin	41

Figure A.7—Multiple voids in epoxy resin	41
Figure A.8—Voids in polymeric sample at a semi-conductive interface	42
Figure A.9—Internal contact problem at tap electrode	42
Figure A.10—Corona discharge under light rain.....	43
Figure A.11—Superimposed internal discharge with corona discharge	43
Figure A.12—Gas pocket between paper layers.....	44
Figure A.13—Point plane discharge under oil.....	44
Figure A.14—Voids and surface discharge under harmonic distortion.....	45
Figure A.15—Generic: Surface discharge in air	45
Figure A.16—Generic: Point plane discharge in air	46
Figure A.17—Generic: Floating potential with metallic gap.....	46
Figure B.1—Screenshot example for $R_m = 50 \Omega$	47
Figure B.2—Screenshot example for $R_m = 184.2 \Omega$	48
Figure C.1—Example of test equipment positioning (unit in mm).....	52
Figure C.2—Example of an antenna for the test circuit shown in Figure C.1	53
Figure C.3—PD mapping of the Faraday cage	54
Figure C.4—HV test laboratory shielding.....	55
Figure C.5—Completed test laboratory	56

List of Tables

Table 1—Pulse train response of PD instruments..... 20

Table C.1—Comparison of PD test circuits for bushings 49

Table C.2—Comparison of PD test circuits for instrument transformers 50

IEEE Guide for the Electrical Measurement of Partial Discharges in High Voltage Bushings and Instrument Transformers

1. Overview

1.1 Scope

This guide describes the test procedure for electrical measurement of partial discharge (PD) in bushings and instrument transformers using wide-band measuring instruments for the evaluation of the apparent charge level of PD occurring under ac and dc test voltages.

1.2 Purpose

For the detection of PD events in bushings and instrument transformers when subjected to high voltage tests, it is common practice to measure the apparent charge of the current pulses originating in insulation defects. Depending on the bandwidth used for electrical PD signal processing, this process is characterized as either narrow-band or wide-band signal processing. Without preference for either method, this document focuses on the wide-band PD signal processing described in IEC 60270.

The general diction of this guide, when referring to PD measurement systems, reflects the common use of it within ac systems. PD measurement is also mandatory during testing of dc system components under dc high voltage and is, therefore, also considered in this guide. Since synchronization between partial discharge and voltage waveform is not possible in this case, there is no time-based pattern for the measured partial discharge.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

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.

IEC 60270, High-voltage test techniques—Partial discharge measurements.⁸

IEC/IEEE 65700-19-03, Bushings for DC application.

IEEE Std 4™, IEEE Standard for High-Voltage Testing Techniques.^{9,10}

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.

IEEE Std C57.13.5™, IEEE Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above.

IEEE Std C57.19.00™, IEEE Standard General Requirements and Test Procedure for Power Apparatus Bushings.

IEEE Std C57.19.01™, IEEE Standard for Performance Characteristics and Dimensions for Power Transformer and Reactor Bushings.

IEEE Std C57.113™, IEEE Recommended Practice for Partial Discharge Measurements in Liquid-Filled Power Transformers and Shunt Reactors.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹¹

apparent charge level: Mean value of the apparent charge of partial discharge (PD) pulse trains measured in terms of picocoulombs (pC).

calibrating charge: Charge of artificial partial discharge (PD) pulses generated by a calibrator.

calibrating circuit: Interconnection of the partial discharge (PD) calibrator with the test object and the PD measuring circuit intended for the determination of the scale factor k .

⁸IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

⁹IEEE publications are available from The Institute of Electrical and Electronics Engineers, Inc., (<https://standards.ieee.org/>).

¹⁰The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

¹¹*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

PD scale factor k : Ratio of the partial discharge (PD) instrument reading to the PD calibrator injection value.

NOTE—In modern PD measuring devices, the scale factor k is 1.¹²

largest repeatedly occurring partial discharge (PD) magnitude q_{IEC} : Largest magnitude recorded by a PD measuring instrument.

background noise: partial discharge (PD) levels measured during PD test, which do not originate from the test object (IEC 60270)

PD-free bushing/test object: Bushing/test object known as having a measured partial discharge (PD) level lower than the PD limit for the bushing/test object.

inception voltage level: While raising the voltage level during a partial discharge (PD) test, the voltage at which an increase in PD over the background noise is observed.

3.2 Acronyms and abbreviations

CMRR	Common-mode rejection ratio
PD	Partial discharge
PRPD	Phase resolved partial discharge
pC	picocoulomb
S/N	Signal-to-noise ratio
GST	Grounded specimen test
UST	Ungrounded specimen test

4. Specification of PD measuring circuits

4.1 General

For measurement of apparent charge, the main components are as follows:

- Test object
- High voltage and ground leads
- Coupling capacitor
- Coupling device(s)
- Measuring instrument for the processing of partial discharge (PD) pulses
- HV source

4.2 Test circuit and measuring system for alternating voltage

4.2.1 Test room

When low pC PD test levels are a requirement, special test room arrangements are necessary. The following measures can help reduce the background noise:

- The test room grounding point is to be separate from the main building ground

¹²Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

- A Faraday cage type construction
- An isolated ac power supply for the measuring instrumentation

More details are provided in [Annex C](#).

4.2.2 Test circuit

Multiple physical test circuits can be used depending on the type of unit under test. All test circuits share the following principles:

- The voltage source should be capable of supplying the total load of the test circuit. The ac test voltage tolerance is $\pm 3\%$. The ac test voltage measuring circuit should comply with IEEE Std 4TM and IEEE Std C57.113TM.¹³
- Blocking impedances (high frequency filters) can be located either on the LV, HV, or both sides of the step-up transformer.
- A PD-free coupling capacitor C_k is required. The highest sensitivity would be realized if $C_k \gg C_a$, where C_a is the test object capacitance (IEC 60270). This condition implies additional loading on the high voltage supply. An acceptable sensitivity is achieved with a C_k value of 1 nF. The capacitance C_k of 1 nF is widely used by HV test laboratories.
- Other capacitance value of the coupling capacitor can be used as long as the background noise (during the Calibration process) is lower than 50% of the PD limit.

4.2.2.1 Background noise during the test

During the PD test, when the test voltage is applied, the test circuit and/or the power source generate some background noise. This background noise level is acceptable as long as this level is below the PD limit.

4.2.3 PD measuring system for apparent charge

A balanced or unbalanced PD measuring method may be used. Method selection will depend on the laboratory's ability to isolate the background noise.

4.2.3.1 Coupling device for the unbalanced circuit

The PD signal is measured from the bushing tap of a bushing ([Figure 5](#)) and from the ground of the test object for instrument transformers ([Figure 11](#) and [Figure 16](#)).

A coupling device is the primary element used to discern the PD components and optionally, integrate a means for the measurement of the test voltage. This coupling device is seen as a passive or active four-terminal network (quadrupole). The quadrupole converts the input current to an output voltage. The PD and power source voltage detected at the coupling device are transmitted to the measuring instrument by a coaxial cable or by an optical link.

NOTE—Some high voltage laboratories have noise levels less than 1 pC when using the unbalanced measuring circuit.

4.2.3.2 Coupling device for the balanced circuit

The coupling device for balanced circuit can be viewed as a PD detection device having two PD signal inputs: one from the low voltage side of the test object (C_1 for bushing/casing for instrument transformers), and the other from the low voltage side of the coupling capacitor.

¹³Information on references can be found in [Clause 2](#).