



IEEE

IEC/IEEE 65700-19-03

Edition 1.0 2014-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Bushings for DC application

Traversées pour application en courant continu





THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2014 IEC, Geneva, Switzerland

Copyright © 2014 IEEE

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue
New York, NY 10016-5997
United States of America
stds.ipr@ieee.org
www.ieee.org

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About the IEEE

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

About IEC/IEEE publications

The technical content of IEC/IEEE publications is kept under constant review by the IEC and IEEE. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 21 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.



IEEE

IEC/IEEE 65700-19-03

Edition 1.0 2014-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Bushings for DC application

Traversées pour application en courant continu

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.080.20

ISBN 978-2-8322-6336-5

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references.....	9
3 Terms, definitions and symbols.....	10
3.1 Terms and definitions.....	10
3.2 List of variables.....	12
4 Ratings.....	13
4.1 Rated voltages.....	13
4.1.1 Rated continuous DC voltage.....	13
4.1.2 Rated peak voltage.....	13
4.2 Insulation levels.....	13
4.3 Rated currents.....	13
4.3.1 Pure DC applications.....	13
4.3.2 Combined voltage applications.....	14
4.4 Rated frequency.....	14
4.5 Pollution parameters.....	14
5 Operating conditions.....	15
5.1 General.....	15
5.2 Factors affecting the design, testing and application.....	16
5.3 Altitude correction.....	17
5.4 Interchangeability.....	18
6 General requirements.....	19
6.1 Electrical requirements.....	19
6.2 Mechanical requirements.....	19
6.3 Nameplate markings.....	19
7 Test requirements.....	20
7.1 General requirements.....	20
7.2 Test Conditions.....	20
7.2.1 Air temperature.....	20
7.2.2 Humidity.....	20
7.2.3 Correction factors.....	20
7.3 Test classification.....	21
7.3.1 Type (or design) tests.....	21
7.3.2 Routine tests.....	22
7.3.3 Special tests.....	22
8 Type tests.....	22
8.1 Dry power-frequency voltage withstand test with partial discharge measurement.....	22
8.1.1 Applicability.....	22
8.1.2 Test method and requirements.....	22
8.1.3 Acceptance.....	22
8.2 Dry lightning impulse voltage withstand test (BIL).....	22
8.2.1 Applicability.....	22
8.2.2 Test method and requirements.....	22

8.2.3	Acceptance	23
8.3	Dry or wet switching impulse voltage withstand test (SIL).....	23
8.3.1	Applicability.....	23
8.3.2	Test method and requirements	23
8.3.3	Acceptance	23
8.4	Electromagnetic compatibility tests (EMC)	23
8.4.1	Emission test	23
8.4.2	Immunity test	24
8.5	Temperature rise test	24
8.5.1	Applicability.....	24
8.5.2	Test method and requirements	24
8.5.3	Acceptance	25
8.6	Cantilever load withstand test.....	25
8.6.1	Applicability.....	25
8.6.2	Test method and requirements	25
8.6.3	Acceptance	26
8.7	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings	26
8.8	Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings	26
8.9	Verification of dimensions	27
8.10	Draw-lead bushing cap pressure test.....	27
8.10.1	Applicability.....	27
8.10.2	Test method and requirements	27
8.10.3	Acceptance	27
9	Routine tests	27
9.1	Measurement of dielectric dissipation factor ($\tan \delta$) and capacitances	27
9.1.1	Applicability.....	27
9.1.2	Test method and requirements	27
9.1.3	Acceptance	27
9.2	Dry lightning impulse voltage withstand test (BIL)	28
9.2.1	Applicability.....	28
9.2.2	Test method and requirements	28
9.2.3	Acceptance	28
9.3	Dry power-frequency voltage withstand test with partial discharge measurement	28
9.3.1	Applicability.....	28
9.3.2	Test method and requirements	28
9.3.3	Acceptance	29
9.4	DC applied voltage withstand test with partial discharge measurement.....	29
9.4.1	Applicability.....	29
9.4.2	Test method and requirements	30
9.4.3	Acceptance	30
9.5	Polarity reversal test with partial discharge measurement	31
9.5.1	Applicability.....	31
9.5.2	Test method and requirements	31
9.5.3	Acceptance	32
9.6	Dry Switching impulse withstand test	32
9.6.1	Applicability.....	32
9.6.2	Test method and requirements	33

9.6.3	Acceptance	33
9.7	Test of tap insulation	33
9.8	Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings	33
9.9	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings	33
9.10	Tightness test on gas-filled, gas-insulated and gas-impregnated bushings	33
9.11	Tightness test at the flange or other fixing device	33
9.12	Visual inspection and dimensional check	33
10	Special tests	33
10.1	Artificial pollution test	34
10.1.1	Applicability	34
10.1.2	Test method and requirements	34
10.1.3	Acceptance	34
10.2	Even wetting DC voltage test	34
10.2.1	Applicability	34
10.2.2	Test method and requirements	34
10.2.3	Acceptance	35
10.3	Uneven wetting DC voltage test	35
10.3.1	Applicability	35
10.3.2	Test method and requirements	35
10.3.3	Acceptance	35
11	Recommendations for transport, storage, erection, operation and maintenance	36
11.1	Conditions during transport, storage and installation	36
11.2	Installation	36
11.3	Unpacking and lifting	36
11.4	Assembly	36
11.4.1	Mounting	36
11.4.2	Connections	37
11.4.3	Final installation inspection	37
11.5	Operation	37
11.6	Maintenance	38
11.6.1	General	38
11.6.2	Recommendation for the manufacturer	38
11.6.3	Recommendations for the user	38
11.6.4	Failure report	39
12	Safety	40
12.1	Electrical aspects	40
12.2	Mechanical aspects	40
12.3	Thermal aspects	40
13	Environmental aspects	40
Annex A	(informative)	41
A.1	Bushings used in voltage source converters (VSC) HVDC schemes	41
A.1.1	Introduction	41
A.1.2	Design	43
A.1.3	Tests	44
A.1.4	Supporting Published Material	44
Annex B	(informative)	45

B.1	Temperature rise test methods for the determination of the equivalent test current	45
B.1.1	Introduction	45
B.2	Basics concerning the losses in distorted operation	45
B.3	Analytical calculation	46
B.4	Finite element method calculation	46
B.5	Calculation by enhancement factors as described in IEC 61378–1	47
B.6	Examples of calculation	48
B.6.1	Calculation based on the analytical method	49
B.6.2	Calculation based on Finite Element Method	50
B.6.3	Calculation based on the enhancement factor according IEC 61378–1	51
B.7	References	52
	Bibliography	53
	Figure 1 – Altitude correction factor	18
	Figure 2 – Polarity reversal test profile	31
	Figure A.1 – Two-level VSC HVDC converter station applied in a bipolar scheme with DC cable transmission	42
	Figure A.2 – Multi-level VSC HVDC converter station applied in a monopolar scheme with DC overhead line transmission	43
	Table 1 – Temperature of ambient air and immersion media (see 5.1)	16
	Table 2 – Type, routine and special tests	21
	Table 3 – Minimum values of cantilever withstand load	26
	Table 4 – Maximum values of $\tan \delta$ and $\tan \delta$ increase	28
	Table 5 – Maximum values of partial discharge quantity	29
	Table B.1 – Valve side connected bushing current harmonic spectrum	48
	Table B.2 – Calculation based on the analytical method	49
	Table B.3 – Calculation based on Finite Element Method	50
	Table B.4 – Calculation based IEC 61378-1 enhancement factor F_{CE}	51

INTERNATIONAL ELECTROTECHNICAL COMMISSION

BUSHINGS FOR DC APPLICATION**FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. 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 contained in its standards. Use of IEEE Standards documents is wholly voluntary. IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC/IEEE Publication or any other IEC or IEEE Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent 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.

This International Standard has been prepared by a joint working group of sub-committee 36A: Insulated bushings, of IEC technical committee 36: Insulators and Bushing subcommittee of the IEEE-PES transformer committee¹.

This bilingual version (2019-01) corresponds to the monolingual English version, published in 2014-07.

The text of this standard is based on the following documents:

FDIS	Report on voting
36A/173/FDIS	36A/174/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

¹ A list of IEEE participants can be found at the following URL:
<http://standards.ieee.org/downloads/65700/65700-19-03-2014/65700-19-03-2014_wg-participants.pdf>.

INTRODUCTION

In this first edition of IEC/IEEE 65700-19-03, service experiences as well as established market requirements have been harmonized with existing IEC and IEEE standards, primarily:

IEC 60137, *Insulated bushings for alternating voltages above 1 000 V*

IEC 62199, *Bushings for DC application*

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

IEEE Std C57.19.03™, *IEEE Standard Requirements, Terminology and Test Code for Bushings for DC Application*

This dual numbered standard replaces the previous IEC and IEEE DC bushing standards.

Where applicable, reference is also made to the following standards:

IEC 61462, *Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment*; and

IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*.

Non-ceramic bushing insulators are widely used in DC applications and this standard applies to similar qualification procedures on all types of insulators, except for the artificial pollution test. Preparation of a bushing for an artificial pollution test destroys the surface of a composite insulator and therefore cannot be performed on such bushings.

The range of type tests and routine tests has been carefully planned, considering that high voltage direct current (HVDC) power transmission is a mature technology, but still with limited service experience compared to AC systems and voltage coordination may vary with different system HVDC design practices.

Work on IEEE Std C57.19.03 edition 1 was started in 1988 within the Working Group on Bushings for DC Applications of the Bushing Subcommittee of the IEEE Transformers Committee. The working group decided to address requirements for these bushings in a self-standing document because many problems specific to this type of bushing were being experienced within the industry and other available standards on bushings were inadequate for this purpose. The main reference for the resulting document was its counterpart for ac bushings, IEEE Std C57.19.00-1991 and IEC 60137. Requirements were also coordinated with the CIGRE Joint Working Group 12/14.10 as well as with the HVDC Converter Transformer and Smoothing Reactor Subcommittee of the IEEE Transformers Committee, which developed standards for these HVDC apparatus during the same time frame.

IEEE Std C57.19.03:1996 was approved by the IEEE-SA Standards Board on 20 June 1996 and published on 6 January 1997. During the reaffirmation process for this document in 2002, several errors in the document were reported. All known errors were corrected in a corrigendum in December 2005. This revised standard includes the corrections made in the corrigendum.

Work on IEC 62199 started in 2000 by IEC SC 36A, the insulated bushings subcommittee of IEC TC 36, the insulators technical committee, and was largely based on IEEE Std C57.19.03. Edition 1 was published in 2004.

After work on the revision of IEEE Std C57.19.03 was started by IEEE it was agreed at a meeting of IEC TC36 in Sao Paulo in 2008 to approach IEEE to establish a Joint Maintenance Team under the Dual Logo Standard procedure. This was agreed and work on the new document IEC/IEEE 65700-19-03 was started in 2009.

BUSHINGS FOR DC APPLICATION

1 Scope

This International Standard applies to outdoor and indoor bushings of any voltage used on DC systems, of capacitance graded or gas insulated types for use as components of oil-filled converter transformers and smoothing reactors, as well as air-to-air DC bushings. This standard does not apply to the following:

- cable terminations (potheads);
- bushings for instrument transformers;
- bushings for test power supplies;
- bushings applied with gaseous insulation (other than air at atmospheric pressure) external to the bushing;
- bushings for industrial application;
- bushings for traction application;
- bushings for distribution class transformers.

This standard makes reference to IEC 60137 for general terms and conditions and defines the special terms used, operating conditions, ratings, test procedures as well as general mechanical and electrical requirements for bushings for DC application.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050, *International Electrotechnical Vocabulary (IEV)*. Available from: <http://www.electropedia.org/>

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-5, *Insulation co-ordination – Part 5: Procedures for high-voltage direct current (HVDC) converter stations*

IEC 60076-1, *Power Transformers – Part 1: General*

IEC 60076-2, *Power Transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-7, *Power Transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60137:2008, *Insulated bushings for alternating voltages above 1000 V*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*