



**IEEE**

**IEC/IEEE 65700-19-03**

Edition 2.0 2025-07

# INTERNATIONAL STANDARD

---

**Bushings for DC application**

IEC/IEEE 65700-19-03 Ed.2.0 - Preview only Copy via ILNAS e-Shop

IEC/IEEE 65700-19-03:2025-07(en)



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2025 IEC, Geneva, Switzerland

Copyright © 2025 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 Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://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](mailto:stds.ipr@ieee.org)  
[www.ieee.org](http://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 publications search - [webstore.iec.ch/advsearchform](http://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 It also gives information on projects, replaced and withdrawn publications.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](http://webstore.iec.ch/justpublished)

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

### IEC Customer Service Centre - [webstore.iec.ch/csc](http://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](mailto:sales@iec.ch).

### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

# CONTENTS

- FOREWORD..... 7
- INTRODUCTION..... 9
- 1 Scope..... 10
- 2 Normative references ..... 10
- 3 Terms, definitions, acronyms and variables ..... 12
  - 3.1 Terms and definitions..... 12
  - 3.2 List of acronyms and variables ..... 14
- 4 Profiles and use of normative references ..... 16
- 5 Ratings..... 16
  - 5.1 Rated voltages..... 16
    - 5.1.1 Rated continuous DC voltage ..... 16
    - 5.1.2 Rated peak voltage ..... 16
    - 5.1.3 Rated harmonic voltages ..... 16
  - 5.2 Insulation levels ..... 16
  - 5.3 Rated currents ..... 16
    - 5.3.1 General ..... 16
    - 5.3.2 Pure DC voltage applications..... 17
    - 5.3.3 Combined voltage applications ..... 17
  - 5.4 Rated frequency ..... 18
  - 5.5 Unified Specific Creepage Distance ..... 18
- 6 Operating conditions..... 20
  - 6.1 General..... 20
  - 6.2 Factors affecting design, testing and application ..... 21
  - 6.3 Altitude correction ..... 22
  - 6.4 Interchangeability ..... 23
  - 6.5 Transformer insulating liquid ..... 23
- 7 General requirements ..... 23
  - 7.1 Nameplate markings ..... 23
- 8 Test requirements..... 24
  - 8.1 General requirements ..... 24
  - 8.2 Test conditions ..... 24
    - 8.2.1 Air temperature..... 24
    - 8.2.2 Humidity ..... 24
    - 8.2.3 Correction factors ..... 24
  - 8.3 Test classification ..... 25
    - 8.3.1 Type (design) tests ..... 25
    - 8.3.2 Routine tests ..... 26
    - 8.3.3 Special tests ..... 26
- 9 Type (design) tests ..... 26
  - 9.1 Dry power-frequency voltage withstand test with partial discharge measurement..... 26
    - 9.1.1 Applicability ..... 26
    - 9.1.2 Test method and requirements ..... 26
    - 9.1.3 Acceptance..... 26
  - 9.2 Dry lightning impulse voltage withstand test (LI or BIL) ..... 26
    - 9.2.1 Applicability ..... 26

9.2.2	Test method and requirements .....	26
9.2.3	Acceptance.....	27
9.3	Dry or wet switching impulse voltage withstand test (SI or BSL).....	27
9.3.1	Applicability .....	27
9.3.2	Test method and requirements .....	27
9.3.3	Acceptance.....	27
9.4	Electromagnetic compatibility tests (EMC) .....	27
9.4.1	Emission test.....	27
9.5	Temperature rise test.....	28
9.5.1	Applicability .....	28
9.5.2	Test method and requirements .....	28
9.5.3	Acceptance.....	29
9.6	Cantilever load withstand test .....	29
9.6.1	Applicability .....	29
9.6.2	Test method and requirements .....	29
9.6.3	Acceptance.....	30
9.7	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings.....	30
9.8	Internal pressure test on gas-filled, gas-insulated and gas-impregnated bushings .....	31
9.9	Verification of dimensions .....	31
9.10	Draw-lead bushing cap pressure test .....	31
9.10.1	Applicability .....	31
9.10.2	Test method and requirements .....	31
9.10.3	Acceptance.....	31
10	Routine tests .....	31
10.1	Measurement of dielectric dissipation factor ( $\tan \delta$ ) and capacitances .....	31
10.1.1	Applicability .....	31
10.1.2	Test method and requirements .....	31
10.1.3	Acceptance.....	31
10.2	Dry lightning impulse voltage withstand test (LI or BIL) .....	32
10.2.1	Applicability .....	32
10.2.2	Test method and requirements .....	32
10.2.3	Acceptance.....	32
10.3	Dry power-frequency voltage withstand test with partial discharge measurement.....	32
10.3.1	Applicability .....	32
10.3.2	Test method and requirements .....	32
10.3.3	Acceptance.....	33
10.4	DC applied voltage withstand test with partial discharge measurement .....	34
10.4.1	Applicability .....	34
10.4.2	Test method and requirements .....	34
10.4.3	Acceptance.....	35
10.5	Polarity reversal test with partial discharge measurement .....	35
10.5.1	Applicability .....	35
10.5.2	Test method and requirements .....	35
10.5.3	Acceptance.....	37
10.6	Dry switching impulse voltage withstand test.....	37
10.6.1	Applicability .....	37
10.6.2	Test method and requirements .....	37

10.6.3	Acceptance.....	38
10.7	Test of tap insulation.....	38
10.8	Internal pressure test on gas-filled, gas-insulated, and gas-impregnated bushings .....	38
10.9	Tightness test on liquid-filled, compound-filled and liquid-insulated bushings .....	38
10.10	Tightness test on gas-filled, gas-insulated and gas-impregnated bushings .....	38
10.11	Tightness test at the flange or other fixing device .....	38
10.12	Visual inspection and dimensional check .....	38
11	Special tests.....	38
11.1	General.....	38
11.2	Artificial pollution test.....	38
11.2.1	Applicability .....	38
11.2.2	Test method and requirements .....	38
11.2.3	Acceptance.....	39
11.3	Even wetting DC voltage test .....	39
11.3.1	Applicability .....	39
11.3.2	Test method and requirements .....	39
11.3.3	Acceptance.....	39
12	Recommendations for transport, storage, erection, operation, and maintenance.....	39
12.1	General.....	39
12.2	Conditions during transport, storage, and installation .....	40
12.3	Installation .....	40
12.4	Unpacking and lifting .....	40
12.5	Assembly .....	40
12.5.1	General .....	40
12.5.2	Mounting .....	40
12.5.3	Connections .....	41
12.5.4	Final installation inspection.....	41
12.6	Operation.....	41
12.7	Maintenance .....	42
12.7.1	General .....	42
12.7.2	Recommendation for the manufacturer .....	42
12.7.3	Recommendations for the user .....	42
12.7.4	Failure report.....	43
13	Safety.....	44
13.1	General.....	44
13.2	Electrical aspects.....	44
13.3	Mechanical aspects .....	44
13.4	Thermal aspects .....	44
14	Environmental aspects .....	44
Annex A (informative) Bushings used in voltage source converters (VSC) HVDC schemes .....		45
A.1	Overview.....	45
A.2	Design .....	47
Annex B (informative) Temperature rise test methods for the determination of the equivalent test circuit.....		49
B.1	Overview.....	49
B.2	Basics concerning the losses in distorted operation .....	49
B.3	Analytical calculation .....	50

B.4	Finite element method calculation .....	50
B.5	Calculation by enhancement factors as described in IEC 61378-1 .....	51
B.6	Examples of calculation based on different approaches .....	52
B.6.1	General .....	52
B.6.2	Analytical method .....	53
B.6.3	Finite Element Method .....	55
B.6.4	Enhancement factor according to IEC 61378–1 .....	56
Annex C (informative)	Typical HVDC topologies.....	58
C.1	Overview.....	58
C.2	Typical LCC topologies .....	58
C.3	Typical VSC topologies .....	61
Annex D (informative)	Uneven wetting DC voltage test .....	63
D.1	Overview.....	63
D.2	Historical background to uneven wetting DC voltage test .....	63
D.3	Test description .....	63
D.3.1	Test method and requirements .....	63
D.3.2	Acceptance.....	64
Annex E (informative)	Examples of calculation of minimum creepage and arcing distances under polluted conditions .....	65
E.1	General.....	65
E.2	Transformer and wall bushings for combined voltage applications.....	65
E.3	Wall bushings for pure DC voltage application .....	69
Annex F (informative)	IEC / IEEE cross references .....	73
Bibliography	.....	75
Figure 1	– Factor $m$ on the coordination switching impulse withstand voltage .....	22
Figure 2	– Polarity reversal test profile.....	36
Figure A.1	– Two-level VSC HVDC converter station applied in a bipolar scheme with DC cable transmission .....	46
Figure A.2	– Multi-level VSC HVDC converter station applied in a monopolar scheme with DC overhead line transmission .....	47
Figure C.1	– Explanation of symbols .....	58
Figure C.2	– Bipolar LCC configuration with two 6-pulse bridges per pole .....	59
Figure C.3	– Bipolar LCC configuration with four 6-pulse bridges per pole. Only one pole is shown but that pole follows the same principle .....	60
Figure C.4	– Mid-point earthed LCC converter configuration with two 6-pulse bridges per converter. Often used for Back-to-Back configurations.....	61
Figure C.5	– Symmetric VSC converter configuration.....	61
Figure C.6	– Asymmetric VSC converters forming a bipolar configuration .....	62
Figure E.1	– Composite insulator real geometry.....	70
Figure E.2	– Composite insulator simplified geometry .....	71
Table 1	– Temperature of ambient air and immersion media .....	20
Table 2	– Type, routine, and special tests .....	25
Table 3	– Minimum values of cantilever withstand load .....	30
Table 4	– Maximum values of $\tan \delta$ and $\tan \delta$ increase.....	32
Table 5	– Maximum values of partial discharge quantity.....	34

Table B.1 – Valve side connected bushing current harmonic spectrum .....	52
Table B.2 – Calculation based on the analytical method .....	54
Table B.3 – Calculation based on Finite Element Method.....	55
Table B.4 – Calculation based on IEC 61378-1 enhancement factor $F_{CE}$ .....	56

## 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 document(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 <https://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.

IEC/IEEE 65700-19-03 has been prepared by a joint working group of sub-committee 36A: Insulated bushings, of IEC technical committee 36: Insulators and Bushing, in cooperation with subcommittee of the IEEE-PES transformer committee, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE. It is an International Standard.

This document is published as an IEC/IEEE Dual Logo standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) 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*, and IEEE Std C57.19.00™, *IEEE Standard General Requirements and Test Procedures for Outdoor Power Apparatus Bushings*;
- b) inclusion of voltage source converter (VSC) technologies

The text of this International Standard is based on the following IEC documents:

Draft	Report on voting
36A/255/FDIS	36A/260/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with the rules given in the ISO/IEC Directives, Part 2, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications/](http://www.iec.ch/publications/).

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

## INTRODUCTION

In this second 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*

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

Voltage source converter (VSC) technologies have also been included.