IEC/IEEE 65700-19-03

Edition 2.0 2025-07

INTERNATIONAL STANDARD

Bushings for DC application

ICS 29.080.20

ISBN 978-2-8327-0383-0

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

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 δ) 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 δ and tan δ 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

© IEC/IEEE 2025

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. The main document types developed by IEC are described in greater detail at 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 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.

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 liquid-filled converter transformers and smoothing reactors, as well as air-to-air DC bushings. It applies to both line commutated converter (LCC), as well as voltage source converter (VSC) technologies. This document 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 document refers 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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE For this document, bushings complying with IEC standards (IEC profile, 3.1.20) refer to IEC documents, and bushings complying with IEEE standards (IEEE profile, 3.1.21) refer to IEEE documents, unless stated otherwise. A cross-reference list is given in Annex F.

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 60071-11, *Insulation co-ordination – Part 11 : Definitions, principles and rules for HVDC system*

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 mineral-oil-immersed power transformers*

IEC 60137:2017, *Insulated bushings for alternating voltages above 1 000 V*

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

IEC 60296, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF_6) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60422, *Mineral insulating oils in electrical equipment – Supervision and maintenance guidance*

IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC TS 60815-2, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

IEC TS 60815-4, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 4: Insulators for d.c. systems*

IEC TS 61245, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on d.c. systems*

IEC 61462, *Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with AC rated voltage greater than 1 000 V AC and D.C. voltage greater than 1 500 V – Definitions, test methods, acceptance criteria and design recommendations*

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

IEC/IEEE 60076-57-129:2017, *Power transformers – Part 57-129: Transformers for HVDC applications*

IEEE Std 4™, *IEEE Standard Techniques for High-Voltage Testing*

IEEE Std 430™, *IEEE Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines and Substations*

IEEE Std C37.123™, *IEEE Guide to Specifications for Gas-Insulated, Electric Power Substation Equipment*

IEEE Std C62.82.1™, *IEEE Standard for Insulation Coordination – Definitions, Principles, and Rules*

IEEE Std C62.82.2™, *IEEE Guide for the Application of Insulation Coordination*

IEEE Std C57.106™, *IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment*

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

IEEE Std C57.12.00™, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.10™, *IEEE Standard Requirements for Liquid-Immersed Power Transformer*

IEEE Std C57.12.80™, *IEEE Standard Terminology for Power and Distribution Transformers*

IEEE Std C57.12.90™, *IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.91™, *IEEE Standard Test Code for Dry-Type Distribution and Power Transformers*

IEEE Std C57.19.00™, *IEEE General Requirements and Test Procedures for Outdoor Apparatus Bushings (ANSI)*

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

IEEE Std C57.19.100™ *IEEE Guide for Application of Power Apparatus Bushings*

IEC/IEEE 60076-57-129:2017, *Power transformers – Part 57-129: Transformers for HVDC applications*

CISPR 16-1 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods*

CISPR 18-2, *Radio interference characteristics of overhead power lines and high-voltage equipment – Parts 2: Methods of measurement and procedure for determining limits*

---

1 Subscription is available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.