INTERNATIONAL
STANDARD

NORME
INTERNATIONALE

Insulated bushings for alternating voltages above 1 000 V

Traversées isolées pour tensions alternatives supérieures à 1 000 V
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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Insulated bushings for alternating voltages above 1 000 V

Traversées isolées pour tensions alternatives supérieures à 1 000 V

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 29.080.20

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSULATED BUSHINGS FOR ALTERNATING VOLTAGES ABOVE 1 000 V

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. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60137 has been prepared by sub-committee 36A: Insulated bushings, of IEC technical committee 36: Insulators.

This seventh edition cancels and replaces the sixth edition, published in 2008, and constitutes a technical revision.

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

- Resin-impregnated synthetic (RIS) bushings has been introduced.
- Bushings with \( U_m \leq 1.1 \text{kV}, U_m = 1 \text{100 kV} \) and \( U_m = 1 \text{200 kV} \) have been introduced.
- Temperature rise testing has been included for liquid-insulated bushings according to clause to 3.4.
- Introducing dry lightning impulse testing as a routine test for all transformer bushings with \( U_m > 72.5 \text{kV} \).
- The altitude correction procedure has been revised ( > 1 000 m).
• An explanation about Very Fast Transient (VFT) phenomenon and its impact on bushings has been included.

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

<table>
<thead>
<tr>
<th>FDIS</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>36A/187/FDIS</td>
<td>36A/189/RVD</td>
</tr>
</tbody>
</table>

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

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

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

• reconfirmed,
• withdrawn,
• replaced by a revised edition, or
• amended.
INTRODUCTION

In the preparation of the current edition of this standard further consideration has been given to the test requirements for power transformers as described in IEC 60076-3:2013.
1 Scope

This International Standard specifies the characteristics and tests for insulated bushings.

This standard is applicable to bushings, as defined in Clause 3, intended for use in electrical apparatus, machinery, transformers, switchgear and installations for three-phase alternating current systems, having highest voltage for equipment above 1 000 V and power frequencies of 15 Hz up to and including 60 Hz.

Subject to special agreement between purchaser and supplier, this standard may be applied, in part or as a whole, to the following:

- bushings used in other than three-phase systems;
- bushings for high-voltage direct current systems;
- bushings for testing transformers;
- bushings for capacitors.

Special requirements and tests for transformer bushings in this standard apply also to reactor bushings.

This standard is applicable to bushings made and sold separately. Bushings which are a part of an apparatus and which cannot be tested according to this standard should be tested with the apparatus of which they form part.

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.

IEC 60038, IEC standard voltages


IEC 60059, IEC standard current ratings

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

IEC 60068-2-17:1994, Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing

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

IEC 60076-5, Power transformers – Part 5: Ability to withstand short circuit

IEC 60076-7, Power transformers – Part 7: Loading guide for oil-immersed power transformers
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IEC 60216-2, Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria

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

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

IEC 60376, Specification of technical grade sulfur hexafluoride (SF₆) for use in electrical equipment

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

IEC 60480, Guidelines for the checking and treatment of sulfur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use

IEC 60505, Evaluation and qualification of electrical insulation systems

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 61099, Insulating liquids – Specifications for unused synthetic organic esters for electrical purposes

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

IEC TS 61463, Bushings – Seismic qualification

IEC 62155:2003, Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V

IEC 62217, Polymeric HV insulators for indoor and outdoor use – General definitions, test methods and acceptance criteria

IEC 62271-1, High-voltage switchgear and controlgear – Part 1: Common specifications

IEC Guide 109, Environmental aspects – Inclusion in electrotechnical product standards

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
3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 bushing
device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulates the conductors from it; the means of attachment (flange or fixing device) to the partition forms part of the bushing

Note 1 to entry: The conductor may form an integral part of the bushing or be drawn into the central tube of the bushing.


3.2 liquid-filled bushing
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with mineral oil or other insulating liquid

3.3 compound-filled bushing
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with an insulating compound

3.4 liquid-insulated bushing
bushing in which the major insulation consists of mineral oil or another insulating liquid, enclosed by an insulating envelope

Note 1 to entry: These bushings are often of an open design which require proper processing after installation in order to avoid trapped air and subsequent partial discharges during testing or in service.

3.5 gas-filled bushing
bushing in which the space between the inside surface of the insulating envelope and the solid major insulation is filled with gas (other than ambient air) at atmospheric pressure or higher

Note 1 to entry: This definition includes bushings which are intended to form an integral part of gas-insulated equipment, the gas of the equipment being in communication with that of the bushing.

3.6 gas-insulated bushing
bushing in which the major insulation consists of gas (other than ambient air) at atmospheric pressure or higher

Note 1 to entry: This definition includes bushings which are intended to form an integral part of gas-insulated equipment, the gas of the equipment being in communication with that of the bushing.

Note 2 to entry: A bushing which contains solid insulating materials other than the envelope containing the gas (e.g. support for conducting layers or insulating cylinder), is a combined insulation bushing (see 3.14).

Note 3 to entry: A bushing in which the desired voltage grading is obtained by an arrangement of conducting or semi-conducting layers incorporated in an insulating material (e.g. plastic film) is referred to as a gas insulated capacitance graded bushing.
3.7 **gas-impregnated bushing**
bushing in which the major insulation consists of a core wound from paper or plastic film (GIF) and subsequently treated and impregnated with gas (other than ambient air) at atmospheric pressure or higher

Note 1 to entry: the core is contained in an insulating envelope. The space between the core and the insulating envelope being filled with the same gas as used for the impregnation.

3.8 **oil-impregnated paper bushing**
OIP busing in which the major insulation consists of a core wound from paper and subsequently treated and impregnated with an insulating liquid, generally mineral oil

Note 1 to entry: The core is contained in an insulating envelope, the space between the core and the insulating envelope being filled with the same insulating liquid as that used for impregnation.

3.9 **resin-bonded paper bushing**
RBP busing in which the major insulation consists of a core wound from resin-coated paper

Note 1 to entry: During the winding process, each paper layer is bonded to the previous layer by its resin coating and the bonding achieved by curing the resin.

Note 2 to entry: A resin-bonded paper bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

3.10 **resin-impregnated paper bushing**
RIP busing in which the major insulation consists of a core wound from untreated paper and subsequently impregnated with a curable resin

Note 1 to entry: A resin-impregnated paper bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

3.11 **resin-impregnated synthetics bushing**
RIS busing in which the major insulation consists of a core wound from synthetics subsequently impregnated with a curable resin

Note 1 to entry: A resin-impregnated synthetics bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

Note 2 to entry: If not otherwise stated by the manufacturer, bushings in accordance with 3.11 shall be considered as RIP bushings according 3.10.

3.12 **ceramic, glass or analogous inorganic material bushing**
bushing in which the major insulation consists of a ceramic, glass or analogous inorganic material

3.13 **cast or moulded resin-insulated bushing**
bushing in which the major insulation consists of a cast or moulded organic material with or without an inorganic filler
3.14 **combined insulation bushing**
bushing in which the major insulation consists of a combination of at least two different insulating materials

3.15 **capacitance graded bushing**
bushing, in which a desired voltage grading is obtained by an arrangement of conducting or semiconducting layers incorporated into the insulating material


3.16 **indoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure, but not exposed to outdoor atmospheric conditions


3.17 **outdoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure and exposed to outdoor atmospheric conditions


3.18 **outdoor-indoor bushing**
bushing, both ends of which are intended to be in ambient air at atmospheric pressure. One end is intended to be exposed to outdoor atmospheric conditions, and the other end not to be exposed to outdoor atmospheric conditions


3.19 **indoor-immersed bushing**
bushing, one end of which is intended to be in ambient air but not exposed to outdoor atmospheric conditions and the other end to be immersed in an insulating medium other than ambient air (e.g. liquid or gas)

Note 1 to entry: This definition includes bushings operating in air at temperatures above ambient, such as occur with air-insulated ducting.


3.20 **outdoor-immersed bushing**
bushing, one end of which is intended to be in ambient air and exposed to outdoor atmospheric conditions and the other end to be immersed in an insulating medium other than ambient air (e.g. liquid or gas)


3.21 **completely immersed bushing**
bushing, both ends of which are intended to be immersed in an insulating medium other than ambient air (e.g. liquid or gas)
3.22 plug-in type bushing
bushing for separable connector
bushing, one end of which is immersed in an insulating medium and the other end designed to receive a separable insulated cable connector, without which the bushing cannot function

3.23 highest voltage for equipment
$U_m$
highest r.m.s. value of phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standard

3.24 rated phase-to-earth voltage
maximum r.m.s. value of the voltage which the bushing withstands continuously between the conductor and the earthed flange or other fixing device, under the operating conditions specified in Clause 5

3.25 rated current
$I_r$
maximum r.m.s. value of current which the bushing can carry continuously under the operating conditions specified in Clause 5, without exceeding the temperature rise limits of Table 2

3.26 rated thermal short-time current
$I_{th}$
r.m.s. value of a symmetrical current which the bushing withstands thermally for the rated duration ($t_{th}$) immediately following continuous operation at rated current with maximum temperatures of ambient air and immersion media in accordance with 5.3

3.27 rated dynamic current
$I_d$
peak value of a current which the bushing withstands mechanically

3.28 temperature rise
difference between the measured temperature of the hottest spot of the metal parts of the bushing which are in contact with insulating material and the ambient air temperature (see 4.8)

3.29 rated frequency
$f_r$
frequency at which the bushing is designed to operate
3.30 **rated filling pressure of gas for insulation**

the pressure in Pascal (Pa) for insulation referred to the standard atmospheric conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the bushing is filled before being put into service, or automatically replenished.

3.31 **maximum internal operating gas pressure**

pressure, when the bushing is in operation, carrying rated current at the highest temperatures in accordance with 5.3

3.32 **maximum external operating gas pressure**

maximum pressure of the gaseous insulating medium in which the bushing is partially or completely immersed when in operation.

3.33 **design pressure** (of the enclosure)

pressure used to determine the thickness of the enclosure.

3.34 **leak rate** (of gas-filled, gas-insulated, gas-impregnated and gas-immersed bushings)

quantity of dry gas at a given temperature that flows through a leak per unit of time and for a known difference of pressure across the leak.

Note 1 to entry: The basic SI unit for leak rate is “Pascal cubic metre per second (Pa × m$^3$/s)”. The derived units “Pa × cm$^3$/s” and “bar × cm$^3$/s” are used in this standard, as they better conform to the orders of magnitude used in common industrial practice. It should be remembered that: 1 Pa × m$^3$/s = 10$^6$ Pa × cm$^3$/s = 10 bar × cm$^3$/s.

[source: IEC 60068-2-17:1994, 1.1]

3.35 **hollow insulator**

insulator which is open from end to end, with or without sheds.

Note 1 to entry: An insulating envelope may consist of one insulator unit or two or more permanently assembled insulator units.

[source: IEC 60050-471:2007, 471-01-8, modified (removal of "including end fittings", modified Note 1 to entry)]

3.36 **creepage distance**

shortest distance along the surface of an insulator between two conductive parts.

Note 1 to entry: The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

Note 2 to entry: If high-resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.


3.37 **arcing distance**

shortest distance in air external to the insulator between metallic parts which normally have the operating voltage between them.

Note 1 to entry: The terms “dry arcing distance” or “taut string distance” are also used.
Note 2 to entry: The arcing distance may be shorter than the values for external clearances in air stated in IEC 60076-3.

[SOURCE: IEC 60050-471:2007, 471-01-01, modified (Notes to entry added)]

3.38 test tap measuring tap tanδ tap
connection, accessible from outside the bushing, insulated from the flange or other fixing device, made to one of the outer conducting layers of a capacitance graded bushing in order to allow measurements of dissipation factor, capacitance and partial discharge whilst the flange of the bushing is earthed

Note 1 to entry: This connection should be earthed directly when it is not used.

Note 2 to entry: When the test tap is used for condition monitoring, in service, care should be taken to avoid an open circuit.

3.39 voltage tap potential tap capacitance tap
connection, accessible from outside the bushing, insulated from the flange or other fixing device, made to one of the outer conducting layers of a capacitance graded bushing in order to provide a voltage source whilst the bushing is in operation

Note 1 to entry: This connection should be earthed directly when it is not used.

Note 2 to entry: This tap can also be used for the measurement of dissipation factor, capacitance and partial discharge.

3.40 rated voltage of the voltage tap
maximum voltage at which the tap is designed to supply the associated equipment, with the rated load connected thereto, when the rated phase-to-earth voltage is applied to the bushing at the rated frequency

3.41 composite bushing
bushing with an insulating envelope consisting of a resin impregnated fibre tube with or without a polymeric compound covering

Note 1 to entry: For bushings defined in 3.9 to 3.13, the polymeric compound may be applied directly on to the bushing major insulation.

3.42 capacitance (of bushing)

3.42.1 main capacitance \( C_1 \)
capacitance between the high-voltage conductor and the test tap or the voltage tap of a capacitance-graded bushing

3.42.2 tap capacitance \( C_2 \)
capacitance between the test tap or the voltage tap and the mounting flange of a capacitance-graded bushing