

IEEE Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V

IEEE Power and Energy Society

Sponsored by the
Switchgear Committee

IEEE
3 Park Avenue
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USA

IEEE Std C37.100.1™-2018
(Revision of IEEE Std C37.100.1-2007)

IEEE Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V

Sponsor

Switchgear Committee
of the
IEEE Power and Energy Society

Approved 5 December 2018

IEEE-SA Standards Board

Abstract: This standard applies to alternating current (ac) switchgear, designed for both indoor and outdoor installation and for operation at service frequencies up to and including 60 Hz on systems having voltages above 1000 V.

This standard is applied in relevant equipment standards by a normative reference to this standard, IEEE Std C37.100.1, on a section or clause-by-clause basis. [Annex A](#) of this standard provides recommendations for its application. The inclusion of this standard as a normative reference shall not imply that all of the requirements contained herein apply as a default. In the absence of a normative reference, this standard shall be considered informative only. In case of a conflict in requirements, the requirements of the relevant equipment standard shall prevail.

Keywords: common, IEEE C37.100.1, rated, rating, requirement, specification, switch, switchgear, test

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Introduction

This introduction is not part of IEEE Std C37.100.1-2018, IEEE Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V.

This document, with the exception of formatting and reference updates, is exactly the same as IEEE C37.100.1-2007 having made no technical changes. There was a revised document that was heavily harmonized with IEC; however, copyright permission was ultimately not obtained. In order to comply with the copyright complaint and in light of the impending expiration of the active document, IEEE Std C37.100.1-2007, the decision was made to revert back to the 2007 version of the document and only update the formatting.

This standard was written specifically to collect into one document the requirements that are common in many IEEE power switchgear standards. It follows the concept already in place in IEC 62271-1 [B23]. In some cases, the requirements are equivalent to those in several existing switchgear standards; in other cases, they represent a compromise among two or more standards that have minor (or moderate) differences in the requirement. Still other requirements are taken from IEC 62271-1 [B23].

One distinct exception is the treatment of altitude correction factors or air density correction factors. This standard introduces a departure from the historical approach for altitude correction factors as they apply to applications above 1000 m. Refer to 3.3.2 and Annex B for these details.

The expected benefits of this common requirements concept is to reduce many of the minor inconsistencies among the various switchgear standards and, where differences must remain, to have them highlighted by exception to these common requirements.

It is the intention of the IEEE Switchgear Committee that the relevant (switchgear) standards will adopt the provisions of this standard by normative reference. Specific clauses may be adopted as follows:

- a) Without exception (the default)
- b) With exceptions
- c) With additional requirements or a combination of item b) and item c), as deemed appropriate to the relevant standard

Refer to Annex A for specific recommendations for use with a relevant standard.

In an effort to promote harmonization, this standard is formatted similar to IEC 62271-1 [B23].

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IEEE Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V

1. Overview

1.1 Scope

This standard applies to alternating current (ac) switchgear, designed for both indoor and outdoor installation and for operation at service frequencies up to and including 60 Hz on systems having voltages above 1000 V.

This standard is applied in relevant equipment standards by a normative reference to this standard, IEEE Std C37.100.1, on a section or clause-by-clause basis. [Annex A](#) of this standard provides recommendations for its application.

The inclusion of this standard as a normative reference shall not imply that all of the requirements contained herein apply as a default. In the absence of a normative reference, this standard shall be considered informative only. In case of a conflict in requirements, the requirements of the relevant equipment standard shall prevail.

NOTE 1—In general, this standard applies to all high-voltage power switchgear designed to IEEE C37™ series. Exceptions include low-voltage standards (less than 1000 V) and protective relay standards.¹

NOTE 2—For the use of this standard, “high voltage” (see IEV 601-01-27)² is the rated voltage above 1 kV. However, the term “medium voltage” (see IEV 601-01-28) is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV.

NOTE 3—There are many common requirements found in the IEEE C37 switchgear standards. These include service conditions, ratings, such as temperature rise limits, and test methods. This common requirements standard is provided to promote standardization of the requirements and to simplify the maintenance of these standards.

1.2 Purpose

This document does not include a purpose statement.

¹Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

²IEV refers to the International Electrotechnical Vocabulary and may be found in IEC 60050-XXX standards [B1], [B2], [B3], [B4], [B5]. For more information on these references, see the bibliography in [Annex K](#).

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.

NOTE 1—References to IEC standards are either informative or offer an alternative to an IEEE standard. The user is cautioned that the IEEE standard and the IEC standard, while comparable, may not be equivalent. The use of an IEC standard should be based on agreement among the user, the manufacturer, and the certifying test laboratory. Use of an IEC standard for a design (type) test should be noted in the test report.

NOTE 2—International standards not referenced in this clause are to be considered informative and are listed in the bibliography in [Annex K](#).

ANSI C37.85, American National Standard for Switchgear—Alternating-Current High-Voltage Power Vacuum Interrupters—Safety Requirements for X-Radiation Limits.³

ANSI C63.2, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications.

ASTM D 2472, Standard Specification for Sulfur Hexafluoride.⁴

CISPR 11, Industrial, scientific and medical (ISM) radio-frequency equipment—Electromagnetic disturbance characteristics—Limits and methods of measurement.⁵

IEC 60060-1, High-voltage test techniques—Part 1: General definitions and test requirements.⁶

IEC 60060-2, High-voltage test techniques—Part 2: Measuring systems.

IEC 60085, Electrical insulation—Thermal classification.

IEC 60417, Graphical symbols for use on equipment.

IEC 60529, Degrees of Protection Provided by Enclosures (IP Code).

IEC/TR 62271-300, High-voltage switchgear and controlgear—Part 300: Seismic qualification of alternating current circuit-breakers.

IEEE Std 1™, IEEE Recommended Practice—General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation.^{7, 8}

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

³ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁴ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

⁵CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembe, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations.

IEEE Std C37.122.5™, IEEE Guide for Moisture Measurement and Control in SF₆ Gas-Insulated Equipment.

IEEE Std C37.301™, IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques—Partial Discharge Measurements.

IEEE Std 1313.2™, IEEE Guide for the Application of Insulation Coordination.

IEEE Std C37.010™, IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.24™, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear.

IEEE Std C37.81™, IEEE Guide for Seismic Qualification for Class 1E Metal-Enclosed Power Switchgear Assemblies.

IEEE Std C37.90.1™, IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.

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

NEMA 107, Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus.⁹

NEMA CC 1, Electric Power Connectors for Substations.

NEMA MG 1, Motors and Generators.

3. Normal (usual) and special (unusual) service conditions

3.1 General

Unless otherwise specified, switchgear, including the operating devices and the auxiliary equipment that form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal (usual) service conditions listed in 3.2.

If any of the actual service condition requirements differ from these normal (usual) service conditions, switchgear and associated operating devices and auxiliary equipment shall be designed to comply with any special conditions required by the user, or appropriate application arrangements shall be made. (See 3.3.)

NOTE—Appropriate action should also be taken to ensure proper operation of other components, such as relays.

⁹ NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

3.2 Normal (usual) service conditions

3.2.1 Indoor switchgear

The normal (usual) service conditions for indoor switchgear are as follows:

- a) The ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is –30 °C for class “minus 30 indoor.”
- b) The influence of solar radiation may be neglected.
- c) The altitude does not exceed 1000 m above sea level. (Switchgear ratings are based on sea level. See [Annex B](#) for considerations at application above sea level.)
- d) The ambient air is not significantly polluted and would be classified as having pollution level I “light” according to [Table C.1](#) in [Annex C](#).
- e) The conditions of humidity are as follows:

- 1) The average value of the relative humidity, measured over a period of 24 h, does not exceed 95%.
- 2) The average value of the relative humidity, over a period of one month, does not exceed 90%. For these conditions, condensation may occasionally occur.

NOTE 1—Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2—To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed and tested for such conditions should be used.

NOTE 3—Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear. Condensation may also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

- f) Vibration due to causes external to the switchgear and controlgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the low performance level defined in IEEE Std 693.¹⁰ The manufacturer will assume that, in the absence of specific requirements from the user, there are none.¹¹

3.2.2 Outdoor switchgear

The normal (usual) service conditions for outdoor switchgear are as follows:

- a) The ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is –30 °C for class “minus 30 outdoor.”

Rapid temperature changes should be taken into account.

- b) Solar radiation as much as 1044 W/m² (a clear day at noon). The specific latitude of location should be considered. See IEEE Std C37.24 for details on evaluating the effects of solar radiation.

NOTE 1—Under certain conditions of solar radiation, appropriate measures, e.g., roofing, forced ventilation, etc., may be necessary or derating may be used in order not to exceed the specified allowable temperature rises.

- c) The altitude does not exceed 1000 m above sea level. (Switchgear ratings are based on sea level. See [Annex B](#) for considerations at application above sea level.)

¹⁰For information on references, see [Clause 2](#).

¹¹The interpretation of the term “insignificant” is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his or her analysis shows that the risk is “insignificant.”

- d) The ambient air may be polluted by dust, smoke, corrosive gas vapors, or salt. The pollution does not exceed the pollution level II—medium according to [Table C.1](#) in [Annex C](#).
- e) The ice coating, particularly for equipment with exposed movable parts, does not exceed 1 mm. Refer to the relevant equipment standards for specific ice ratings and requirements.

NOTE 2—Typical ice classes are 1 mm for class 1, 10 mm for class 10, and 20 mm for class 20.

- f) The wind speed does not exceed 40 m/s (144 km/h) (90 mi/h).¹²
- g) The presence of condensation and/or precipitation should be taken into account.

NOTE 3—Characteristics of precipitation are defined in IEEE Std 4.

- h) Vibration due to causes external to the switchgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the low performance level defined in IEEE Std 693. The manufacturer will assume that, in absence of specific requirements from the user, there are none.¹³

3.3 Special (unusual) service conditions for both indoor and outdoor switchgear

3.3.1 General

When switchgear may be used under conditions that are different from the normal service conditions given in [3.2.1](#) and [3.2.2](#), the user's requirements should refer to the standardized steps in [3.3.2](#) through [3.3.7](#).

3.3.2 Altitude

The basis of rating for switchgear is standard reference atmosphere, commonly known as sea level conditions. Historically, switchgear has been successfully applied at altitudes up to 1000 m without the use of an altitude correction factor.

For installations at an altitude higher than 1000 m, the required insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels at sea level by the altitude correction factor K_a in accordance with [Figure 1](#).

3.3.3 Exposure to excessive pollution

For installation in a location with polluted ambient air, a pollution level from [Table C.1](#) in [Annex C](#) should be selected.

3.3.4 Temperature and humidity

For installation in a location where the ambient temperature can be outside the normal (usual) service condition range stated in [3.2.1](#) and [3.2.2](#), the preferred ranges of minimum and maximum temperature to be specified should be selected from one of the following:

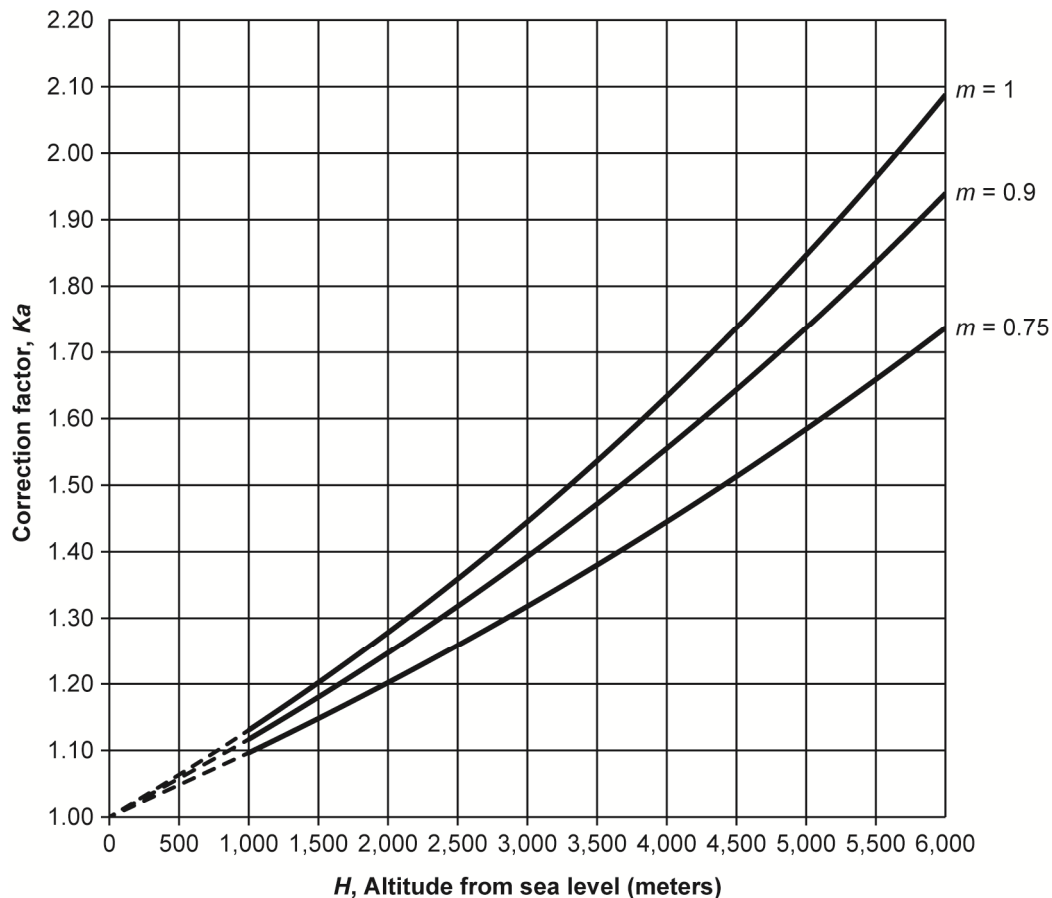
- a) $-40\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$ for cold climates (class “minus 40 outdoor” or class “minus 40 indoor”)
- b) $-50\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$ for very cold climates (class “minus 50 outdoor”)

¹²Actual conversion: 40 m/s = 89.48 mi/h; 40.2 m/s = 90 mi/h.

¹³See Footnote 11.

- c) $-15\text{ }^{\circ}\text{C}$ and $+50\text{ }^{\circ}\text{C}$ for hot climates
- d) $-5\text{ }^{\circ}\text{C}$ and $+55\text{ }^{\circ}\text{C}$ for very hot climates

NOTE—IEC switchgear standards have preferred special (unusual) service conditions for minimum and maximum temperature of $-50\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$ for very cold climates and $-5\text{ }^{\circ}\text{C}$ and $+55\text{ }^{\circ}\text{C}$ for very hot climates.



The altitude correction factor can be calculated with the following equation taken from 4.2.2 of IEC 60071-2:1996 [B9]:

$$K_a = e^{m \left(\frac{H}{8150} \right)}$$

where

H is the altitude (meters)

m is taken as fixed value in each case for simplification as follows:

- $m = 1$ for power-frequency, lightning impulse, and phase-to-phase switching impulse voltages
- $m = 0.9$ for longitudinal switching impulse voltage (i.e., across the isolation gap)
- $m = 0.75$ for phase-to-earth switching impulse voltage

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Figure 1—Altitude correction factor

Humidity varies widely throughout application locations, seasons, and daily conditions. Users should be aware that, like relative air density discussed in [Annex B](#), extreme humidity conditions (arid or desert environments) might affect the dielectric strength of air. Users should consult IEEE Std 4 for humidity correction that may be appropriate in their specific application.

The use of apparatus in an ambient temperature lower than $-30\text{ }^{\circ}\text{C}$ or higher than $40\text{ }^{\circ}\text{C}$ shall be considered as special. Temperatures below $-30\text{ }^{\circ}\text{C}$ create a harsh environment for switchgear. Many users in colder climates routinely experience $-50\text{ }^{\circ}\text{C}$ temperatures. The following should be considered for low ambient temperature environments:

- Operating times may be slower than rated times.
- Wax precipitation of insulating oil “cloud point” may occur where the oil becomes extremely viscous, creating excessive drag.
- Humidity in air system freezes, sticking operating and blast valves.
- Liquefaction of sulfur hexafluoride (SF_6) may occur, necessitating derating of interrupting ratings and dielectric ratings unless heaters are utilized.
- Embrittlement of plastics, composites, and metals may lead to failure during breaker or switching device operation.
- Hydraulic or pneumatic equipment, including fluid dampers, may be affected.
- Special lubricants may be required to prevent sluggishness or freezing of bearings.
- Density and pressure switches may malfunction or may be out of range.
- Heaters for the mechanism or gas may be required.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature and/or atmospheric pressure may occur, resulting in condensation even indoors. In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be as high as 98%.

3.3.5 Exposure to abnormal vibration, shock, or tilting

Standard switchgear is designed for mounting on substantially level structures free from vibration, shock, or tilting. Where any of these abnormal conditions exists, recommendations for the particular application should be obtained from the manufacturer.

For installations where earthquakes are likely to occur, the user should specify a severity level in accordance with IEEE Std 693.¹⁴ For nuclear Class 1E equipment, the user should specify a level in accordance with IEEE Std C37.81. Other unusual forms of vibration such as close proximity to mine blasting or mobile applications should be identified. The user should specify the operational requirements, including whether functionality must be maintained:

- Before and after the seismic event, or
- Before, during, and after the seismic event

¹⁴The severity level of earthquakes may also be determined in accordance with IEC/TR 62271-300.

3.3.6 Other special (unusual) service conditions

3.3.6.1 Exposure to damaging fumes, vapor, steam, oil vapors, salt air, and hot and humid climate

Equipment that may be exposed to damaging fumes, vapor, steam, oil vapors, salt air, and hot and humid climate should be protected. One or more of the following precautions should be considered:

- a) Provision may be necessary to avoid condensation on all electrical insulation and current-carrying parts.
- b) Insulation and bushings with extra creep distance may be required.
- c) In cases where particular exposure represents a hazard to insulation integrity, special maintenance including insulator washing may be necessary.
- d) Materials resistant to fungus growth may be required.
- e) Installation in a positive pressure room system with appropriate filtration equipment may be required.
- f) Installation of heaters in mechanism cabinets and indoor switchgear may be required.

3.3.6.2 Exposure to excessive dust or abrasive, magnetic, or metallic dust

Equipment that may be exposed to excessive dust or abrasive, magnetic, or metallic dust should be protected. One or more of the following precautions, a) through c), should be considered:

- a) Totally enclosed non-ventilated equipment or compartments may be necessary.
- b) Where current-carrying equipment designed for ventilated operation is enclosed in a non-ventilated compartment, derating may be necessary.
- c) Installation in a positive pressure room with appropriate filtration equipment may be necessary.

3.3.6.3 Exposure to explosive mixtures of dust or gases

Standard switchgear is not designed for use in explosive atmospheres. For this type of service, special consideration should be given in conjunction with requirements of applicable regulatory bodies so that acceptable equipment is selected.

3.3.6.4 Unusual space limitations

Unusual space limitations should be considered special.

3.3.7 Other parameters

Any other unusual or special environmental, operational, or other conditions prevailing at the location where switchgear is to be placed in service should be identified.

NOTE—For other special environmental conditions, the user is referred to IEC 60721-1 [B15].¹⁵

¹⁵The numbers in brackets correspond to those of the bibliography in Annex K.

4. 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.¹⁶

An asterisk (*) indicates that at the time this standard was approved, there were no corresponding definitions in the *IEEE Standards Dictionary Online*.

disconnecter: A mechanical switching device that provides, in the open position, an isolating distance in accordance with specified requirements. (See IEC 60050-441:1984 [B3].)

NOTE 1—A disconnecter is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnecter occurs. It is also capable of carrying currents under normal conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit.

IP coding*: A coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water, and to give additional information in connection with such protection. (See 3.4 of IEC 60529.)

isolating distance (of a pole of a mechanical switching device)*: The clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position meeting the functional requirements specified for disconnecters. Clearance is the shortest path between the conductive parts.¹⁷

non-sustained disruptive discharge (NSDD): Disruptive discharge associated with current interruption, that does not result in the resumption of power frequency current or, in the case of capacitive current interruption does not result in current in the main load circuit.

vacuum interrupter*: A switching component in which high-voltage electrical contacts operate in a highly evacuated, hermetically sealed environment.

NOTE 2—Refer to [Annex H](#) for additional information about terms used in this standard.

5. Ratings

5.1 General

The common ratings of switchgear, including their operating devices and auxiliary equipment, should be selected from the following:

- a) Rated maximum voltage (V) or (U_r)¹⁸
- b) Rated insulation level (U_d), (U_s), (U_p)
- c) Rated power frequency (f_r)
- d) Rated continuous current (I_r)
- e) Rated short-time withstand current (I_k)
- f) Rated peak withstand current (I_p)

¹⁶*IEEE Standards Dictionary Online* is available at: [IEEE Xplore](#).

¹⁷This definition is a combination of three definitions taken from IEC 60050-441:1984 [B3]. See [Annex J](#).

¹⁸A listing of symbols for numerical variables or parameters used in this standard is given in [Annex H](#). In some cases, the IEEE symbol and the IEC symbol are not the same. In such cases, the IEEE symbol is listed first followed by the IEC symbol.

- g) Rated duration of short circuit (t_k)
- h) Rated supply voltage of closing and opening devices and of auxiliary circuits (U_a)
- i) Rated supply frequency of closing and opening devices and of auxiliary circuits
- j) Rated pressure of compressed gas supply for insulation or operation

NOTE—Other rated characteristics may be necessary and should be specified in the relevant equipment standards.

5.2 Rated maximum voltage (V) or (U_r)

5.2.1 General

The rated maximum voltage indicates the upper limit of the highest voltage of systems for which the switchgear is intended. The preferred values of rated maximum voltage are given in 5.2.2 and 5.2.3.

5.2.2 Range I for rated maximum voltages of 245 kV and below

Series A (based on the current practice in North America and some other countries):

4.76 kV, 8.25 kV, 15 kV, 15.5 kV, 25.8 kV, 27 kV, 38 kV, 48.3 kV, 72.5 kV, 123 kV,
145 kV, 170 kV, and 245 kV

Series B:

3.6 kV, 7.2 kV, 12 kV, 17.5 kV, 24 kV, 36 kV, 52 kV, 72.5 kV, 100 kV, 123 kV,
145 kV, 170 kV, and 245 kV

NOTE 1—The series A voltages are applicable to North America and some other countries. The series B voltages are generally used outside North America. The series B voltages are the same as those identified as series I in IEC 62271-1 [B23]. Voltages from both series are considered preferred in this standard.

NOTE 2—Refer to Annex I for proposed values of rated maximum voltages for future design.

5.2.3 Range II for rated maximum voltages above 245 kV

300 kV, 362 kV, 420 kV, 550 kV, and 800 kV

5.3 Rated insulation level, U_d , U_s , U_p

The rated insulation level of switchgear shall be selected from the values given in Table 1a, Table 1b, Table 2a, and Table 2b.

In these tables, the withstand voltage applies at the standardized reference atmosphere [temperature (20 °C), pressure (101.3 kPa), and humidity (11 g/m³)]¹⁹ specified in IEEE Std 4. Insulation withstand capability is affected by altitude. For special service conditions, see 3.3 and Annex B.

NOTE—For further information on insulation coordination, refer to IEEE Std 1313.1 [B25], IEEE Std 1313.2, or to IEC 60071-1 [B8] and IEC 60071-2 [B9].

¹⁹The standard reference atmosphere in English units is: temperature (68 °F), pressure (29.914 in of Hg), and humidity (0.011 oz/ft³).

The rated values for lightning impulse withstand voltage (U_p), switching impulse withstand voltage (U_s) (when applicable), and power frequency withstand voltage (U_d) shall be selected without crossing the horizontal marked lines in [Table 1a](#), [Table 1b](#), [Table 2a](#), and [Table 2b](#). The rated insulation level is specified by the rated lightning impulse withstand voltage phase to ground.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltages, the type of neutral grounding of the system, and the type of overvoltage limiting devices. (See IEEE Std 1313.2.²⁰)

The “common values” as used in [Table 1a](#) and [Table 1b](#) apply to phase-to-ground, between phases, and across the open switching device, if not otherwise specified in this standard. The withstand voltage values “across the isolating distance” are valid only for switching devices where the clearance between open contacts is designed to meet the functional requirements specified for disconnectors. For withdrawable devices, the isolating distance may be determined when the device is in the “disconnected” position. The term “common value” is used to make a distinction between the normal rating, where there is no intention to meet the added safety requirements for disconnectors, and the increased rating “across the isolating distance,” where the intention is to meet the added safety requirements for disconnectors. In the first case, the “common value” applies across the open switching device, i.e., the interrupting device. In the second case, the withstand value “across the isolating distance” may apply across the interrupting device or across an auxiliary disconnecting means, such as an auxiliary disconnecting switch or a withdrawable device.

²⁰See also: IEC 60071-2 [B9].

Table 1a—Rated insulation levels for rated maximum voltages of range I, series A^a

Rated maximum voltage $V(U_r)$ kV (rms value)	Rated power frequency withstand voltage U_d kV (rms value)			Rated lightning impulse withstand voltage U_p kV (peak value)		
	Common value ^f		Across isolating distance ^c	Common value ^f	Across isolating distance ^c	2 μ s chopped wave ^b
	Dry 1 min	Wet 10 s ^g	Dry 1 min			
Col. 1	Col. 2	Col. 2a	Col. 3	Col. 4	Col. 5	Col. 6
4.76 ^d	19	—	21	60	66	—
8.25 ^d	36	—	40	95	105	—
8.25 ^e	38	30	42			—
15 ^d	36	30	40	95	105	—
15.5 ^d	50	45	55	110	121	142
15.5 ^e	50	45	55			
25.8 ^d	60	50	66	125	138	—
				150	165	194
27.0 ^d	60	50	66	125	138	—
27.0 ^e	70	60	77	150	165	—
38 ^d	70	60	77	150	165	—
	80	75	88	200	220	258
38 ^e	95	80	105	200	220	—
48.3 ^d	105	95	—	250	—	322
48.3 ^e	120	100	132	250	275	—
72.5 ^d	160	140	—	350	—	452
72.5 ^e	175	145	193	350	385	—
123 ^d	260	230	—	550	—	710
123 ^e	280	230	308	550	605	—
145 ^d	310	275	—	650	—	838
145 ^e	335	275	369	650	715	—
170 ^d	365	315	—	750	—	968
170 ^e	385	315	424	750	825	—
245 ^d	425	350	—	900	—	1160
245 ^e	465	385	512	900	990	—

^a For rated maximum voltages higher than 72.5 kV up to and including 245 kV, the values in Table 1b are also applicable.

^b The 2 μ s chopped wave test requirement only applies to outdoor breakers.

^c Isolation of indoor circuits is normally achieved by withdrawing the removable switching device. Refer to relevant equipment standards for testing methods and requirements where this method of isolation is applicable.

^d These ratings are generally applicable to switchgear equipment that is not used for isolation, e.g., high-voltage circuit breakers and reclosers and may not include requirements across the isolation gap. Refer to relevant equipment standards for requirements across the isolation gap.

^e These ratings are generally applicable to switchgear equipment that is used for circuit isolation, e.g., high-voltage switches. Refer to relevant equipment standards.

^f Common values are discussed in 5.3.

^g Power-frequency withstand tests under wet conditions are only required for outdoor switchgear.

**Table 1b—Rated insulation levels for rated maximum voltages of range I, series B
(generally used outside of North America)**

Rated voltage $V(U_r)$ kV (rms value)	Rated short-duration power-frequency withstand voltage U_d kV (rms value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value (See Note 2)	Across isolating distance	Common value (See Note 2)	Across isolating distance
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
3.6	10	12	20	23
			40	46
7.2	20	23	40	46
			60	70
12	28	32	60	70
			75	85
17.5	38	45	75	85
			95	110
24	50	60	95	110
			125	145
36	70	80	145	165
			170	195
52	95	110	250	290
72.5	140	160	325	375
100	150	175	380	440
	185	210	450	520
123	185	210	450	520
	230	265	550	630
145	230	265	550	630
	275	315	650	750
170	275	315	650	750
	325	375	750	860
245	360	415	850	950
	395	460	950	1050
	460	530	1050	1200

NOTE 1—The term “short-duration power frequency withstand voltage” comes from the insulation coordination standard, IEEE Std 1313.1 [B25]. In 3.33 of IEEE Std 1313.1 [B25], the term “standard power-frequency short-duration voltage shape” is defined as a sinusoidal voltage with frequency between 48 Hz and 62 Hz and duration of 60 s. A similar definition appears in item a) of 3.18 of IEC 60071-1 [B8].

NOTE 2—Common values are discussed in 5.3.

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Table 2 a—Rated insulation levels for range II

Rated maximum voltage $V(U_r)$ kV (rms value)	Rated power-frequency withstand voltage U_d kV (rms value)		Rated switching impulse withstand voltage U_s kV (peak value)		Rated lightning impulse withstand voltage U_p kV (peak value)		2 μ s chopped wave withstand voltage kV (peak value)
	Phase-to-ground and between phases ^a	Across open switching device ^{b, c}	Phase-to- ground, breaker closed	Across open switching device ^{b, c}	Phase-to-ground and between phases	Across open switching device ^{b, c}	
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
362	555	555	825	900	1300	1300	1680
550	860	890	1175	1300	1800	1800	2320
800	960	1056	1425	1500	2050	2050	2640

^a Values of Column 2 are applicable:

- a) For type tests, phase-to-ground
- b) For routine tests, phase-to-ground, phase-to-phase, and across the open switching device

^b Values of Columns 3, 5, 7, and 8 are applicable for type tests only.

If the general arrangement of the three-phase set results in a large distance between installed phases, dielectric withstand tests between phases are not required. If there is doubt, phase-to-phase tests are required, especially on a design with one common supporting frame for the three phases.

^c Values across open switching device refer to the open interrupting gap. Refer to relevant equipment standards for ratings across the isolating distance where equipment is rated as an isolator.

**Table 2b—Additional rated insulation levels for rated voltages of range II
(generally used outside of North America)**

Rated voltage $V(U_r)$ kV (rms value)	Rated power-frequency withstand voltage U_d kV (rms value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-ground and between phases ^c	Across open switching device and/or isolating distance ^d	Phase-to-ground and across open switching device	Between phases ^{d,e}	Across isolating distance ^{a,d}	Phase-to-ground and between phases	Across open switching device and/or isolating distance ^{b,d}
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
300	380	435	750 850	1125 1275	700(+245)	950 1050	950(+170) 1050(+170)
362	450	520	850 950	1275 1425	800(+295)	1050 1175	1050(+205) 1175(+205)
420	520	610	950 1050	1425 1575	900(+345)	1300 1425	1300(+240) 1425(+240)
550	620	800	1050 1175	1680 1760	900(+450)	1425 1550	1425(+315) 1550(+315)
800	830	1150	1300 1425	2210 2420	1100(+650)	1800 2100	1800(+455) 2100(+455)

^a In Column 6, values in brackets are the peak values of the power-frequency voltage $U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

^b In Column 8, values in brackets are the peak values of the power-frequency voltage $0,7 U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

^c Values of Column 2 are applicable:

- a) For type tests, phase-to-ground
- b) For routine tests, phase-to-ground, phase-to-phase, and across the open switching device

^d Values of Columns 3, 5, 6, and 8 are applicable for type tests only.

^e The values in Column 5 are derived using the multiplying factors stated in Table 3 of IEC 60071-1 [B8].

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5.4 Rated power frequency (f_r)

The preferred values of the rated power frequency are 50 Hz and 60 Hz.

5.5 Rated continuous (normal) current and temperature rise

5.5.1 Rated continuous (normal) current (I_r)

The rated continuous current of switchgear is the rms value of the current that switchgear shall be able to carry continuously under specified conditions of use and behavior.

The values of rated continuous currents for new design should be selected from the R10 series.²¹ The R10 series comprises the numbers: 1, 1.25, 1.6, 2, 2.5, 3.15, 4, 5, 6.3, 8, and their products by 10^n . The historic values of 600 A, 1200 A, 3000 A, and 6000 A are also considered as preferred values.

NOTE—Rated currents for temporary or for intermittent duty are subject to agreement between manufacturer and user.

5.5.2 Temperature rise

The temperature rise of any part of switchgear shall not exceed the temperature rise limits specified in [Table 3](#) under the conditions specified in the test clauses.

Equipment may be assigned an overload capability for higher than rated normal current for a temporary period provided the temperature does not exceed the maximum value temperature specified in [Table 3](#).

Equipment may be assigned an overload capability for higher than rated normal currents based on a lower ambient temperature provided the temperature does not exceed the maximum value temperature specified in [Table 3](#).

Refer to IEEE Std C37.010 for application information on overloads.

NOTE—In the case of a switch, the overload capability may exceed its breaking capability.

²¹The R10 series of numbers is described in IEC 60059 [B6]. Each number in the series is approximately 125% greater than the preceding number.

Table 3—Limits of temperature and temperature rise for various parts, materials, and dielectrics of high-voltage switchgear

Nature of the part, of the material and of the dielectric (see points and notes below)		Maximum value	
		Temperature (°C)	Temperature rise at ambient air temperature not exceeding 40 °C (K) (See Note 3)
1	Contacts (see point 4)		
	Bare-copper or bare-copper alloy		
	— In air	75	35
	— In SF ₆ (sulfur hexafluoride (see point 5)	105	65
	— In oil	80	40
	Silver-coated or nickel-coated (see point 6)		
	— In air	105	65
	— In SF ₆ (see point 5)	105	65
	— In oil	90	50
	Tin-coated (see point 6)		
	— In air	90	50
	— In SF ₆ (see point 5)	90	50
	— In oil	90	50
2	Connection, bolted or the equivalent (see point 4)		
	Bare-copper, bare-copper alloy or bare-aluminum alloy		
	— In air	90	50
	— In SF ₆ (see point 5)	115	75
	— In oil	100	60
	Silver-coated or nickel-coated		
	— In air	115	75
	— In SF ₆ (see point 5)	115	75
	— In oil	100	60
	Tin-coated		
	— In air	105	65
	— In SF ₆ (see point 5)	105	65
	— In oil	100	60
3	All other contacts or connections made of bare metals or coated with other materials	(See point 7)	(See point 7)
4	Terminals for the connection to external conductors by screws or bolts (see points 8 and 14)	(See point 14)	(See point 14)
	— Bare	90	50
	— Silver, nickel, or tin-coated	105	65
	— Other coatings	(See point 7)	(See point 7)
5	Oil for oil switching devices (see points 9 and 10)	90	50
6	Metal parts acting as springs	(See point 11)	(See point 11)

Table continues

Nature of the part, of the material and of the dielectric (see points and notes below)		Maximum value	
		Temperature (°C)	Temperature rise at ambient air temperature not exceeding 40 °C (K) (See Note 3)
7	Materials used as insulation and metal parts in contact with insulation of the following classes (see point 12) — Y — A — E — B — F — Enamel: oil base synthetic — H — C other insulating material	90 105 120 130 155 100 120 180 (See point 13)	50 65 80 90 115 60 80 140 (See point 13)
8	Any part of metal or of insulating material in contact with oil, except contacts	100	60
9	Accessible parts (See Note 4) — Expected to be touched in normal operation — Which need not be touched in normal operation	50 70	
NOTE 1—The points referred to in this table are those of 5.5.3. NOTE 2—Refer to Annex J for a discussion of this table with respect to the comparable table in IEC 62271-1:2007 [B23] and to the requirements of several relevant equipment standards. NOTE 3—The symbol “K” for the kelvin is used in this standard to refer to a temperature increment. As a temperature increment (e.g., temperature rise), the degree kelvin is equal to the degree Celsius, 1 K ≡ 1 °C ≡ 1.8 °F; as temperature on a scale, 273.15 K ≡ 0 °C ≡ 32 °F and 0 K is absolute zero. The kelvin is written as “K” without the “°” degree symbol. NOTE 4—The maximum value temperatures for group 9 are lower than those given in the comparable table in IEC 62271-1 [B23]. See Annex J.			

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5.5.3 Particular points of Table 3

The following points are referred to in Table 3 and shall be considered as part of the table:

- Point 1: According to its function, the same part may belong to several categories as listed in Table 3. In this case, the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.
- Point 2: For vacuum switching devices, the values of temperature and temperature rise limits are not applicable for parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 3.