

IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear

IEEE Power and Energy Society

Sponsored by the
Switchgear Committee



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IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear

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IEEE Power and Energy Society

Approved 26 March 2015

IEEE-SA Standards Board

Abstract: Metal-enclosed, low-voltage switchgear—which contains either stationary or drawout, manually or electrically operated low-voltage ac or dc power circuit breakers in individual metal compartments, in three-pole, four-pole, two-pole, or single-pole construction—is covered. Rated maximum voltage levels are 254 V, 508 V, 635 V, 730 V, or 1058 Vac; and 300/325 V, 600 V, 800 V, 1000 V, 1200 V, 1500 V, 1600 V, or 3200 Vdc. The preferred continuous current ratings of the main bus in ac designs are 1600 A, 2000 A, 3000 A, 3200 A, 4000 A, 5000 A, 6000 A, 8000 A, or 10 000 A. For dc designs, the preferred ratings are 1600 A, 2000 A, 2500 A, 3000 A, 4000 A, 5000 A, 6000 A, 8000 A, 10 000 A, or 12 000 A. The switchgear may also contain associated control, instruments, metering, protective, and regulating devices as necessary. The standard deals with service conditions, ratings, temperature limitations, and classification of insulating materials, insulation (dielectric) withstand voltage requirements, test procedures, and application.

Keywords: circuit breaker, control, cumulative loading, current transformers, drawout, IEEE C37.20.1™, indoor, instrumentation, load current-carrying, metal-enclosed, metering, outdoor, protection, stationary, switchgear

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Introduction

This introduction is not part of IEEE Std C37.20.1™-2015, IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.

This standard has been revised to reflect needed technical changes that have been suggested since the last revision to IEEE Std C37.20.1™ that was published in 2002. Major editorial and technical changes have been incorporated. The more significant changes include the following:

- a) Expansion of maximum voltage ratings to include 730 Vac and 1058 Vac, plus 600 Vdc and 1500 Vdc, to coordinate with changes being made to the NEC, IEEE Std C37.13™, and IEEE Std C37.14™.
- b) The historic altitude correction factors in previous editions have been retained.

This standard includes only the requirements for metal-enclosed low-voltage power circuit breaker switchgear. These requirements were previously a part of IEEE Std C37.20™-1969 (Reaff 1981), IEEE Standard for Switchgear Assemblies Including Metal-Enclosed Bus (1974 consolidated edition). Other types of equipment previously included in IEEE Std C37.20-1969 are incorporated in separate publications.

The IEEE Switchgear Assemblies subcommittee of the IEEE Power and Energy Switchgear Committee was responsible for this revision.

The working group expresses its deep appreciation to Christina Long for her work in creating and editing this document.

This publication is one of a series covering switchgear assemblies as follows:

- a) IEEE Std C37.20.1™, IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.
- b) IEEE Std C37.20.2™, IEEE Standard for Metal-Clad Switchgear.
- c) IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV-38 kV).
- d) IEEE Std C37.20.7™, IEEE Guide for Testing Switchgear Rated 38 kV or below for Internal Arcing Faults
- e) IEEE Std C37.21™, IEEE Standard for Control Switchboards.
- f) IEEE Std C37.23™, IEEE Standard for Metal-Enclosed Bus.
- g) PC37.20.9, IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV–52 kV Incorporating Gas Insulation Systems^a

^a Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE. Note that PC37.20.9 is in process.

Figure A depicts types of switchgear assemblies and standards pertinent to switchgear assemblies.

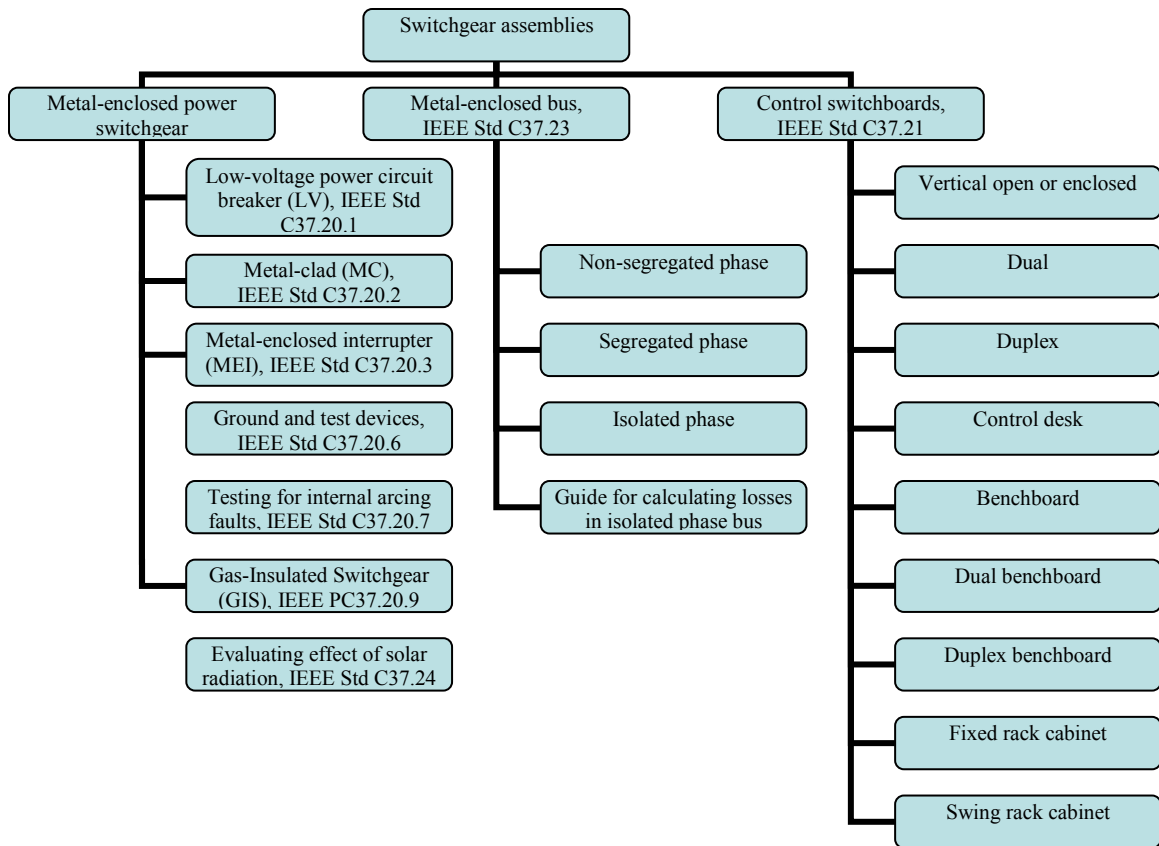


Figure A—Types of switchgear assemblies

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1. Scope

This standard covers metal-enclosed low-voltage power circuit breaker switchgear assemblies containing, but not limited to, such devices as low-voltage power circuit breakers (fused or unfused); other interrupting devices; switches, control, instrumentation, and metering; and protective and regulating equipment.

This standard is concerned with enclosed, rather than open, indoor and outdoor switchgear assemblies. It includes types of equipment that are part of secondary unit substations. It does not apply to equipment covered by industrial control standards, communication switchboards, communication switching equipment, switchboards for use on board ships, or dead-front distribution switchboards.

In this standard, metal-enclosed low-voltage power circuit breaker switchgear shall be called LV switchgear. For LV ac switchgear, the [nominal system](#) voltage shall be 1000 Vac or below; for LV dc switchgear, the [rated maximum](#) voltage shall be 3200 Vdc or below.

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.](#)

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~~ANSI C37.16-2000, Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors: Preferred Ratings, Related Requirements, and Application Recommendations.~~

ANSI C37.50 ~~1989~~, Low-Voltage AC Power Circuit Breakers Used in Enclosures—Test Procedures.¹

ANSI C37.51 ~~1989 (Reaff 1995)~~, Metal-Enclosed Low-Voltage AC Power-Circuit-Breaker Switchgear Assemblies—Conformance Test Procedures.

ANSI Z535.4 ~~1998~~, Product Safety Signs and Labels.

[ASTM A90/A90M Standard Test Method for Weight \(Mass\) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.](#)²

[ASTM A653/653M Standard Specification for Steel Sheet, Zinc-Coated \(Galvanized\) or Zinc-Iron Alloy-Coated \(Galvannealed\) by the Hot-Dip Process.](#)

ASTM B117 ~~1997~~, Standard Practice for Operating Salt Spray (Fog) Apparatus.³

ASTM D229 ~~2001~~, Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation.

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ASTM D412-~~1998A~~, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.

ASTM D714-~~1987 (Reaff 1994)~~, Standard Test Method for Evaluating Degree of Blistering of Paints.

ASTM D1535-~~2001~~, Standard Practice for Specifying Color by the Munsell System.

ASTM D1654-~~1992~~, Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.

ASTM G21-~~1996~~, Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.

~~IEEE Std 1TM-2001, General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.~~^{4,5}

~~IEEE Std 4TM-1995, IEEE Standard Techniques for High Voltage Testing.~~

~~IEEE Std 100TM, The Authoritative Dictionary of IEEE Standard Terms, Seventh Edition.~~

IEEE Std 120TM-~~1989 (Reaff 1997)~~, IEEE Master Test Guide for Electrical Measurements in Power Circuits.³

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~~IEEE Std 142TM-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book).~~

~~IEEE Std 241TM-1990 (Reaff 1997), IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book).~~

~~IEEE Std 242TM-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).~~

IEEE Std 316TM-1971, IEEE Standard Requirements for Direct Current Instrument Shunts.⁴ (~~Note:~~ This document has been withdrawn by IEEE, but the requirements for dc instrument shunts have not been adequately reflected in other standards. Therefore, IEEE Std 316-1971 continues as the relevant reference).

IEEE Std ~~446TM-1995 (Reaff 2000)~~, [693TM](#), IEEE Recommended Practice for ~~Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book).~~ [Seismic Design of Substations.](#)

[IEEE Std 1653.6TM, IEEE Trial-Use Recommended Practice for Grounding of DC Equipment Enclosures in Traction Power Distribution Facilities.](#)

IEEE Std C37.2TM, ~~1996 (Reaff 2001)~~, IEEE Standard Electrical Power System Device Function Numbers, [Acronyms](#), and Contact Designations.

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IEEE Std C37.13TM, ~~1990 (Reaff 1995)~~, IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.

IEEE Std C37.14TM, ~~1999~~, IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures.

[IEEE Std C37.16TM, IEEE Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low Voltage AC \(635 V and below\) and DC \(3200 V and below\) Power Circuit Breakers.](#)⁵

~~IEEE Std C37.24TM 1986 (Reaff 1998), IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal Enclosed Switchgear.~~

IEEE Std C37.26TM, ~~IEEE 1972 (Reaff 1996)~~, Standard Guide for Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits.

IEEE Std C37.81TM ~~1989 (Reaff 1999), IEEE Guide for Seismic Qualification of Class 1E Metal Enclosed Power Switchgear Assemblies.~~

~~IEEE Std C37.100TM, IEEE 1992 (Reaff 2001)~~, Standard Definitions for Power Switchgear.⁶

⁵ [When this standard was approved, information in IEEE Std C37.16 was in the process of being incorporated into IEEE Std C37.13 \(for LV ac circuit breakers\) or IEEE Std C37.14 \(for LV dc circuit breakers\). Upon approval of IEEE Std C37.13 and/or IEEE Std C37.14, all references in this document \(IEEE Std C37.20.1\) to IEEE Std C37.16 shall be interpreted as referring to IEEE Std C37.13 or IEEE Std C37.14, as applicable.](#)

⁶ [IEEE Std C37.100 will be withdrawn at the end of 2018. Definitions pertinent to switchgear assemblies will be incorporated in a new standard being developed under PAR PC37.20.10, in preparation. General definitions, applicable to a wider range of standards, will continue to be available in the IEEE Standards Dictionary Online.](#)

[IEEE Std C37.100.1™, IEEE Standard of Common Requirements for High Voltage Power Switchgear Rated Above 1000 V.](#)

IEEE Std C57.13™~~1993~~, IEEE Standard Requirements for Instrument Transformers. NEMA CC1-~~1993~~, Electric Power Connectors for Substations.⁷

NEMA WC70~~1999~~/ICEA S-95-658, ~~Non-Shielded~~ Power Cables rated 2000 V or less [for the distribution of Electrical Energy](#). NFPA 70-~~2002~~, National Electrical Code[®] (NEC[®]).⁸

UL 486A-~~1997~~ [486B](#), Wire Connectors and Soldering Lugs for Use With Copper Conductors.⁹

[UL 1332, Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment.](#)

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http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

[Note that](#) the definitions of terms contained in this standard, or in other standards referred to in this standard, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.

~~If a term is not defined in this standard, the definition in IEEE Std C37.100-1992¹⁰ applies. An asterisk (*) following a definition indicates that the definition in this standard is not contained in IEEE Std C37.100-1992 while a dagger (†) indicates that the definition differs from that in IEEE Std C37.100-1992.~~

3.1 General

auxiliary compartment: That portion of the switchgear assembly that is assigned to the housing of auxiliary equipment, such as voltage transformers, control power transformers, or other miscellaneous devices.*

circuit breaker compartment: That portion of a switchgear assembly that contains one [low-voltage power](#) circuit breaker and the associated primary conductors and secondary control connection devices, ~~including~~ [and may include](#) current transformers.*

design tests: Tests made by the manufacturer to determine the adequacy of the design of a particular type, style, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions if specified, and may be used to demonstrate compliance with applicable standards of the industry.†

¹⁰~~Information on references can be found in Clause 2.~~

NOTE

~~1—Design tests are made on representative apparatuses or prototypes to verify the validity of design analyses and calculation methods and to substantiate the ratings assigned to all other apparatuses of basically the same design. These tests are not intended to be made on every design variation or to be used as part of normal production. The applicable portion of these design tests may also be used to evaluate modifications of a previous design and to ensure that performance has not been adversely affected. Test data from previous similar designs may also be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.~~

2—Design tests are sometimes called type tests.¹¹

field tests: Tests made after the switchgear assembly has been installed at its place of utilization.

mechanism-operated cell switch: *See:* **mechanism-operated contact.**

mechanism-operated contact (MOC): A circuit breaker mechanism-operated auxiliary switch which is mounted in the stationary housing and is operated by linkage which cooperates with the circuit breaker mechanism. *Syn:* mechanism-operated cell switch.

metal-enclosed low-voltage power circuit breaker (LV) switchgear: Metal-enclosed low-voltage switchgear of multiple or individual enclosures, including the following equipment as required:

- a) Low-voltage power circuit breakers (fused or unfused) in accordance with IEEE Std C37.13-~~1990~~ or IEEE Std C37.14-~~1999~~.[‡]

¹¹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

- b) Bare bus and connections
- c) Instrument and control power transformers
- d) Instruments, meters, and relays
- e) Control wiring and accessory devices

The low-voltage power circuit breakers are contained in individual grounded metal compartments and controlled either remotely or from the front of the enclosure. The circuit breakers may be stationary or removable (drawout) type; when of removable type, mechanical interlocks are provided for proper operating sequence.†

NOTE—Bare bus and connections meet the requirements of this standard. However, the manufacturer may provide insulated bus and/or connections when required to meet dielectric requirements or as an option.

metal-enclosed power switchgear (ME): A switchgear assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors or removable covers, or both.†

~~3.1.7 mechanism-operated cell switch. See: mechanism-operated contact (MOC).~~

~~3.1.8 mechanism-operated contact (MOC): A circuit-breaker mechanism-operated auxiliary switch which is mounted in the stationary housing and is operated by linkage which cooperates with the circuit-breaker mechanism. Syn: mechanism-operated cell switch.*~~

production tests: Tests made for quality control by the manufacturer on every device or representative samples, or on parts or materials as required to verify during production that the product meets the design specifications and applicable standards.[‡]

NOTE

~~1—Certain quality assurance tests on identified critical parts of repetitive high production devices may be tested on a planned statistical sampling basis.~~

~~2—~~Production tests are sometimes called routine tests.

switchgear: A general term covering switching and interrupting devices and their combination with associated control, instruments, metering, protective, and regulating devices; also assemblies of these devices with associated interconnections, accessories, and supporting structures used primarily in connection with the generation, transmission, distribution, and conversion of electric power.[‡]

switchgear assembly: An assembled equipment (indoor or outdoor) including, but not limited to, one or more of the following categories: switching, interrupting, control, instrumentation, metering, protective, and regulating devices; together with their supporting structures, enclosures, conductors, electrical interconnections, and accessories. ~~See:~~ [Refer to](#) Figure A in the Introduction.[‡] [for types of switchgear assemblies and related standards.](#)

[**through current test:** A term used to describe a short-circuit, short-time, or momentary test in which the current flowing through the test specimen is required to be maintained at or above specified levels for a specified duration.](#)

tin-surfaced or equivalent: Metallic materials having satisfactory long-term performance that operate within the limits established for tin-surfaced electrical contact parts and conducting mechanical joints.*

truck-operated cell switch: *See:* **truck-operated contact** ~~(TOC)~~.

truck-operated contact (TOC): A circuit breaker truck-operated auxiliary switch which is mounted in the compartment of a removable circuit breaker and is operated by the circuit breaker frame. *Syn:* **truck-operated cell switch.**^{*}

vertical section: That portion of the switchgear assembly between two successive vertical delineations, and may contain one or more circuit breakers, auxiliary compartments, and associated primary conductors.[‡]

4. Normal (usual) service conditions

Standards for the design and performance of LV switchgear are based on usual service conditions as described below. The selection of equipment for a particular application can be based on the construction and ratings as defined in this standard provided that the following usual service conditions exist:

- a) The temperature of the cooling air (ambient air temperature) surrounding the enclosure of the LV switchgear is within the limits of -30 °C and +40 °C. If ambient temperatures below -5 °C will be experienced while in service, the manufacturer should consider addition of space heating or other means to enable proper circuit breaker operation. If the circuit breaker is suitable for operation correctly in an ambient of -30 °C (instead of the IEEE Std C37.13 minimum ambient of -5 °C), no special measures should be needed.
- b) The altitude of the installation does not exceed 2000 m above sea level.
- c) The effect of solar radiation is not significant. (The principles stated in IEEE Std C37.24-~~1986~~ [B10]¹² may be used for guidance.)

¹²The numbers in brackets correspond to those of the bibliography in Annex A.

- d) The ambient air is not significantly polluted and would be classified as having pollution level I “light” according to IEEE Std C37.100.1.¹³
- 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 water vapor pressure, over a period of 24 h does not exceed 2.2 kPa.
 - 3) The average value of the relative humidity over a period of one month does not exceed 90%.
 - 4) The average value of the water vapor pressure over a period of one month does not exceed 1.8 kPa.

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—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.

¹³ The information in items “d” through “f” is based on IEEE Std C37.100.1, subclause 2.1.1; and IEC 62271-1 [B2], subclause 2.1.1.

- 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. In the absence of specific requirements from the user, there are none.¹⁴
- g) Unusual service conditions, such as those outlined in 8 [Annex B, clause B.1](#), do not prevail.

The user should review B.1 [in Annex B](#) for unusual service conditions and other considerations when preparing specifications for LV switchgear because those unusual conditions impact the equipment design.

5. Ratings

5.1 General

The ratings of a switchgear assembly are designations of operating limits under ~~specified~~ [normal \(usual\) service](#) conditions ~~of ambient temperature, temperature rise, etc.~~ Where the switchgear assembly comprises a combination of primary and secondary circuits, each may be given ratings.

Low-voltage switchgear shall have the following ratings:

- a) Rated maximum voltage
- b) Rated power frequency
- c) Rated insulation level

¹⁴ The 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) Rated continuous current
- e) Rated short-time withstand current
- f) Rated short-circuit withstand current

The designated ratings in this standard are preferred, but are not to be considered restrictive. In addition to these ratings, a switchgear assembly may have interrupting or switching capabilities, which are determined by the ratings of the particular interrupting and switching devices that are integral parts of the switchgear assembly. Refer to specific standards for the ratings of these devices.

5.2 Voltage and insulation levels

5.2.1 General

[The preferred rated maximum voltages and corresponding insulation levels are detailed in this section.](#)

5.2.2 Rated maximum voltage and insulation levels for LV ac switchgear

The rated maximum voltage of LV ac switchgear is the highest rms voltage for which the equipment is designed, and is the upper limit for operation. The rated insulation level of LV ac switchgear is equal to the power frequency withstand voltage. The rated maximum voltages and corresponding insulation levels for LV ac switchgear are listed in Table 1.

Table 1— Voltage and insulation levels for LV ac switchgear

Rated maximum voltage (V rms)	Typical nominal system voltage (V rms)	Insulation levels ^a	
		Power frequency withstand (kV rms)	Reference dc withstand (kV) ^b
254	240	2.2	3.1
508	480	2.2	3.1
635	600	2.2	3.1
730	690	3.0	4.2
1058	1000	3.0	4.2

(New)

Rated maximum voltage (rms)	Insulation levels (kV) ^a	
	Power frequency withstand (rms)	Reference dc withstand ^b
254	2.2	3.1
508	2.2	3.1
635	2.2	3.1

(Deleted)

^a For field test values, see 6.5.

^b The column headed, “dc withstand” is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each voltage class of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment; or that a dc withstand test represents an acceptable alternative to the power frequency withstand tests specified in this standard, either for design tests, production tests, conformance tests, or field tests. While power frequency withstand tests are preferred, it is recognized that users may choose to use dc withstand tests for field tests of assembled switchgear for reasons of convenience and availability of test apparatus. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of 1 min.

5.2.3 Rated maximum voltage and insulation levels for LV dc switchgear

The rated maximum voltage of LV dc switchgear is the highest average dc voltage for which the equipment is designed, ~~and is the upper limit for operation~~. The rated insulation level of LV dc switchgear is equal to the power frequency withstand voltage. The rated maximum voltages and corresponding insulation levels for LV dc switchgear are listed in Table 2.

Table 2— Voltage and insulation levels for LV dc switchgear

Rated maximum voltage (V)	Insulation levels ^a	
	Power frequency withstand (kV rms)	Reference dc withstand (kV) ^b
300	2.2	3.1
325	2.2	3.1
600	2.2	3.1
800	3.7	5.2
1000	4.6	6.5
1200	4.8	6.8
1500	5.4	7.6
1600	5.4	7.6
3200	8.8	12.4

(New)

Rated maximum voltage (rms)	Insulation levels (kV) ^a	
	Power frequency withstand (rms)	Reference dc withstand ^b
300	2.2	3.1
325	2.2	3.1
800	3.7	5.2
1000	4.6	6.5
1200	4.8	6.8
1600	5.4	7.6
3200	8.8	12.4

(Deleted)

^a For field test values, see 6.5.

^b For LV dc switchgear rated above 325 Vdc, it is preferred that a dc withstand voltage test be used. For tests conducted with dc voltage, the dc voltage is no less than 1.414 times the ac root-mean-square (rms) listed voltage.

5.3 Rated power frequency

The rated power frequency of a device, or an assembly, is the frequency of the circuit at which it is designed to perform. (Ratings for ac equipment are based on a frequency of 60 Hz.)

5.4 Rated current

5.4.1 General

LV assemblies have current ratings as follows:

- a) Rated continuous current.
- b) Rated short-time withstand current [for assemblies with at least one unfused feeder (load) circuit breaker].
- c) Rated short-circuit withstand current.

5.4.2 Rated continuous current

The rated continuous current of LV switchgear is the maximum current in rms amperes at rated power frequency or direct current that can be carried continuously by the primary circuit components, including buses and connections, without causing temperatures or temperature rises in excess of specified limits for the following:

- a) Any primary or secondary circuit component
- b) Any insulating medium, or structural or enclosing member

The specified temperature and temperature rise limits applicable to switchgear assemblies are given in 5.4.2 through 5.4.6.

5.4.3 Continuous current ratings

The preferred rms continuous current ratings of the main bus in LV ac switchgear are 1600 A, 2000 A, 3000 A, 3200 A, 4000 A, ~~or~~ 5000 A, 6000 A, 8000 A, and 10 000 A. In LV dc switchgear, the preferred continuous current ratings are 1600 A, 2000A, 2500 A, 3000 A, 4000 A, 5000 A, 6000 A, 8000 A, 10 000 A, ~~or~~ and 12 000 A.

The continuous current rating of a vertical section bus riser shall be equal sized to be able to meet the ~~frame size of the LV power~~ cumulative circuit breaker ~~connected to that riser~~ load (see ~~ANSI C37.16-2000 or IEEE Std C37.14-1999~~; B.4.3.4 in Annex B) of that section, but is not required to exceed the continuous current rating of the main bus.

EXCEPTION—The continuous current rating of riser bus may be as modified by the allowable cumulative loading of multiple circuit breakers in the same section (see Table B.4), or by lower continuous current ratings for current transformers. In no case does the riser bus rating need to be greater than the rating of the main bus.

5.4.4 Rated short-time withstand current

The rated short-time withstand current of a LV ac switchgear assembly, ~~or a LV dc switchgear assembly rated 300V or 325V (dc)~~, is the designated limit of available (prospective) current at which it shall be required to withstand its short-time current duty cycle (two periods of 0.5 s current flow, separated by a 15 s interval of zero current) at rated maximum voltage under the prescribed test conditions. This current is expressed in rms symmetrical amperes and is measured from the envelope of the available current wave at a time one-half cycle after current is established.

The rated short-time withstand current of a LV dc switchgear assembly ~~for use with solid state rectifiers (regardless of rated voltage), or rated above 325V (dc)~~, is the designated limit of available (prospective) sustained rms current it shall be capable of carrying for not less than 250 ms.

Both LV ac and LV dc switchgear assemblies shall have a preferred short-time withstand current rating equal to the short-time current rating of the ~~smallest frame size~~ lowest rated unfused circuit breaker used in the assembly, ~~as listed in ANSI C37.16-2000.~~

5.4.5 Rated short-circuit withstand current

The rated short-circuit withstand current of a LV ac assembly, ~~or a LV dc switchgear assembly rated 300 or 325V (dc)~~, is the designated limit of available (prospective) current at rated maximum voltage that it shall be required to withstand for a period of no less than four cycles on a 60 Hz basis under the prescribed test conditions. This current is expressed in rms symmetrical amperes and is measured from the envelope of the available current wave at a time one-half cycle after current is established.

For a LV dc switchgear assembly, the rated short-circuit withstand current shall be the peak current that it shall be required to withstand when tested using a dc source.

Low-voltage ac switchgear assemblies shall have preferred short-circuit withstand current ratings equal to the short-circuit current rating of the ~~smallest frame size~~ [lowest-rated](#) circuit breaker used in the assembly, as covered in ~~ANSI IEEE Std C37.16-2000~~ [13](#). The power factor (X/R ratio) shall be as required in 6.2.6.2.

Low-voltage dc switchgear assemblies shall meet the ratings and test parameters required for LV dc power circuit breakers, as covered in IEEE Std C37.14 ~~-1999 and ANSI C37.16-2000~~.

5.4.6 Application information on rated short-circuit withstand current

NOTES

The rated short-circuit withstand current determines the [minimum](#) bus bracing which is required of the design. [The bus bracing may be able to withstand higher values than the stated rating. When adding or upgrading circuit breakers, consult the manufacturer about the capabilities of the bus bracing.](#)

For LV ac and [LV](#) dc switchgear assemblies with no fused circuit breakers, the rated short-circuit withstand current is the short-circuit current rating of the circuit breaker with the lowest short-circuit current rating in the assembly.

For LV ac switchgear assemblies with all fused circuit breakers, the rated short-circuit withstand current is the short-circuit current rating of the fused circuit breakers [with the lowest short-circuit rating](#) used in the assembly.

For LV ac switchgear assemblies with both fused and unfused circuit breakers, the rated short-circuit withstand current is the short-circuit current rating of the unfused circuit breaker with the lowest short-circuit current rating in the assembly.

The rated short-circuit withstand current (~~from notes 2, 3, or 4 above~~), which is expressed in rms symmetrical amperes, times 2.3 (for unfused circuit breaker assemblies) or times 2.16 (for fused circuit breaker assemblies), equals the peak current for which the assembly ~~must~~ shall be qualified by the short-circuit current withstand tests of 6.2.5. The short-circuit withstand current can also be expressed in rms asymmetrical amperes by multiplying times 1.33 or 1.247 for unfused and fused circuit breaker assemblies, respectively. The rms asymmetrical current values for low-voltage switchgear assemblies are similar in concept to the rms asymmetrical momentary current ratings for medium-voltage switchgear assemblies, except that larger multipliers are required for medium-voltage switchgear assemblies for the higher X/R ratings. The short-circuit withstand current has also sometimes been called bus bracing, but continued use of this term is discouraged. If bus bracing is used, the specifier ~~must~~ should state whether the current is in rms symmetrical or rms asymmetrical amperes. Refer to the ~~column~~ multiplying factors for ~~the Table 2 of~~ curve MM in IEEE Std C37.26-~~1972~~ for multipliers to convert from rms symmetrical amperes to rms asymmetrical amperes at a specific power factor or X/R ratio.

5.5 Temperature limitations

5.5.1 ~~Limiting temperature~~ General

The limiting temperature for LV switchgear is the maximum temperature permitted for the following:

- a) Any component such as insulation, buses, instrument transformers, and switching and interrupting devices
- b) Air in cable termination compartments
- c) Any noncurrent-carrying structural parts

- d) Air surrounding devices

5.5.2 Temperature limits for insulating materials

The total temperature to which insulating materials are subjected shall not exceed the values listed in Table 3 for the various classes of insulating materials.

Table 3—Temperature limits for insulating materials as used in switchgear assemblies

Class of insulating material	Limit of hottest-spot temperature rise (°C)	Limit of hottest-spot total temperature (°C)
Class 90	50	90
Class 105	65	105
Class 130	90	130
Class 155	115	155
Class 180	140	180
Class 220	180	220
NOTE 1—For additional information on temperature limits, see IEEE Std 1 [B3]. NOTE 2—These temperature limits for insulating materials may not apply to insulation in circuit breakers or other devices. For temperature limitations on devices, refer to the appropriate standards for the devices. See also 5.5.4.		

[\(New\)](#)

Class of insulating material	Limit of hottest-spot temperature rise (°C)	Limit of hottest-spot total temperature (°C)
Class 90	50	90
Class 105	65	105
Class 130	90	130
Class 155	115	155
Class 180	140	180
Class 220	180	220

(Deleted)

NOTES

1—For additional information on temperature limits, see IEEE Std 1-2001.

2—These temperature limits for insulating materials may not apply to insulation in circuit breakers or other devices. For temperature limitations on devices, refer to the appropriate standards for the devices. See also 5.5.4.

5.5.3 Temperature limits for buses and connections

The total temperature and temperature rise of buses and connections shall not exceed the values listed in Table 4.

5.5.4 Temperature limitations for air surrounding devices within an enclosed assembly

The temperature of the air surrounding all devices within an enclosed assembly, considered in conjunction with their rating and loading as used, shall not cause these devices to operate outside their rated temperature range when the enclosure of the assembly is surrounded by air in an ambient temperature range of $-30\text{ }^{\circ}\text{C}$ ~~to~~ [and](#) $+40\text{ }^{\circ}\text{C}$.

5.5.5 Temperature limitations for air surrounding insulated power cables

The temperature of the air surrounding insulated power cables within any compartment of an enclosed assembly shall not exceed $65\text{ }^{\circ}\text{C}$ when the assembly is [as follows](#):

- a) Equipped with devices having maximum current rating for which the assembly is designed
- b) Carrying rated continuous current [\(or allowable cumulative load current in accordance with Table B.4\)](#) at rated voltage and at rated power frequency or direct current, whichever applies
- c) In ~~an~~ ambient air temperature of $40\text{ }^{\circ}\text{C}$

NOTE—This temperature limitation is based on the use of $90\text{ }^{\circ}\text{C}$ insulated power cables. Use of lower temperature rated cables requires special consideration.

Table 4—Temperature and temperature rise limits for buses and connections as used in switchgear assemblies

Type of bus or connection	Limit of hottest-spot temperature rise (°C)	Limit of hottest-spot total temperature (°C)
Buses and connections with unplated copper to copper connecting joints	30	70
Buses and connections silver-surfaced or equivalent connecting joints ^b	65	105
Buses and connections tin-surfaced or equivalent connecting joints ^b	65	105
Connection to insulated cables unplated copper to copper ^a	30	70
Connections to insulated cables silver-surfaced or equivalent ^a	45	85
Connections to insulated cables tin-surfaced or equivalent ^a	45	85
Shunt terminals (in LV dc switchgear)	c	c

(New)

Type of bus or connection (see NOTE 1)	Limit of hottest-spot temperature rise (°C)	Limit of hottest-spot total temperature (°C)
Buses and connections with unplated copper to copper connecting joints	30	70
Buses and connections silver-surfaced or equivalent connecting joints	65	105
Buses and connections tin-surfaced or equivalent connecting joints	65	105
Connection to insulated cables unplated copper to copper ^a	30	70
Connections to insulated cables silver-surfaced or equivalent ^a	45	85
Connections to insulated cables tin-surfaced or equivalent ^a	45	85
Shunt terminals (in LV dc switchgear)	see NOTE 2	see NOTE 2

(Deleted)

^a Based on 90 °C insulated cables. Refer to 5.5.5.

NOTES

^b All aluminum buses shall have silver-surfaced or equivalent, or tin-surfaced or equivalent connecting joints. Welded bus connections are not considered connecting joints.

^c No specified limit except to avoid damaging adjacent parts.

5.5.6 Temperature limitations for external parts subject to contact by personnel

Temperature limitations for external parts subject to contact by personnel are as follows:

- a) External parts handled by the operator in the normal course of his or her duties shall have no higher total temperature than 50 °C.
- b) External surfaces accessible to an operator in the normal course of his or her duties shall have no higher total temperature than 70 °C.
- c) External surfaces not accessible to an operator in the normal course of his or her duties shall have no higher total temperature than 110 °C.

5.6 Current transformer ratings (LV ac switchgear)

5.6.1 Current transformer mechanical ratings

The mechanical ratings of current transformers shall be such that they ~~will~~ are able to successfully withstand the short-circuit current for which the associated circuit-interrupting devices are applied. When the primary circuit is protected by current-limiting fuses, the current transformers shall successfully withstand the maximum peak let-through current [peak let through current (I_p) and ampere-squared-seconds (I^2t)] of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the short-circuit current shall be considered as being four cycles.

5.6.2 Current transformer thermal ratings

The thermal ratings of current transformers shall be such that they ~~will~~ are able to successfully withstand the short-circuit current for which the associated circuit-interrupting devices are applied. When the primary circuit is protected by current-limiting fuses, the current transformers shall successfully withstand the maximum I^2t of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the short-circuit shall be considered as being 1 s.

The continuous thermal current rating factor of a current transformer shall be chosen so that the established temperature limits for the current transformer ~~will~~ are not be exceeded at the rated secondary current of the current transformer or the rated continuous current of the main circuit, whichever is lower. See 4.4.2 of IEEE Std C57.13-~~1993~~.

5.6.3 Current transformer ambient temperature

Current transformers for use in switchgear assemblies shall be rated on the basis of at least 55 °C ambient temperature in accordance with ~~4.1.1.2 in~~ IEEE Std C57.13-~~1993~~.

5.7 Phase current transformer accuracies

Accuracies tabulated hereafter are the minimum that shall be supplied. The manufacturer should be consulted if higher accuracies are required by the user. It should be recognized that current transformers with higher accuracies may not meet the requirements of 5.6.1 and 5.6.2.

For installation in LV ac switchgear, the standard current transformer accuracies for metering are listed in Table 5.

Table 5— Standard metering accuracy class ratings^a for current transformers in LV ac switchgear

Ratio	B-0.1	B-0.2
100:5	1.2	2.4 ^b
150:5	1.2	2.4 ^b
200:5	1.2	1.2
300:5	0.6	0.6
400:5	0.6	0.6
600:5	0.6	0.6
800:5	0.3	0.3
1200:5	0.3	0.3
1500:5	0.3	0.3
2000:5	0.3	0.3
3000:5	0.3	0.3
4000:5	0.3	0.3
5000:5	0.3	0.3
6000:5	0.3	0.3
8000:5	0.3	0.3
10 000:5 ^b	0.3	0.3

(New)

Ratio	B 0.1	B 0.2
100:5	1.2	2.4 ^b
150:5	1.2	2.4 ^b
200:5	1.2	1.2
300:5	0.6	0.6
400:5	0.6	0.6
600:5	0.6	0.6
800:5	0.3	0.3
1200:5	0.3	0.3
1500:5	0.3	0.3
2000:5	0.3	0.3
3000:5	0.3	0.3
4000:5	0.3	0.3
5000:5	0.3	0.3
6000:5	0.3	0.3

(Deleted)

^a See IEEE Std C57.13-~~1993~~.

^b Not in IEEE Std C57.13-~~1993~~.

5.8 Instrument shunts for use in LV dc switchgear

Instruments shunts used in LV dc switchgear shall have continuous current ratings that are consistent with the circuit breakers with which they are used (see 5.4.2), and selected per IEEE Std 316-1971, Clause 6.2. It is recommended that the selected shunt current rating be 150% of the circuit breaker continuous current rating to which they are connected, but at a minimum equal to the circuit breaker continuous current rating. Note that LV dc traction switchgear applications often require elevated overload duty cycles which affect shunt rating selection. Refer to Clause B.7.4 in Annex B for additional information. The shunts shall have rated secondary output voltage ~~of to~~ which coordinates with the associated metering and protective devices (typically 50 mV or 100 mV). Shunts shall mechanically withstand the short-circuit current rating of their associated circuit breaker, and shall withstand the thermal effects of the short-time withstand current rating of their associated circuit breaker. Shunts used in LV dc switchgear shall meet the requirements of IEEE Std 316-1971. Shunts are basically a resistance element, and can influence bus temperature rise, particularly in certain locations within the switchgear assembly. Refer to IEEE Std 120-~~1989~~ and IEEE Std 316-1971 for recommendations regarding application of shunts.

Note that it is recommended that the capabilities and performance limitations of the specific shunts used be obtained from the manufacturer and considered in the design.

6. Tests

6.1 General

This clause establishes physical and electrical conditions for tests and methods of determining temperatures and test values. All apparatuses and devices in the power circuit shall be mounted in their normal locations during tests. No statement in this clause is to be construed as modifying the test requirements for devices included in switchgear assemblies.

Tests are classified as design tests, production tests, conformance tests, and field tests. These are generally defined in Clause 3 or in IEEE Std C37.100-1992.

6.2 Design tests

6.2.1 General

Design tests are made on representative apparatuses or prototypes to verify the validity of design analyses and calculation methods and to substantiate the ratings assigned to all other apparatuses of basically the same design. These tests are not intended to be made on every design variation or to be used as part of normal production. The applicable portion of these design tests may also be used to evaluate modifications of a previous design and to determine that performance has not been adversely affected. Test data from previous similar designs may also be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

Design tests, as applicable, shall be made in accordance with 6.2.2 through 6.2.12.

6.2.2 Test arrangements

For the tests specified in 6.2.3 through 6.2.6, the test arrangement construction shall consist of an indoor vertical section of circuit breaker compartments plus an additional representative structure (to simulate actual installation of two adjacent sections), so that the main bus extends through both sections and includes a main bus splice.

For the tests specified in 6.2.4 through 6.2.6, the test circuit shall be configured with the test power source connected to the main bus in such a manner that the test current passes through a main bus splice.

For the tests specified in 6.2.3, the section (riser) bus shall be the configuration with the least clearances (typically, the largest size [conductors](#)) intended for use with the circuit breaker used in the test arrangement.

For the tests specified in 6.2.4 through 6.2.6, the section (riser) bus shall be the minimum size furnished by the manufacturer for the frame size of the circuit breaker used in the test arrangement. The intent is to perform the continuous current and short-circuit current tests with the smallest bus ([conductor cross-sectional area](#)) configuration.

[For LV dc switchgear, tests specified in 6.2.4 through 6.2.6 include shunts mounted in their normal location and in such a manner that the test current passes through the shunt.](#)

[Heating effect of installed shunts must not cause series-connected bus connections directly adjacent to the shunt terminals to exceed specified limits in accordance with Table 4 during the rated continuous current tests in 6.2.4.](#)

Voltage transformers, control power transformers, and associated disconnecting means and fuses are not required for the tests specified in 6.2.4 through 6.2.6. If they are present in the sample, they should not have any effect on the test and need not be removed.

For the tests specified in 6.2.5 through 6.2.6, the circuit resistance of each phase shall be measured with a dc current of at least 100 A ~~flowing~~ prior to the test as a baseline for performance evaluation.

- Test arrangement 1: 1–600 A frame [circuit](#) breaker with 1600 A main bus
- Test arrangement 2: 1–800 A frame [circuit](#) breaker with 1600 A main bus

~~Test arrangement 3: 1–1600 A frame breaker with 1600 A main bus~~

~~Test arrangement 4: 1–2000 A frame breaker with 2000 A main bus~~

~~Test arrangement 5: 1–3000 A frame breaker with 3000 A main bus~~

~~Test arrangement 6: 1–3200 A frame breaker with 3200 A main bus~~

~~Test arrangement 7: 1–4000 A frame breaker with 4000 A main bus~~

~~Test arrangement 8: 1–5000 A frame breaker with 5000 A main bus~~

For frame and bus ratings not covered above, the test arrangement will include a [circuit](#) breaker of the frame size to be tested. The main bus shall be of equal ~~ampacity~~ [continuous current rating of the frame size to be tested](#).

If the switchgear is manufactured in both stationary and drawout designs and the bus design is identical for both, the stationary design may be qualified by testing only the drawout design.

6.2.3 Dielectric tests

Power frequency withstand tests on LV switchgear shall be performed to demonstrate the ability of the insulation system to withstand the voltages in accordance with Table 1 ([LV ac](#)) and Table 2 ([LV dc](#)) as appropriate for the rating(s) of the switchgear assembly. All voltages shall be measured ~~in accordance with~~ [using the methods of](#) IEEE Std 4-1995, [B4]. The voltage is to be increased gradually from zero to the required test value within 5 s to 10 s and shall be held at that value for 1 min.

The ac test voltages shall be essentially sinusoidal and applied with a minimum crest value equal to 1.414 times the specified values. The frequency of the test voltage shall be within $\pm 20\%$ of the rated power frequency of LV ac switchgear, or 60 Hz $\pm 20\%$ for ~~the~~ LV dc switchgear being tested with a power frequency voltage. For LV dc switchgear rated above 325 Vdc, it is preferred that a dc withstand voltage test be used. For tests conducted with dc voltage, the dc voltage shall be no less than 1.414 times the ac rms listed voltage. If a test transformer of less than 500 VA is used, a suitable voltmeter shall be provided to measure the applied output voltage directly. The applicable test voltage, in accordance with Table 1 and Table 2, shall be applied for a period of 1 min to the primary circuit of the LV switchgear in the following manner:

- a) For equipment with stationary devices and for equipment with drawout-mounted devices with the removable elements in the connected position, apply the test voltage as follows:
 - 1) With the circuit breaker contacts closed, between each phase [and neutral \(if present\)](#) of the switchgear assembly individually with the frame and the other phases and the neutral bus (if present) grounded.
 - 2) With the circuit breaker contacts open, between each terminal of the switchgear assembly with the frame and all other terminals grounded.
- b) With the drawout circuit breaker in the test position and closed, apply the test voltage as follows: