

IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems

IEEE Power and Energy Society

Developed by the
Switchgear Committee

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Abstract: Metal-enclosed switchgear assemblies incorporating gas insulating systems containing, but not limited to, such devices as interrupter switches; selector switches; fuses; circuit breakers; control, instrumentation, and metering devices; and protective equipment are covered in this standard. Equipment for the control and protection of apparatus used for distribution of electrical power is also included, but not specifically limited to, in this standard.

Keywords: IEEE C37.20.9™, metal-enclosed power switchgear, metal-enclosed switchgear incorporating gas insulating systems (MEGIS), switchgear, switchgear assembly

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Introduction

This introduction is not part of IEEE Std C37.20.9-2019, IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems.

This standard provides the requirements for switchgear that incorporate gas (typically SF₆) at higher than ambient pressure as an insulation medium for alternating-current applications rated above 1 kV up to 52 kV. This standard recognizes the growing use of gas-insulated switchgear and is one of a series covering switchgear assemblies as follows (see [Figure 1](#)):

- a) IEEE Std C37.20.2TM, IEEE Standard for Metal-Clad Switchgear¹
- b) IEEE Std C37.20.3TM, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV to 38 kV)
- c) IEEE Std C37.20.4TM, IEEE Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear
- d) IEEE Std C37.20.6TM-2015, IEEE Standard for 4.76 kV to 38 kV Rated Ground and Test Devices Used in Enclosures [\[B33\]](#)²
- e) IEEE Std C37.20.1TM-2015, IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear [\[B32\]](#)
- f) IEEE Std C37.20.9TM-2019, IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems (this standard)
- g) IEEE Std C37.21TM-2017, IEEE Standard for Control Switchboards [\[B34\]](#)
- h) IEEE Std C37.23TM-2015, IEEE Standard for Metal-Enclosed Bus [\[B35\]](#)

¹Information on references can be found in [Clause 2](#).

²The numbers in brackets correspond to those of the bibliography in [Annex K](#).

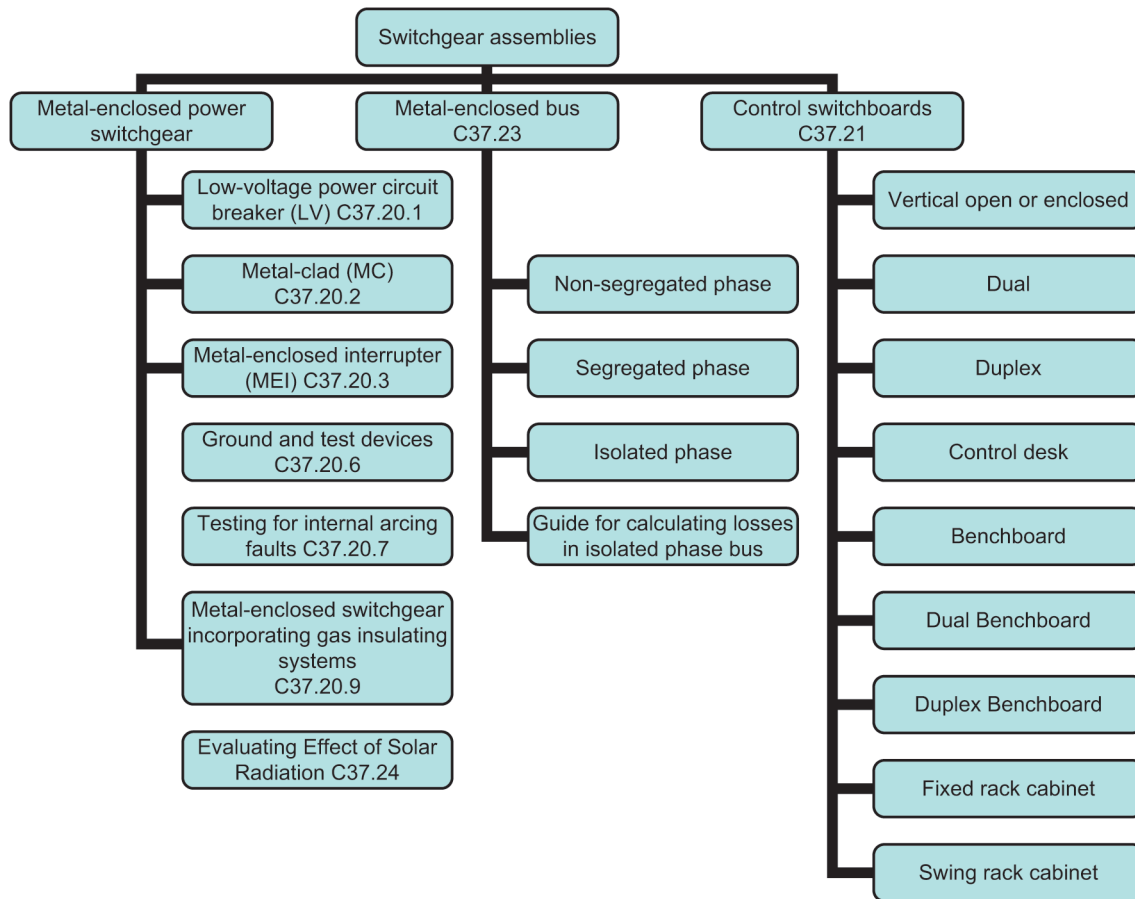


Figure 1—Publications about switchgear assemblies

There was much discussion about voltage transformer protection during the development of this document. The agreement was made to require primary fuse protection for the transformer based mainly on the National Electric Code® (NEC®) requirement. Similar IEC documents do not have a requirement for fuses. Many IEC-based MV and HV designs do not use fuses and have decades of installed service. The debate has been whether the fuse protects the system when the transformer fails or whether the transformer is protected by the fuse. The first position indicates that higher performances from and reliability of the transformers are needed. The second position suggests that investigations into both the transformers and the fuses used are needed. As the primary voltage increases, the ability of the fuse to protect the transformer is reduced. This is because the primary wire used inside some voltage transformers may melt before the primary fuse interrupts the circuit. Some internal transformer and secondary faults are also not protected by primary fuses. Work will be conducted in the future with the National Fire Protection Association (NFPA) and the transformer committee in an attempt to address these issues.

SF₆ is recognized worldwide as having a very high global warming potential (GWP) of 22 800 years (as benchmarked with the 1.0-GWP value of CO₂ gas); thus, other gases are currently being developed and studied for use in metal-enclosed, gas-insulated switchgear (MEGIS) equipment. There is not a leading candidate for a replacement gas at this time; however, consideration and requirements for future gases have been included in this document.

Acknowledgments

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IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems

1. Scope

This standard covers the design, testing, and installation of metal-enclosed switchgear that incorporates gas (typically SF₆) at higher than ambient pressure as an insulation medium for alternating-current applications rated above 1 kV to 52 kV. The contents of the switchgear may include but are not limited to circuit breakers, switches, bushings, buses, instrument transformers, cable terminations, instrumentation, metering and controls, and protective relays. In a vertical section of the switchgear, some or all of the medium-voltage compartment(s) shall be composed of a gas pressure system for the primary insulating medium. This standard covers both indoor and outdoor installations.

This standard covers switchgear using sealed pressure systems or closed pressure systems. Switchgear employing controlled pressure systems is not covered by this standard.

This standard also does not cover switchgear that is covered under IEEE Std C37.20.2^{TM3}, IEEE Std C37.20.3TM, or IEEE Std C37.74TM-2014 [B38]⁴ that uses individual components that are gas-insulated such as switches, circuit breakers, and other equipment, nor does it fully cover those components that are covered by their individual component standards.

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.

Accredited Standards Committee C2, National Electrical Safety Code[®](NESC[®]).^{5,6}

ANSI (NEMA) C37.85, Alternating-Current High-Voltage Power Vacuum Interrupters—Safety Requirements for X-Radiation Limits.⁷

³Information on references can be found in [Clause 2](#).

⁴The numbers in brackets correspond to those of the bibliography in [Annex K](#).

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⁷ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

ANSI Z535.4, Standard for Product Safety Signs and Labels.

ASME, Boiler & Pressure Vessel Code—Section 8: Rules for Constructions of Pressure Vessels—Division 1.⁸

ASTM A90/A90M-2011, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.⁹

ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

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

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

ASTM D714-2009, Standard Test Method for Evaluating Degree of Blistering of Paints.

ASTM D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

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

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

ASTM D2303, Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials.

ASTM D2472, Standard Specification for Sulfur Hexafluoride.

ASTM D5628, Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (T up or Falling Mass).

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

EN 50181, Plug-in Type Bushings Above 1 kV up to 52 kV and from 250 A to 2.50 kA for Equipment Other Than Liquid Filled Transformers.¹⁰

IEC 60060-1, High-Voltage Test Techniques—Part 1: General Definitions and Test Requirements.¹¹

IEC 60068-1, Environmental Testing—Part 1: General and Guidance.

IEC 60068-2-17, Basic Environmental Testing Procedures—Part 2: Tests—Test Q: Sealing.

IEC 60137, Insulated Bushings for Alternating Voltages Above 1000 V.

IEC 60376, Specification of Technical Grade Sulfur Hexafluoride (SF₆) for Use in Electrical Equipment.

IEC 60480, Guidelines for the Checking and Treatment of Sulphur Hexafluoride (SF₆) Taken from Electrical Equipment and Specification for Its Re-use.

⁸ASME publications are available from the American Society of Mechanical Engineers (<https://www.asme.org/>).

⁹ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

¹⁰EN publications are available from the European Committee for Standardization (CEN) (<https://www.cen.eu/>).

¹¹IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

IEC 60507, Artificial Pollution Tests on High-Voltage Ceramic and Glass Insulators to Be Used on A.C. Systems.

IEC 60815, Parts 1 to 3: Selection and Dimensioning of High-Voltage Insulators Intended for Use in Polluted Conditions.

IEC 61243-5, Live Working—Voltage Detectors—Part 5: Voltage Detecting Systems (VDS).

IEC 61869-6, Instrument Transformers—Part 6: Additional General Requirements for Low-Power Instrument Transformers.

IEC 62271-4, High-Voltage Switchgear and Controlgear—Part 4: Handling Procedures for Sulfur Hexafluoride (SF₆) and Its Mixtures.

IEC 62271-200, High-Voltage Switchgear and Controlgear—Part 200: AC Metal-Enclosed Switchgear and Controlgear for Rated Voltages Above 1 kV and Up to and Including 52 kV.

IEC 62271-206, High-Voltage Switchgear and Controlgear—Part 206: Voltage Presence Indicating Systems for Rated Voltages above 1 kV and Up to and Including 52 kV.

NOTE—IEC 61243-5 and IEC 62271-206 are being combined into a new document, IEC 62271-213, Voltage Detecting and Indicating Systems.¹²

IEC 62271-306, High-Voltage Switchgear and Controlgear—Part 306: Guide to IEC 62271-100, IEC 62271-1 and Other IEC Standards Related to Alternating Current Circuit Breakers.

IEC TS 62271-304, High-Voltage Switchgear and Controlgear—Part 304: Design Classes for Indoor Enclosed Switchgear and Controlgear for Rated Voltages Above 1kV Up to and Including 52 kV to Be Used in Severe Climatic Conditions.

IEEE Std 4™, IEEE Standard for High-Voltage Testing Techniques.^{13,14}

IEEE Std 386™, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Rated 2.5 kV through 35 kV.

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

IEEE Std C37.04™, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers.¹⁵

IEEE Std C37.06™, IEEE Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V.

IEEE Std C37.09™, IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.017™, IEEE Standard for Bushings for High-Voltage [over 1000 V (AC)] Circuit Breakers and Gas-Insulated Switchgear.

¹²Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

¹³The IEEE standards or products referred to in [Clause 2](#) are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

¹⁴IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁵As this standard goes to press, IEEE Std C37.04 is being revised and, when approved, will include information previously in IEEE Std C37.06. All references to IEEE Std C37.06 should be interpreted to be references to IEEE Std C37.04 when the new revision of IEEE Std C37.04 is published.

IEEE Std C37.2™, IEEE Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations.

IEEE Std C37.20.2™, IEEE Standard for Metal-Clad Switchgear.

IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV–38 kV).

IEEE Std C37.20.4™, IEEE Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear.

IEEE Std C37.20.7™, IEEE Guide for Testing Switchgear Rated up to 52 kV for Internal Arcing Faults.

IEEE Std C37.20.10™, IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies.

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

IEEE Std C37.41™, IEEE Standard Design Tests for High-Voltage (>1000 V) Fuses and Accessories.

IEEE Std C37.42™, IEEE Standard Specifications for High-Voltage (>1000 V) Fuses and Accessories.

IEEE Std C37.48™, IEEE Guide for the Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

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

IEEE Std C37.100.5™, IEEE Standard for Common Definitions for Switchgear.

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

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.

NEMA 260, Safety Labels for Pad-Mounted Switchgear and Transformers Sited in Public Areas.¹⁶

NEMA CC1, Electric Power Connection for Substations.

NEMA LI 1-2012, Industrial Laminating Thermosetting Products.

NEMA LI 6, Relative Temperature Indices of Industrial Thermosetting Laminates.

NEMA WC 70, Power Cables Rated 2000 V or Less for the Distribution of Electrical Energy (ICEA S-95-658).

NFPA 70, National Electrical Code®(NEC®).^{17,18}

UL 50V, Outline of Investigation for Infrared Viewports.¹⁹

UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

¹⁶NEMA publications are available from the National Electrical Manufacturers Association (<https://www.nema.org/>).

¹⁷NFPA publications are published by the National Fire Protection Association (<https://www.nfpa.org/>).

¹⁸National Electrical Code and NEC are both registered trademarks of the National Fire Protection Association, Inc.

¹⁹UL publications are available from Underwriters Laboratories (<https://www.ul.com/>).

UL 486A-B, Wire Connectors and Soldering Lugs for Use With Copper Conductors.

UL 746B, Polymeric Materials—Long Term Property Evaluations.

UL 1332, Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment.

3. 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.²⁰

ambient air temperature: The average temperature of the surrounding air that comes in contact with the enclosure.

ambient pressure: The pressure of the surrounding medium (such as a gas) that comes in contact with the equipment.

auxiliary compartment: That portion of the switchgear assembly that encloses auxiliary equipment, such as voltage transformers, control power transformers, or other miscellaneous devices.

bus compartment: That portion of the switchgear assembly that contains the primary bus structure.

bypass switch: A nonload interrupting switch used in parallel with another device such that closing the bypass switch will commutate current flow via the switch and allow the other device to be removed from the circuit.

Example: A switch used for bypass feeders in transfer bus schemes.

cable (termination) compartment: That portion of the switchgear assembly that contains provisions for connecting the switchgear to external circuits.

circuit breaker compartment: That portion of the switchgear assembly that contains one circuit breaker or other primary interrupting device and the associated primary conductors.

closed pressure system for gas: A volume that is replenished only periodically by manual connection to an external gas source.

compartment of metal-enclosed, gas-insulated switchgear (MEGIS): A portion of a vertical section of a gas-insulated switchgear assembly that is enclosed except for openings necessary for interconnection providing insulating gas isolation from other compartments. A compartment may be designated by the main components in it, for example, circuit breaker compartment, disconnect switch compartment, bus compartment, and so on, or it can contain multiple components.

conformance tests: Tests made to demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned production tests prior to initiation of the conformance test program.

controlled pressure system for gas: A volume that is automatically replenished from an external or internal gas source.

design pressure of compartment: The maximum gas pressure to which a gas-insulated switchgear compartment will be subjected under normal service conditions, including the heating effects of rated continuous current.

²⁰*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org/>.

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 that may be used to demonstrate compliance with applicable standards of the industry.

NOTE—Design tests are sometimes called “type tests.”

disconnecting switch (or isolating switch): A mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or an equipment from the source of power. It is required to carry normal load current continuously, as well as abnormal or short-circuit currents for short intervals as specified. It is also required to open or close circuits either when negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the switch poles occurs.

drawout element (device): A (disconnecting) device in which the removable portion may be removed from the stationary portion without the necessity of unbolting connections or mounting supports. It contains high-voltage components and coordinates with all safety interlocking functions.

NOTE—The drawout element is similar to the definition of a “removable element” in IEEE Std C37.20.2 and IEEE Std C37.20.10.

encapsulate: The process by which a solid dielectric insulating material is bonded to a live (energized) part or the live part is embedded in the insulating material with the exception of the electrical connections. The process is a molding process and excludes all other means of adhesion such as painting or dipping. The insulation material may or may not provide mechanical support for the live parts. Encapsulated solid dielectric insulation is used in this standard.

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

gas compartment: *See:* **compartment of metal-enclosed, gas-insulated switchgear (MEGIS).**

gas-insulated switchgear (GIS): A multicomponent assembly, enclosed in a grounded metallic housing in which the primary insulating medium is (typically) SF₆ and which normally includes buses, switches, circuit breakers, and other associated equipment.

gas leakage: The leakage rate is the amount of gas that escapes related to the total amount (mass or volume) of gas in each compartment at rated filling pressure (or density). It is expressed in percentage per year.

gas monitoring system: Any instrumentation for measuring, indicating, or giving remote warning of the condition or change in condition of the gas in the enclosure, such as pressure, density, or moisture content.

grounding switch: A mechanical switching device by means of which a circuit or a piece of apparatus may be electrically connected to ground.

interrupter compartment: The portion of the switchgear assembly that contains one interrupting device (such as an interrupter switch, fuse interrupter switch combination, a drawout circuit breaker, or stationary circuit breaker) and the associated primary conductors.

isolated phase: A construction in which each phase conductor is enclosed by an individual metal housing separated from adjacent conductor housings by an air or a gas space.

metal-enclosed, gas-insulated switchgear (MEGIS): A switchgear assembly completely enclosed on all sides and top with metal. At least one compartment is usually filled with gas (typically SF₆) although other gases are permitted at a higher than ambient pressure as an insulating medium. The switchgear may or may not contain additional internal metal compartments. There may be ventilating openings on the exterior surfaces

of the enclosure to cool the sealed compartments. Inspection windows may also be provided on the exterior of the sealed or the nonsealed enclosure. The switchgear contains primary power circuit switching or interrupting devices, or both, with buses and connections and includes control and auxiliary devices. Access to the interior of the enclosure, if required or allowed, is provided by doors or removable covers.

metal-enclosed interrupter switchgear: Metal-enclosed power switchgear including the following equipment as required:

- a) Interrupter (interrupter switches and/or circuit breakers)
- b) Fuses (current-limiting or noncurrent-limiting)
- c) Bare or insulated bus and connections
- d) Instrument transformers
- e) Control wiring and accessories
- f) An isolating switch with visible break contacts for stationary circuit breakers (non-drawout)

metal-enclosed (ME) power switchgear: A switchgear assembly completely enclosed on all sides and the top with sheet metal (except for ventilating openings and inspection windows, viewing panes, or similar items) 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.

NOTE—Metal-clad switchgear, metal-enclosed interrupter switchgear, metal-enclosed gas-insulated switchgear, and low-voltage circuit breaker switchgear are specific types of metal-enclosed power switchgear.

minimum functional pressure p_{mc} (or density ρ_{mc}): Insulation and/or switching pressure (in Pa), below which some rated characteristics of switchgear are not maintained. It is referenced at the standard atmospheric air conditions of +20 °C and 101.3 kPa (or density) and may be expressed in relative or absolute terms.

partitioned metal-enclosed, gas-insulated switchgear: Any metal-enclosed, gas-insulated switchgear (MEGIS) assembly in which multiple circuit interrupters and disconnects (intended to connect to separate sources or loads) are connected. Multiple partitioned MEGIS blocks or assemblies may be interconnected to complete a single MEGIS line-up. While partitioning between block type groupings can take place, nonpartition MEGIS will have fewer partitions than a semipartitioned MEGIS or fully partitioned MEGIS with an identical number of vertical sections. There is no gas sharing between gas compartments.

NOTE—See [Annex F](#).

permissible leakage rate (Fp): Maximum permissible absolute leakage rate of gas specified for a part, a component, or a subassembly, or by using the tightness coordination (TC) chart, for an arrangement of parts, components, or subassemblies connected together in one pressure system.

NOTE—Taken from 3.6.6.5 of IEC 62271-1:2017 [B18].

polyphase assembly: A construction in which all phases of the primary circuit are enclosed by a common metal housing.

pressure indicator: A gauge, instrumentation, or other device for measuring, indicating, or otherwise observing pressure.

NOTE—The device may or may not provide remote detection and may or may not be temperature compensated.

pressure relief device: A device intended to limit the pressure in a gas-filled compartment in the event of an overpressure. It may be a design feature (e.g., a specific resealable pressure relief feature of the compartment), a dedicated device (e.g., bursting disc), or something similar.

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

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

NOTE 2—Production tests are sometimes called “routine tests.”

rated filling pressure p_{re} : Insulation and/or switching pressure (in Pa), to which the assembly is filled before putting into service. It is referenced at the standard atmospheric air conditions of +20 °C and 101.3 kPa (or density) and may be expressed in relative or absolute terms.

rated supply voltage of closing and opening devices and of auxiliary circuits (U_a): The supply voltage of closing and opening devices and auxiliary and control circuits shall be understood to mean the voltage measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

removable element (device): A (disconnecting) device that may be removed from the stationary portion but requires unbolting connections and/or mounting supports. It contains high-voltage components and does require coordination with stationary interlocking functions.

NOTE 1—Removable elements are sometimes referred to as “stationary elements.”

NOTE 2—“Removable element” as defined in this document is a non-drawout element, as contrasted with the usage in IEEE Std C37.20.10 and IEEE Std C37.20.2, where the term describes a drawout element.

NOTE 3—Removable element can be a removable circuit breaker or switch.

safety glass: Glass that does not shatter when broken and may be of the laminated, tempered, or wire glass type.

sealed pressure system: Volume for which no further gas or vacuum processing is required during its expected operating life.

solid dielectric insulation: Consists of polymeric dielectric materials, such as silicone rubbers, ethylene propylene diene methylene (EPDM) rubbers, cross-linked ethylene-vinyl acetate (EVA), epoxy resins, and polyurethane used as an encapsulating material for live (energized) parts. The material can only be removed by a tool and/or destruction with the exception of joints when the covering material is the same as the encapsulating material.

NOTE—This definition specifically excludes ceramics, porcelain, glass, air, SF₆ (or other gas), and oil as primary dielectric materials. The coating of the bus is included in the scope of this definition when applied by molding processes.

vertical section: That portion of the switchgear assembly between two successive vertical delineations that may contain one or more interrupters, auxiliary devices, and associated primary conductors. A vertical section is fully self-contained and can be connected by extendable bus to form a switchgear assembly.

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

4.1 Normal (usual) service conditions

4.1.1 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 service conditions listed in this document.

Operation under normal service conditions is considered to be covered by the type tests according to this standard and the relevant product standard.

4.1.2 Indoor switchgear

The normal service conditions for indoor switchgear are as follows:

- a) The ambient air temperature does not exceed 40 °C, and its average value, measured over a period of 24 h, does not exceed 35 °C.
- b) The ambient air temperature does not drop below –5 °C.
- c) There is no influence from solar radiation.
- d) The altitude does not exceed 1000 m above sea level.
- e) The ambient air is not polluted by dust, smoke, corrosive, and/or flammable gases, vapors, or salt and would be considered to have a site pollution severity class (SPS) “very light” according to [Table H.1](#).
- f) 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.

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

NOTE 2—High humidity may also be due to ground-level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

- g) Vibration due to causes external to the switchgear or Earth tremors do not exceed vibrations caused by operation of the switchgear itself.

4.1.3 Outdoor switchgear

The normal service conditions for outdoor switchgear are as follows:

- a) The ambient air temperature does not exceed 40 °C, and its average value, measured over a period of 24 h, does not exceed 35 °C.
- b) The ambient air temperature does not drop below –30 °C.
- c) Solar radiation does not exceed a level of 1044 W/m². During periods above this intensity, the effects of solar radiation may be significant. See IEEE Std C37.24.

NOTE—Details on evaluating the effects of solar radiation are given in IEEE Std C37.24.

- d) The altitude does not exceed 1000 m above sea level.
- e) The ambient air may be polluted by dust, smoke, corrosive gas vapors, or salt. The pollution does not exceed the site pollution severity class (SPS) “light” according to [Table H.1](#) and [Table H.2](#).
- f) Ice coating does not exceed 20 mm.
- g) The wind speed does not exceed 40 m/s (144 km/h) (90 mi/h).
- h) Condensation or precipitations may occur.
- i) Vibration due to causes external to the switchgear or Earth tremors do not exceed vibrations caused by operation of the switchgear itself.

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

4.2.1 General

When MEGIS is expected to be used under conditions that are different from the normal service conditions given in [4.1](#), one should refer to the information in [4.2.2](#) through [4.2.7](#). Unusual service conditions should be brought to the attention of those responsible for the application, manufacture, and operation of the equipment. Consult [Clause 10](#) and [Clause 11](#) for additional construction and application options.

IEC 60068-1 can be used as guidance to define tests to cover certain unusual service conditions.

NOTE—Appropriate action should also be taken to ensure proper operation of other components (e.g., relays and control power transformers) under such conditions.

4.2.2 Altitude

Refer to [10.1.3](#) for application guidance.

4.2.3 Exposure to excessive pollution

For outdoor applications, ambient air that may be polluted by dust, smoke, corrosive gas, vapors, or salt at a level that exceeds a “light” pollution level as defined in [Annex H](#) is considered to be a special condition.

For indoor applications, ambient air that may be polluted by dust, smoke, corrosive gas, vapors, or salt at a level that exceeds severity class (SPS) “very light” as defined by [Table H.1](#) should be classified as “light,” “medium,” “heavy,” or “very heavy” as defined by [Annex H](#).

For indoor applications up to and including 52 kV, IEC/TS 62271-304 should be consulted.

NOTE—More information about exposure to pollution can be found in [Annex H](#).

4.2.4 Temperature and humidity

The rated performances of the equipment shall not be degraded or changed when the equipment is operated within the required range of temperature as stated in [4.1.1](#) or [4.1.2](#). Control devices that provide heat or cooling to ensure these performances may be used.

Refer to [10.1](#) for application guidance.

When MEGIS is applied where the ambient air temperature is higher than 40 °C, the total temperature limits for parts and materials as listed in [Table 2](#) shall not be exceeded, with the exception of external and accessible parts limits in item 7 and item 8 of [Table 2](#) where temperature limits may be exceeded when exposed to

higher than rated ambient conditions. Therefore, for the higher ambient, the equipment should be de-rated to a continuous current value that maintains the total temperature limits given in item 1 through item 6.

When MEGIS is applied where the ambient air temperature is less than $-30\text{ }^{\circ}\text{C}$, space heating and thermal insulation to minimize the effects of such exposure should be considered.

When gases other than SF_6 are used in MEGIS, space heating may be necessary at temperatures higher than $-30\text{ }^{\circ}\text{C}$, depending on the boiling point and pressure in the system in which the gas is used.

4.2.5 Exposure to abnormal vibration, shock, or tilting

Standard switchgear is designed for mounting on substantially level structures free from excessive vibration, shock, or tilting. Where any of these standard conditions may not exist, the requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level according to a relevant standard or specification should be specified by the user.

NOTE—Relevant standards for seismic evaluation are as follows: IEEE Std 693, IEEE Std C37.81, IEC/TR 62271-300 Ed. 1.0 b:2006 [B21], IEC 62271-207 Ed. 2.0 b:2012 [B19], and IEC/TS 62271-210 Ed. 1.0 b:2013 [B20].

Other unusual forms of vibration such as close proximity to mine blasting or mobile applications should be identified.

4.2.6 Wind speed

If the wind speed is expected to be in excess of the normal service wind speed, the requirements for the particular application should be specified by the user.

NOTE—Refer to IEEE Std C37.30.2™-2015 [B36] for additional information on wind loading and wind speed charts.

4.2.7 Other special (unusual) service conditions and 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 by the user. [Clause 10](#) should be consulted.

NOTE—For other special environmental conditions, the user is referred to IEEE Std C37.010™-2016 [B30] or IEC 60721-1 Ed. 2.2 b:2002 [B17].

5. Ratings

5.1 General

The rating and capability of switchgear is a designated limit of operating characteristics that is based on usual service conditions as specified in [4.1](#). The common ratings of switchgear assigned by the manufacturer, including their operating devices and auxiliary equipment, shall be selected from the following (as applicable):

- a) Rated maximum voltage (V) or (U_r)
- b) Rated insulation level (U_d), (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)
- g) Rated duration of short-circuit current (t_k)
- h) Rated supply voltage of auxiliary and control circuits (U_a)

Where the switchgear assembly comprises a combination of primary and secondary circuits, each may be given ratings.

In addition to these ratings, MEGIS may have interrupting or switching capability, which is determined by the rating 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: IEEE Std C37.04 or IEEE Std C37.06 (circuit breakers); IEEE Std C37.20.4 (interrupter switches); and IEEE Std C37.42 (fuses).

- i) The ratings listed in this standard and other referenced standard are preferred but are not considered to be restrictive.
- j) The construction and ratings of this equipment may also, but not necessarily, match the construction and ratings of IEC 62271-200; however, the requirements in this standard take precedence.

5.2 Rated maximum voltage (V) or (U_r)

The rated maximum voltage (V or U_r), as used in this standard, is the phase-to-phase root-mean-square (rms) voltage equal to the maximum system voltage for which the equipment is designed. It indicates the maximum value of the “highest system voltage” of networks for which the equipment may be used. The preferred maximum voltages and corresponding insulation levels for MEGIS are listed in [Table 1](#) of this document.

MEGIS may use voltage-sensitive components such as voltage transformers, surge arresters, or other components with rated insulation levels (power frequency withstand, lightning impulse withstand, or both) that are less than the levels shown in [Table 1](#). The upper limit for the operating voltage may be determined by the rating of these components.

NOTE—The term “rated maximum voltage” used in most IEEE switchgear standards has the same meaning as the term “rated voltage” as used in IEC 62271-1 Ed. 1.0 b:2017 [\[B18\]](#).

5.3 Rated insulation level (U_a , U_p)

The rated insulation level of a MEGIS is its voltage withstand capability with specified magnitudes and waveshapes of voltage applied under specified conditions. Preferred ratings are given in [Table 1](#).

The rated dielectric withstand capability of a MEGIS shall include the following:

- a) Dry power frequency withstand voltage for indoor applications
- b) Dry and wet (where applicable) power frequency withstand voltages for outdoor applications
- c) Dry lightning impulse withstand voltage

Table 1—Voltage and insulation levels for MEGIS

Rated maximum voltage (kV)	Power-frequency withstand voltage (rms) (kV) (U_d) test voltage			Impulse withstand voltage (kV) (U_p) test voltage	Wet test voltages for external insulation exposed to weather (including IEEE C37.017 bushings) (kV) test voltage
	For switchgear with separable insulated connector type terminations per IEEE Std 386	For switchgear with inner cone or outer cone type terminations per EN 50181 / IEC 60137	For switchgear not having IEEE 386 or EN 50181 / IEC 60137 terminations		
4.76	19	19	19	60	—
8.25	34	36	36	95	—
15.0	34	36	36	95	30
27.0	40	50	60	125	50
38.0	50	70	80	150	75
38.0	—	70	80	200	80
48.0	—	95	105	250	95
52.0	—	95	120	250	100

5.4 Rated power frequency (f_r)

The rated power frequency of MEGIS is the frequency at which it is designed to operate. Standard frequencies are 50 Hz and 60 Hz.

5.5 Rated continuous (normal) current and temperature rise

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

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

The specified temperature limits applicable to switchgear assemblies are given in [Table 2](#).

The preferred values of rated continuous current of the main bus in MEGIS shall be 200 A, 600 A, 1200 A, 2000 A, 2500 A, 3000 A, and 4000 A.

The continuous current rating of the individual interrupter compartments shall be equal to the ratings of the switching and interrupting devices used, except as may be modified by lower continuous current ratings for current transformers, power fuses, and so on.

The temperature rise and total temperature of any part of the switchgear shall not exceed the limits specified in [Table 2](#) of this standard under the conditions specified in the test clauses.

NOTE 1—The term “nonoxidizing gas” (NOG) is not used because other kinds of gases may have adverse effects on conductive interfaces. Long-term studies and industry acceptance have not been developed on replacement gases.

NOTE 2—Temperature limits are mostly consistent with IEEE Std C37.100.1™-2007 [B41] and IEEE Std C37.20.2.

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 within an ambient temperature range defined in 4.1.

The temperature of the air surrounding incoming line or load-side insulated cables within compartments of an enclosed assembly shall not exceed 65 °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 at rated voltage and rated power frequency
- c) In an ambient air temperature of 40 °C

This temperature limitation is based on the use of 90 °C insulated power cables. Use of lower temperature rated cables requires special consideration.

Temperature limits for contacts and connections in gases other than SF₆ are limited to those for air due to the evolving nature of the technology.

Table 2—Limits of temperature and temperature rise for various parts, materials, and dielectric materials of MEGIS switchgear^{a, b, c, f}

Nature of the part of the material and of the dielectric		Maximum values	
		Total temperature (°C)	Temperature rise in ambient air temperature not exceeding 40 °C ^j (K)
1	Contacts (carrying rated current) ^d		
	Silver-coated or nickel-coated ^e		
	—In air or other gas	105	65
	—In SF ₆ ^l	105	65
	Bare copper		
	—In air or other gas	75	35
	—In SF ₆ ^l	105	65
2	Connections, bolted or the equivalent ^d		
	—Bare copper, bare copper alloy, or bare aluminum alloy in air	90	50
	—Bare copper in SF ₆ ^l	105	65
	—Silver or nickel coated in SF ₆ ^l	115	75
	—Silver or nickel coated in air or other gas	105	65
	—Tin coated in air	105	65
3	All other contacts or connections made of bare metals or coated with other materials	d, e	d, e

Table continues

Table 2—Limits of temperature and temperature rise for various parts, materials, and dielectric materials of MEGIS switchgear^{a, b, c, f} (continued)

Nature of the part of the material and of the dielectric		Maximum values	
		Total temperature (°C)	Temperature rise in ambient air temperature not exceeding 40 °C ^j (K)
4	Terminals for the connection to external conductors by screws or bolts ^g	^k	^k
	—Bare	70	30
	—Silver, nickel, or tin coated	85	45
	—Silver or nickel coated with IEEE Std 386 or EN 50181/IEC 60137 connectors	105	65
	—Other coatings	^f	^f
5	Metal parts acting as springs	^h	^h
6	Materials used as insulation and metal parts in contact with insulation of the following classes ^j	ⁱ	ⁱ
	—Y (Class 90)	90	50
	—A (Class 105)	105	65
	—E (Class 120)	120	80
	—B (Class 130)	130	90
	—F (Class 155)	155	115
	—H (Class 180)	180	140
	—C (Class 220)	220	180
7	Accessible parts		
	—Expected to be touched in normal operation	50	—
	—Which need not be touched in normal operation	70	—
8	External surfaces not accessible to an operator in the normal course of duties ^j	110	—

^aAccording to its function, the same part may belong to several categories as listed in Table 2. In this case, the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.

^bFor vacuum switching devices, the values of temperature and temperature-rise limits do not apply to parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 2.

^cCare shall be taken to ensure that no damage is caused to the surrounding insulating materials.

^dWhen engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be as follows:

- For contacts, those of the surface material having the lowest value permitted in item 1 of Table 2
- For connections, those of the surface material having the lowest value permitted in item 2 of Table 2

^eThe quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area; otherwise, the contacts shall be regarded as “bare”:

- After the making and breaking test (if any)
- After the short-time withstand current test
- After the mechanical endurance test; according to the relevant specifications for each type of equipment

^fWhen materials other than those given in Table 2 are used, their properties shall be considered, to determine the maximum permissible temperature rises.

^gThe values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.

^hThe temperature shall not reach a value where the elasticity of the material is impaired.

ⁱClasses of insulating materials are those given in IEEE Std 1 [B23] or IEC 60085 [B16].

^jThese values do not take into account any influence on insulation of cable or cable termination.

^kThese values are for connections to bare (uninsulated) cables or bus conductors. For connections to insulated cables, terminals shall not exceed 45 K rise or 85 °C hottest spot total temperature when connected to 90 °C rated cables rated for the full continuous (normal) current of the switchgear.

^lSF₆ means pure SF₆ (not a mixture with other gases) complying with 6.12.

5.6 Rated short-time withstand current (I_k)

The rated short-time withstand current of the MEGIS assembly is the maximum rms symmetrical current that the bus and connections shall be required to carry for the rated duration of the short circuit. The preferred ratings are given in [Table 3](#).

The short-time withstand current ratings of the MEGIS shall be no greater than the short-time withstand ratings of the lowest rated switching devices, protective devices, and the short-time rating of the current transformers used (see IEEE Std C57.13, IEEE Std C37.04, IEEE Std C37.06, and IEEE Std C37.20.4).

NOTE 1—Short-time current is the peak withstand current divided by 2.6 (for 60 Hz) or 2.5 (for 50 Hz).

NOTE 2—Momentary current is historical and is short-time current times 1.55.

Table 3—Preferred short-time current ratings for MEGIS

Line no.	Ratings		(Informative) Momentary current kA, rms (Asymmetrical)
	Rated short-time current kA, rms (Symmetrical)	Rated peak withstand current kA	
	Col 2	Col 3	Col 4
1	12.5	32.5	19.4
2	16.0	42.0	24.8
3	20.0	52.0	31.0
4	25.0	65.0	38.8
5	31.5	82.0	48.8
6	40.0	104.0	62.0
7	50.0	130.0	77.5
8	63.0	164.0	97.7

5.7 Rated peak withstand current (I_p)

This rating defines the peak current associated with the first major loop of the rated short-time withstand current that the switchgear can carry in the closed position under its service conditions (see [Clause 4](#)). The preferred ratings are given in [Table 3](#), and the peak withstand current values listed are equal to 2.6 times the rated short-time currents.

For assemblies including generator circuit breakers that comply with standard BS IEC/IEEE 62271-37-013:2015 [\[B13\]](#), the peak withstand current shall be 2.74 times the rated short-time current and all other components (switching devices, disconnecting devices, current transformers, etc.) within the power circuit shall also comply with the 2.74-peak current multiplier.

The peak withstand current ratings of the MEGIS shall be as listed in [Table 3](#) or as modified for generator circuit breakers, but in no case will they be greater than the peak withstand ratings of the lowest rated switching and/or protective devices used in the power circuit (IEEE Std C37.04 and IEEE Std C37.20.4).

NOTE—This rating was previously called the “rated momentary current” and was an rms asymmetrical current. In other documents, this value may also be referred to and can be equated to “peak withstand current.” If the peak withstand current rating is 2.6 times the rated short-time symmetrical current and the duration of the test is 10 cycles, then the requirement for “rated momentary withstand current” has been met.

5.8 Rated duration of short-time withstand current (t_k)

This rating defines the interval of time for which the switchgear can carry, in the closed position, a current equal to its rated short-time withstand current.

The preferred duration of short-time withstand current is 2 s.

The duration for the MEGIS assembly may be limited to a shorter time by a protective device, switch, or current transformer rating, but it shall not reduce the requirement for the bus and connections.

When the rated duration of the short-time withstand current of the load interrupter or isolation/disconnect switch is less than the preferred rating of 2 s, then the MEGIS assembly shall be assigned a rated short-time withstand current duration rating equal to the rating of the switch and the rating shall be noted on the nameplate (see 6.4.1).

NOTE—This preferred rated duration of 2 s is based on the maximum permissible tripping time delay “Y” as specified in “rated closing, latching, and short-time current carrying capability” in IEEE Std C37.04.

5.9 Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)

MEGIS shall be designed to accommodate the control voltage ranges of the components in accordance with the standards applicable to the various components. In particular, it should be noted that the control voltage limits (upper and lower) for components such as circuit breakers and protective relays differ from each other. The control wiring in the MEGIS shall be sized as necessary to help ensure that the rated control voltage limits of the components are met.

5.10 Rated supply frequency of closing and opening devices and of auxiliary circuits

The preferred values of rated supply frequency are dc, 50 Hz, and 60 Hz.

5.11 Rated pressure of compressed gas for insulation and/or operation

There are at present no preferred rated values for pressure of the compressed gas for insulation and/or operation.

5.12 Current transformer ratings

5.12.1 Current transformer mechanical ratings

The mechanical ratings of current transformers shall be such that they can successfully withstand the momentary 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 peak let-through current (see IEEE Std C37.41) of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the momentary current shall be considered as being 10 cycles.

5.12.2 Current transformer thermal ratings

The thermal ratings of current transformers shall be such that they can successfully withstand the short-circuit current for which the associated circuit interrupting devices are applied. When the primary circuit is protected by fuses, the current transformers shall successfully withstand the maximum I^2t let-through (clearing I^2t) of

the fuses (see IEEE Std C37.41). Unless specifically limited to a shorter time by the associated protective equipment, the duration of the short-circuit current shall be considered to be 1 s.

5.12.3 Current transformer ambient temperature

Current transformers for use in switchgear assemblies shall be suitable for use in a 55 °C ambient temperature in accordance with IEEE Std C57.13.

5.12.4 Current transformer accuracies

Refer to [Table 4](#) for current transformer accuracies.

Table 4—Standard accuracy ratings for current transformers in MEGIS switchgear

Ratio	Metering accuracy at standard burden ^a					Relaying accuracy ^c
	B0.1	B0.2	B0.5	B0.9 ^b	B1.8 ^b	
50:5	1.2	2.4 ^d	—	—	—	C or T10
75:5	1.2	2.4 ^d	—	—	—	C or T10
100:5	1.2	2.4 ^d	—	—	—	C or T10
150:5	0.6	1.2	2.4 ^d	—	—	C or T20
200:5	0.6	1.2	2.4 ^d	—	—	C or T20
300:5	0.6	1.2	2.4 ^d	2.4 ^d	—	C or T20
400:5	0.3	0.6	1.2	1.2	2.4 ^d	C or T50
600:5	0.3	0.3	0.3	1.2	2.4 ^d	C or T50
800:5	0.3	0.3	0.3	0.6	1.2	C or T50
1200:5	0.3	0.3	0.3	0.3	0.3	C100
1500:5	0.3	0.3	0.3	0.3	0.3	C100
2000:5	0.3	0.3	0.3	0.3	0.3	C100
3000:5	0.3	0.3	0.3	0.3	0.3	C100
4000:5	0.3	0.3	0.3	0.3	0.3	C100
5000:5	0.3	0.3	0.3	0.3	0.3	C100

^aSee IEEE Std C57.13.

^bThese were formerly standard burdens of B1.0 and B2.0, respectively, which now are classified as relaying burdens in IEEE Std C57.13.

^cThese accuracies may not be sufficient for proper relaying performance under all conditions. To enable proper relaying performance, the user should make an analysis of CT performance considering the relaying requirements for the specific short-circuit currents and secondary circuit impedances.

^dThis metering accuracy is not in IEEE Std C57.13.

5.12.5 Other current sensing devices

Rogowski coils or other types of current sensing devices, upon agreement between the manufacturer and the user, may be used with compatible relays in place of conventional current transformers. Various standards for Rogowski coils and other types of current sensors performance exist or may be under development. Until new or developing standards are implemented, such devices should be specified by the user, and use of these devices is subject to agreement between the user and the manufacturer. If the switchgear design does not provide means for using conventional current transformers, the requirement specified in [Clause 7](#) for current transformers included in the test arrangement is not applicable and the test arrangement shall include the maximum number of physically largest Rogowski coils or other types of current sensors suitable for the equipment. If the switchgear design provides means for using conventional current transformers, the test arrangement specified in [Clause 7](#) is applicable in addition to the inclusion of the maximum number of physically largest Rogowski coils or other type of current sensors suitable for the equipment.

6. Design and construction

6.1 Buses, primary connections, and other components

Buses and primary connections shall be of copper, aluminum, or both. For bus ratings, see 5.5. The bus and connections can be bare or plated. Buses can be insulated or uninsulated. When used, insulation is to be tested per 7.13 as applicable.

Construction of the equipment can be polyphase assembly or single-phase assembly.

6.1.1 Phase or polarity arrangements

The phase or polarity arrangements shall be made to meet the following requirements:

- a) The standard phase arrangement on three-phase assembled switchgear primary connections shall be 1, 2, 3, from front to back, top to bottom, or left to right, as viewed from the main switching device operating mechanism side. Certain types of equipment may require other phasing arrangements and a neutral conductor. In these cases, the phasing shall be suitably indicated.
- b) Panel mounted devices shall be mounted in the same arrangement as specified in item a) as viewed from the front of the panel.
- c) These requirements apply to accessible parts, that is, the cable arrangement. It does not apply to phase arrangements inside gas-insulated and sealed compartments.

6.1.2 Phase sequence

The phase sequence on connection diagrams shall be as follows: When considering voltage to neutral on a polyphase system with respect to the element of time, the voltage of Phase 1 will reach a maximum ahead of the voltage of Phase 2, Phase 3, and so on. This sequence shall be designated as a phase sequence in the order 1, 2, 3, and so on, unless otherwise suitably indicated.

6.1.3 Cable termination compartment

The incoming or outgoing cables and termination points shall not be readily accessible and shall be enclosed, typically, in a separate air-filled compartment or chamber. Access shall be provided by a door or panel.

The MEGIS shall provide space for the devices used for making electric and mechanical connections to the incoming and outgoing cables. Each cable terminal connection point shall meet the bolt hole requirements of NEMA CC1 if applicable.

If the switchgear uses cable terminators, the requirements of IEEE Std 386 or EN 50181 apply.

6.1.4 Main bus splices

When connecting through buses in adjoining vertical sections, the connecting means (bolts, nuts, washers, or other methods) shall not impair the dielectric integrity of the unit. The connection shall be capable of passing the dielectric tests for the ratings of the equipment.

6.1.5 Isolation means

Isolation means shall be provided in MEGIS. The isolating means is required to 1) provide a visible gap (verifiable from outside of the switchgear) and 2) be capable, in the open position, of withstanding the dielectric test specified in 7.2.6.2.1 or 7.2.6.2.2 (as appropriate) at 110% of the rated levels. In addition, disconnecting switches shall be capable of passing the requirements of IEEE Std C37.20.4 for disconnecting switches.

The gap shall be visible by either a window or other means, such as a camera system, meeting the requirements of subclause 6.1.5.1 or 6.1.5.2.

The interrupter switches, circuit breakers and power fuses may be stationary or drawout. Mechanical interlocks shall be provided for proper operating sequence. For stationary circuit breakers, an isolating means is required.

Load interrupter switches, disconnect, bypass or selector switches, and grounding switches shall meet the requirements of IEEE Std C37.20.4. Circuit breakers shall be of the drawout type or stationary type with disconnecting switches and/or grounding switches. Grounding switches shall be interlocked to prevent closing unless the associated circuit breaker is opened. Circuit breakers shall meet the requirements of IEEE Std C37.04, and IEEE Std C37.09.

NOTE—The interrupter switch defined in IEEE Std C37.20.4 will meet these requirements, but other style devices may also meet the listed requirements.

6.1.5.1 Viewing panes (viewing ports and infrared windows)

Materials for the viewing pane shall be one of the following alternatives:

- a) Safety glass with no color shading.
- b) Transparent material with no color shading that complies with 7.13.1.1.4.
- c) Infrared windows or ports are not usually used to view isolation means, and they are not required to have a flammability rating; however, they may be required to have a permanently attached cover that meets the requirements listed as follows. This requirement is placed on the window by the manufacturer of the infrared viewing port or by the application of the viewing port.

A permanently attached cover to protect the material from dirt and scratching may be supplied. When supplied, the cover shall include the following features:

- The fastening device for the cover when closed shall be easily released by hand without the use of a tool.
- The cover must be easily closed by hand and easily secured by hand.
- The cover when closed shall have a permanent label “Viewing Window for Isolating Gap—Open Cover”.
- Test required in A.3.10 may be conducted with the cover over the pane.

6.1.5.2 Alternative viewing systems

To provide a view of the switch contacts, a video camera system may be permitted to be used in place of a direct viewing window provided it meets the criteria specified in this clause. Viewing of the image of the switch can be made with a camera, laptop, or human-machine interface (HMI) attached to the equipment.

The camera shall be a video type with real-time output available so that the user can confirm the movement and position of the switch. Video cameras shall have the following features:

- a) If the camera is located in a high-voltage compartment, it shall be electromagnetically shielded for use in the high-voltage environment.
- b) It shall have an operating and storage temperature range not less than the switchgear in which the camera is being used.

- c) It shall have a minimum mean time between failure (MTBF) of 150 000 h, or it shall be capable of being replaced without opening of the gas-filled compartment.
- d) The camera and its light source shall be capable of being supplied with power from a portable external source. Permanent power may also be available; however, this shall not prevent application of a portable source.
- e) The camera output shall show all phase contacts of the switch in the same view (same screen). In the case of isolated phase construction, and where the phases of the switch operate from a common operating shaft, three cameras shall be used to show all phase contacts of the switch in sequence.
- f) Provisions shall be provided to confirm that the switch being viewed is the intended switch. Examples of methods used to ensure compliance are as follows:
 - 1) Use of a dedicated plug-in connection port for each switch in each cell, with the connection port(s) physically located on that cell, so that a viewing device (e.g., a notebook computer) is plugged into the unique connection port to view each switch in that cell.
 - 2) The switch itself shall be identified clearly by a marking located either on the switch or in close proximity to the switch, such that the camera system views the switch identification at the same time it views the switch contacts.
- g) There shall not be more than one switch in the field of view of any one camera.
- h) The view of the contacts and the switch identification marking (if present) shall be illuminated by a long-life light source(s).

NOTE—A light-emitting diode (LED) light source is one example of a long-life device. Multiple emitters in the LED assembly will likely increase the expected life of the light source.
- i) Where the viewing system replacement cannot be achieved without exposure to bare live parts, then a warning label shall be applied.
- j) Safe shutdown and operating procedures shall be provided in case of failure of the camera systems.
- k) Instructions shall be provided for the replacement of the camera and or light source.

6.2 Grounding

MEGIS shall be provided with a reliable grounding point for connection of an equipment ground conductor (EGC) suitable for specified fault conditions. Parts of metallic enclosures connected to the grounding system may be designed to be part of the ground circuit.

All conductive components and enclosures that may be touched during normal operating conditions and are intended to be grounded shall be designed to carry 30 A (dc) with a voltage drop of maximum 3 V to the grounding point provided at the switchgear or, in the case of remotely mounted enclosures, to the grounding point on the enclosure.

A ground bus shall be included that will electrically connect together the structures in MEGIS and provide for connection to the station ground.

The ground bus shall be capable of carrying the same short-circuit and short-time rating as the main bus; however, there is no required continuous current rating for the ground bus.

The ground bus shall have provisions in the cable compartment for grounding cable terminations.

At points of connection between the ground bus and the assembly, any nonconductive coatings, such as organic coatings (paint), shall be removed or penetrated to ensure good electrical contact.

Circuit connections to the ground bus shall be made so that it is not necessary to open the ground bus circuit to remove any connection made to the ground bus.

Ground connections shall be provided for drawout elements to ensure that they are grounded until the primary circuit is disconnected and the drawout element is moved a safe distance. See test position in IEEE Std C37.20.10.

When mounted on metal switchgear structures, metal cases or frames of instruments, instrument transformers, meters, relays, and similar devices shall be considered as being adequately grounded when secured to these structures by metal mounting hardware with adequate provision for penetrating the organic coating.

6.3 Control and secondary circuits and devices

6.3.1 General

All voltage circuits used for controlling, relaying, or metering shall be protected within the MEGIS as follows:

- a) All circuits supplied from external sources (ac or dc) shall have short-circuit protection. This may be provided by a single set of short-circuit protective devices within the control source incoming section.
- b) All circuits supplied from internal sources (ac and dc) shall have short-circuit protection within the same section as the supply source. If these circuits are supplied by a control power transformer, this protection may be in the primary circuit (only).
- c) Overcurrent protection of voltage circuits may be provided in addition to the required short-circuit protection.
- d) Other circuits supplying loads (such as heaters, receptacles, or lights) shall have overload and short-circuit protection.
- e) Overcurrent protection of current transformer secondary circuits shall not be provided.

6.3.2 Voltage—current sensing, measuring and protection

6.3.2.1 Voltage transformers

The voltage transformers shall comply with IEEE Std C57.13 and shall be protected by meeting the following requirements:

- a) Primary circuits of all voltage transformers shall include current-limiting fuses.
- b) Secondary circuits of all voltage transformers shall include fuses or equivalent protective devices.

EXCEPTION: Fuses may be omitted from secondary circuits of voltage transformers if the secondary burden includes voltage regulators, protective relays, or other devices considered sufficiently essential to the operation of the installation to make it preferable to incur the hazards associated with the possible destruction of the voltage transformer by a sustained secondary short-circuit rather than to risk interruption of the voltage supply to such devices as a result of a momentary secondary short-circuit.

Primary and secondary protective devices may be omitted from voltage-dividing devices such as capacitive and resistive voltage dividers.

6.3.2.2 Low-power voltage and current measuring devices

Low-power measuring devices shall comply with IEC 61869-6.