IEEE Std C37.122-1993(R2002)
(Revision of IEEE Std C37.122-1983,
includes IEEE Std C37.122a-1991)

IEEE Standard for Gas-Insulated Substations

Sponsor

**Substations Committee
of the
IEEE Power Engineering Society**

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IEEE Standards Board

Abstract: The technical requirements for the design, fabrication, testing, and installation of a gas-insulated substation (GIS) are covered. The parameters to be supplied by the purchaser are set, and the technical requirements for the design, fabrication, testing, and installation to be furnished by the manufacturer are established.
Keywords: gas-insulated substation, GIS, GIS design, GIS equipment, GIS installation, GIS testing, SF_6, sulfur hexafluoride

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Introduction

(This introduction is not a part of IEEE Std C37.122-1993, IEEE Standard for Gas-Insulated Substations.)

IEEE Std C37.122-1983 was initiated in the early 1970s when the first gas-insulated substations (GIS) were introduced. Approved in 1983, it contains standards, recommended practices, and guides. Circumstances beyond the control of the responsible Technical Committees delayed its availability to users until late 1988. Simultaneous to its publication, the Gas-Insulated Substations Subcommittee of the IEEE Power Engineering Society (PES) Substations Committee began work on the necessary update, revision, and expansion of the document.

The reliability of GIS has improved greatly since the first installation in the late 1960s. Utilities have taken advantage of the greater flexibility offered by GIS to locate substations closer to load centers with considerable savings in subtransmission systems. In addition, GIS typically offers 20 years or more of operation before major overhaul is required.

During the Working Group and Subcommittee deliberations on the update, it was recognized that users would be better served if the original document were divided in two, becoming IEEE Std C37.122-1993 (a standard) and IEEE Std C37.122.1-1993 (a guide). The two documents can be referred to individually or jointly depending on the purpose of the referral.

An extensive bibliography on gas-insulated substations, consolidating published and updated entries, is provided for the convenience of the user in obtaining detailed information on the subjects covered in this standard.

IEEE Std C37.122a-1991, Supplement to IEEE Std C37.122-1983, IEEE Standard Gas-Insulated Substations, Section 2.2.2: Pressurized Enclosures, has also been included in this standard.

Although all Working Groups of the Gas-Insulated Substations Subcommittee contributed to this revision, the prime responsibility belonged to Working Group K2, Revision of IEEE Std C37.122-1983, which approved this standard. At the time this standard was approved, Working Group K2 had the following membership:

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IEEE Standard for Gas-Insulated Substations

1. Overview

This standard establishes ratings and requirements for planning, design, testing, installation, and operation of gas-insulated substations (GIS) for alternating-current applications for voltages from 72.5 to 800 kV. Typical installations are assemblies of specialized devices such as circuit breakers, switches, bushings, buses, instrumentation, and the gas-insulating system. It does not include certain items that may be directly connected to gas-insulated substations, such as power transformers and protective relaying.

2. References

The following publications shall be used in conjunction with this standard:

Accredited Standards Committee C2-1993, National Electrical Safety Code (ANSI).[1]

ANSI C37.06-1987 American National Standard Switchgear—AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.[2]

ANSI C63.2-1987 American National Standard Specifications for Electromagnetic Noise and Field-Strength Instrumentation, 10 kHz to 40 GHz.

ANSI MC96.1-1982, American National Standard Temperature Measurement Thermocouples.[3]

ANSI/ASME 1992 Boiler and Pressure Vessel Code—Section VIII: Pressure Vessels, Division 1.

ANSI/ASME B31.1-1992, Power Piping.

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[1]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.
[2]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.
[3]ANSI MC96.1-1982 has been withdrawn; however, copies can be obtained from Global Engineering, 1990 M Street NW, Suite 400, Washington, DC, 20036, USA.

ASTM D2472-92 , Specification for Sulfur Hexafluoride.[4]

CENELEC EN 50 052-1988, Specification for Cast Aluminum Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear.[5]

CENELEC EN 50 064-1990, Specification for Wrought Aluminum and Aluminum-Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear.

CENELEC EN 50 069-1991, Specification for Welded Composite Enclosures of Cast and Wrought Aluminum Alloys for Gas-Filled High-Voltage Switchgear and Controlgear.

CENELEC EN 50 089-1992, Specification for Cast Resin Partitions for Metal-Enclosed Gas-Filled High-Voltage Switchgear and Controlgear.

IEC 517: 1990 Gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above (3d ed.).[6]

IEEE Std 24-1984 IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings (ANSI).[7]

IEEE Std 48-1990 IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations (ANSI).

IEEE Std 80-1986 (Reaff 1991) IEEE Guide for Safety in AC Substation Grounding (ANSI).

IEEE Std 100-1992 The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std 119-1974 IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus.[8]

IEEE Std 315-1975 (Reaff 1989) IEEE Standard Graphic Symbols for Electrical and Electronics Diagrams (ANSI).

IEEE Std 367-1987 IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault (ANSI).

IEEE Std 693-1984 (Reaff 1991) IEEE Recommended Practices for Seismic Design of Substations (ANSI).

IEEE Std C37.010-1979 (Reaff 1988) IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.04-1979 (Reaff 1988) IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.09-1979 (Reaff 1988) IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

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[4]ASTM publications are available from the Customer Service Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

[5]CENELEC publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[6]IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[7]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[8]IEEE Std 119-1974 has been withdrawn; however, copies can be obtained from the IEEE Standards Department, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std C37.24-1986 (Reaff 1991) IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear (ANSI).

IEEE Std C37.30-1992 IEEE Standard Definitions and Requirements for High-Voltage Air Switches (ANSI).

IEEE Std C37.38-1989 IEEE Standard for Gas-Insulated Metal-Enclosed Disconnecting, Interrupter, and Grounding Switches (ANSI).

IEEE Std C62.11-1987 IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (ANSI).

3. Definitions

The definitions in this clause are applicable only to the subject treated in this standard. At the time this standard was approved there were no corresponding definitions in IEEE Std 100-1992. [9]

3.1 assembly (GIS): A collection of GIS components which are interconnected and ready for insertion as a subassembly in a GIS, such as a breaker bay shipping assembly. The term is also used to describe a complete GIS.

3.2 auxiliary circuits: All control, indicating, and measuring circuits.

3.3 compartment (GIS): Any gas section of the gas-insulated substation assembly that provides gas isolation.

3.4 continuous enclosure: A bus enclosure in which the consecutive sections of the enclosure are electrically bonded together to provide a continuous current path through the entire enclosure length.

3.5 continuous monitoring: The process of sampling the state of some phenomenon at a time interval shorter than the time constant of the phenomenon.

3.6 gas barrier insulator: An insulating support specifically designed to prevent passage of gas from one gas compartment to another.

3.7 gas density, minimum: The minimum (below normal) operating gas density at which the gas-insulated substation and its components are certified to meet their assigned electrical ratings.

3.8 gas density, normal: The manufacturer's recommended operating gas density (usually expressed as a pressure at 20 °C.

3.9 gas-insulated substation (GIS): A compact, multicomponent assembly, enclosed in a grounded metallic housing in which the primary insulating medium is a compressed gas, and which normally consists of buses, switchgear, and associated equipment.

3.10 gas-insulated surge arrester: A metal-enclosed surge arrester specifically designed for use in a gas-insulated substation.

3.11 gas leakage: Loss of insulating gas from the pressurized compartment.

3.12 metallic enclosure: A grounded, leak-tight enclosure that contains the compressed insulating gas and associated electrical equipment.

3.13 non-continuous enclosure: A bus enclosure in which the consecutive sections of the enclosure are electrically insulated from each other, although each section is connected to ground.

NOTE — This construction prevents longitudinal currents from flowing beyond each enclosure section. This design is no longer in common usage.

3.14 spacer (insulator): An insulator used to support the inner conductor in the enclosure.

[9]Information on references can be found in clause 2..

3.15 transition compartment: A compartment specifically designed for joining gas-insulated substation equipment of different design or manufacture. The compartment provides the necessary transition for the current-carrying conductor and the enclosure.

3.16 type tests: Tests made on representative samples that are intended to be used as a part of routine production. The applicable portions of these type tests may also be used to evaluate modifications of a previous design and to ensure that performance has not been adversely affected.

3.17 water vapor (moisture) content: The amount of water in parts per million by volume (ppmv) that is in the gaseous state and mixed with the insulating gas.

4. Service conditions

4.1 Normal service conditions

Devices conforming to this standard shall meet the electrical, mechanical, thermal, and other requirements of the gas-insulated substation on which it is used and be capable of operation under the following conditions:

4.1.1 Temperature range

The normal ambient temperature range shall be −30 °C to +40 7°C.

4.1.2 Heat absorption due to solar radiation

Solar radiation shall be considered in the design of GIS. IEEE Std C37.24-1986 provides guidance in evaluation of the effects of solar radiation on outdoor apparatus.

4.1.3 Internal pressure

The internal pressure range shall be from 10 Pa to the maximum operating pressure specified by the manufacturer.

4.1.4 Wind and ice

Wind and ice conditions shall correspond to conditions included in Accredited Standards Committee C2-1993 (NESC) for heavy loading on structures.

4.1.5 Electromagnetic interference

The equipment shall not operate falsely or fail to operate because of induced transient or steady-state electromagnetic fields generated during normal service or test conditions.

4.1.6 Power frequency

The standard power frequency shall be 50 Hz or 60 Hz.

4.1.7 Vibration and shock

The equipment shall withstand for its service life the vibration of any directly connected equipment, such as transformers, and the shock caused by the operation or maintenance of the equipment.

4.1.8 Altitude

The normal installation altitude shall not exceed 1000 m (3300 ft). At any altitude, the dielectric characteristics of the internal insulation are identical to those measured at sea level. For installation above 1000 m (3300 ft), only adjustments of air-insulated connections (bushings) and overpressure protective devices are required.

4.2 Special service conditions

Special service conditions are those in which the equipment is used under other than the normal service conditions. Standard assemblies may be applied at special service conditions, but performance may be affected, and special considerations shall be given to these applications.

4.3 Other conditions that may affect design and application

Where other conditions exist, they shall be brought to the attention of the manufacturer. Among such conditions are:

a) Exposure to damaging fumes or vapors, steam, salt air, oil vapors, hot humid climate, excessive dust, abrasive dust, dripping water, falling dirt, explosive mixtures of dust or gases, or extreme high or low temperatures.
b) Unusual location requirements, space or ventilation limits, special duty, frequency or other operating requirements, difficulty of maintenance, non-standard or unstable control voltage, or abnormal vibration.
c) Portions of a single GIS with different environments (such as a portion of the GIS installed partially indoors and partially outdoors).

5. Ratings and requirements

5.1 Equipment ratings

5.1.1 Temperature ratings

The general ratings that all components of the station shall meet or exceed are as follows:

Maximum allowable total temperature:

Main conductor joints = 105 °C

External surfaces = 70 °C

All other conditions regarding temperature limitations are as noted in IEEE Std C37.010-1979 and IEEE Std C37.30-1992 .

5.1.2 Voltage ratings

Required voltage ratings are listed in table 1.

Table 1— Voltage ratings

System voltage	Type test voltages		
Rated max voltage phase-to-phase kV rms	**Rated BIL kV crest**	**Low frequency phase-to-ground withstand kV rms**	**Switching impulse withstand kV crest**
72.5	350	160	
121	550	215	
145	650	310	
169	750	365	
242	900	425	
362	1050	500	825
550	1550	740	1175
800	2100	960	1550

NOTES:
1 — Routine power-frequency (50 Hz or 60 Hz) I min withstand tests shall be conducted prior to shipment from the factory at low-frequency withstand voltages.
2 — Disconnect switch open-gap withstand shall be 10% higher than substation type test values.

5.1.3 Continuous current (A rms) rating at ambient temperature

The value of rated continuous current shall be selected from the following:

Rated continuous current (Arms)
2000
2500
3150
4000
5000
6300

5.1.4 Load current-carrying capability under various conditions of ambient temperature

The variation of rated continuous current with ambient temperature shall be as specified in IEEE Std C37.010-1979 and IEEE Std C37.30-1992.

5.1.5 Short-time load current capability

The short-time load current capability shall be as specified in IEEE Std C37.010-1979.

5.1.6 Rated close and latch current

The rms and peak value of the rated momentary current shall be 1.6 and 2.7 (respectively) times the rated short-time current-carrying capability.

5.1.7 Short-time current-carrying capability

The value for the short-time current-carrying capability shall be selected from the following table:

Short-time current-carrying capability (kA rms)	
20	50
25	63
31.5	80
40	100

The standard durations for the short-time current shall be 1 s or 3 s.

5.2 Pressurized bus enclosures and expansion joints

High-voltage, gas-insulated substations consist basically of grounded, pressurized metal enclosures containing energized high-voltage conductors) and other substation components. Under certain conditions, both conductors and enclosures must carry rated load and short-circuit currents.

Components having pressurized enclosures other than metal, such as gas-insulated to atmospheric air bushings, shall conform to the applicable clause of the latest revision of IEEE Std C37.04-1979 .

GIS enclosures shall be filled with dry compressed gas, such as sulfur hexafluoride (SF_6), which is inert and non-corrosive. To protect the electrical integrity of the equipment, enclosures must be kept closed to preclude the entrance of moisture and foreign particles. Periodic internal inspections are undesirable and not required.

Gas-insulated substations are installed in areas with admission to authorized personnel only, and operated by trained personnel.

5.2.1 Criteria for enclosure design

5.2.1.1 Temperatures

Based on criteria in 4.1.1, the maximum design temperature for purposes of calculating the design pressure of the gas shall be the average of the upper limits of the enclosure and conductor temperatures at rated load current, unless the design pressure can be established from existing temperature-rise test data.

5.2.1.2 Thermal cycling, vibration, shock and seismic

Enclosures shall be designed to withstand all mechanical stresses normally encountered, including thermal cycling, vibration, and shock associated with operation, They shall be designed for seismic loading, if specified.

5.2.1.3 Design pressure

Design pressure is defined as the maximum steady-state gas pressure to which a gas-insulated substation enclosure is subjected under normal operating conditions. It is one factor used in calculations that establish the thickness of the enclosure and the materials and design of associated components.

When designing an enclosure, the following shall be considered:

a) The possible evacuation of the enclosure as part of the filling process (normal)
b) The full differential pressure possible across the enclosure wall or partition (normal)
c) In the case of adjacent gas compartments having different operating pressures, the resulting pressure in the event of a leak between the gas compartments (abnormal)
d) The possibility of an internal fault (abnormal)

5.2.1.4 Calculation methods

Methods for calculating the thickness and construction of the enclosures may be chosen from established pressure vessel codes (see CENELEC EN 50 052-1988, CENELEC EN 50-064-1990, CENELEC EN 50 069-1991, ANSI/ASME 1992 Boiler and Pressure Vessel Code, and ANSI/ASME B31.1-1992). Other equivalent national standards may be used by agreement between the manufacturer and the user. Conformance to local or state codes may also be required and shall be agreed to between the manufacturer and the user.

5.2.1.5 Effects of internal phase-to-ground arc on enclosure

The wall thickness of the enclosure shall be based on the design pressure as well as the following minimum withstand durations without burn-through, unless otherwise specified by the user:

a) 0.1 s for currents of 40 kA and above
b) 0.2 s for lower currents

5.2.1.6 Stress under abnormal pressure

Enclosures shall withstand any increase in pressure due to internal arcs which create an abnormal pressure. The abnormal pressure to be withstood is defined as the pressure caused by an internal arc of current magnitude equal to the rated short-circuit current for a minimum duration of 0.33 s or the fault-clearing time as specified by the user.

Calculation of stress or type tests shall indicate that a rupture shall not occur under abnormal pressure. The rupture pressure shall be equal to or greater than 3.5 times the design pressure for cast and cast-welded enclosures and 2.3 times the design pressure for welded enclosures. The operation of a pressure-relief device or burn-through of the enclosure shall not be considered a rupture.

5.2.1.7 Routine pressure tests

Pressure tests shall be made on all enclosures after manufacture. Standard test pressure shall be at least 1.3 times the design pressure for welded enclosures and 1.5 times the design pressure for cast enclosures.

Alternative non-destructive tests may be agreed upon between the manufacturer and the user.

5.2.1.8 Pressure-relief devices

Pressure-relief devices to relieve abnormal pressure shall be set to operate at a pressure not exceeding 87.5% of the routine test pressure. Especially for indoor installations, a pressure-relief setting shall be chosen so that circuit breakers may clear an internal fault prior to pressure-relief device operation in order to prevent release of arced gases indoors. Pressure-relief devices shall direct the escaping gases away from the normal path of personnel and shall not vent into control cabinets.

5.2.1.9 Tests after erection on site

No pressure tests are prescribed after erection on site.

5.2.2 Supporting structures and platforms

Most bus systems are of the continuous enclosure design, which provides adequate shielding to eliminate induced magnetic heating and to pen-nit grounding as necessary (see 5.6.1 regarding grounding of enclosures). For high-current, non-continuous enclosure designs, consideration shall be given to induced magnetic heating and induced circulating current in nearby metallic members such as support beams, reinforcing rods, and transformer tanks. Suitable insulated gaps in the metallic framework to eliminate closed loops and amortisseur bands around steel members, etc., may be used to eliminate circulating current. The structure shall be designed so that the temperature rise in any of its members or in any adjacent members does not exceed the limits specified in 5.1.1.

Safe access for personnel is required to all viewports, locations from which operation is initiated through automatic or manual means, and other indicators such as pressure gauges. Climbing on the apparatus is not permitted.

5.2.3 Bus expansion joints

Expansion and installation alignment shall be considered in the design of the bus and the enclosure, and expansion joints shall be provided, if required. When bellows are provided in the enclosure for installation alignment, means shall be provided to prevent movement after alignment is complete. Bellows provided to permit movement caused by expansion and contraction or foundation settlement shall have specially designed means to preserve the mechanical strength of the bus and the enclosure as well as contact alignment and penetration. Joints provided for direct connection to transformers shall be designed to inhibit transfer of vibration from the transformer to the bus and the bus enclosure.

5.3 Cable terminations and future expansion facilities

5.3.1 Cable terminations

The following subclauses cover cable terminations for use with gas-insulated substations. Typical uses are for separation of the cable-insulating medium from the gas insulation (oil-gas, gas-gas, solid insulation-gas).

5.3.1.1 Ratings

The ratings of cable terminations shall be compatible with the ratings specified in table 1 and shall include the following information:

a) Rated maximum voltage
b) Rated lightning impulse withstand voltage (BIL)
c) Rated switching impulse withstand voltage (SIWL)
d) Rated gas density (the minimum at which full performance is ensured, stated as pressure at a specified temperature)
e) Rated pressure internal and external
f) Rated continuous and short-circuit currents shall be compatible with the ampacity of the connected cable

g) Power frequency withstand voltage

h) Information necessary to determine overload capability vs. ambient temperature

i) Maximum and minimum cable conductor size

j) Maximum and minimum cable insulation diameter

5.3.1.2 Electrical requirements

The electrical characteristics for cable terminations are as specified in IEEE Std 48-1990 and IEEE Std 24-1984 except as modified under equipment ratings in 5.1.

Isolation insulation shall be incorporated in the cable terminations to prevent circulating currents and to pen-nit cathodic protection of the cable system.

5.3.1.3 Mechanical requirements

Cable terminations shall meet the following requirements:

a) Pressure test as per 5.2 and IEEE Std 48-1990
b) Seismic considerations (if required) as per 5.7
c) Gas leakage requirements as per 5.5
d) Materials used in fabrication shall be compatible with the insulating medium
e) Gas segregation as per 5.3.1

5.3.2 Future expansion facilities

GIS can be expanded, rearranged, or added to equipment not originally furnished without technical difficulties. It is recommended for future expansion of GIS that the user clearly indicate all locations where the future equipment might be joined to the existing GIS.

To provide for efficient planning, the manufacturer shall provide, for each identified location where future expansion might occur, shop drawings showing all pertinent dimensions, tolerances, material and hardware used, gas seals, gas system, pressure, and any other information that will ensure fabrication and installation of future transition compartments with the least labor and outage time. These drawings must be submitted for approval.

5.4 Gas system

Sulfur hexafluoride (SF_6) for use as an electrical insulation material shall conform to the requirements prescribed in ASTM D2472-92.

5.4.1 Gas density

The gas density in each compartment shall be continuously monitored. The monitoring device shall be capable of operating a relay contact upon descending gas density at each of two different density levels. Gas density level settings and functional operating requirements (alarm, trip, etc.) at each level below normal shall be agreed upon between the manufacturer and the user. If the device has a visual indicator, it shall be readable from the ground.

5.4.2 Contacts

Gas density monitors shall have at least two electrically separate contacts, convertible from a to b, at each specified density level. Contact voltage and current rating shall be specified by the user. The manufacturer shall supply contact resetting data (i.e., differential levels at which contacts will return to normal position on increasing gas density). Double-throw break-make contacts (form c) may be used in lieu of convertible contacts.

5.4.3 Calibration

Gas density monitors shall be capable of being calibrated with the monitored equipment in service.

5.4.4 Piping

If gas piping and connections can be disturbed during normal operation or maintenance, they shall be provided with mechanical protection.

5.5 Leakage rate

The leakage rate from any single gas compartment shall not exceed 1% per year. Leakage across the gas barrier insulator shall not prevent vacuum tests on one side with the other side at full pressure.

5.6 Grounding

5.6.1 Grounding of enclosures

The metallic enclosure shall be equipped with standard-type ground pads providing for connections to the ground grid, sized for the short-circuit current at each location which corresponds to the current specified for the installation. All metal parts except those at high voltage must be grounded. For the interconnection of enclosures, frames, etc., bolting or welding is acceptable to provide electrical continuity. Connections must meet the requirements of IEEE Std 80-1986 and IEEE Std 367-1987. The continuity of the grounding circuits shall be ensured, taking into account the thermal and electrical stresses caused by the current they may carry. The grounding system shall prevent excessive step and touch potential.

5.6.2 Grounding of high-voltage circuit

To ensure safety during maintenance work, all high-voltage parts where access is required or provided shall be capable of being grounded.

5.7 Seismic requirements

The two seismic ground motion levels are 0.5 g peak or 0.2 g peak acceleration, and for those areas where seismic considerations are not necessary, there are no specifications for a seismic requirement (see IEEE Std 693-1984).

5.8 Type and routine testing

The following subclauses establish the requirements for testing the GIS components.

Test requirements for gas-insulated circuit breakers, disconnect and grounding switches, instrument transformers, surge arresters, and bushings that may be an integral part of a GIS are specified in IEEE Std C37.30-1992, IEEE Std 48-1990, IEEE Std 24-1984, IEEE Std C37.38-1989, and IEEE Std C62.11-1987.

The purpose of the test procedures is to verify that all GIS components can perform satisfactorily, both electrically and mechanically, at the ratings assigned and to establish that production sections, after assembly, are free of defects and can perform satisfactorily.

5.8.1 Type tests

Type tests provide a method of demonstrating that the apparatus meets the specifications.

5.8.1.1 Rated continuous current

Type tests shall demonstrate that the gas-insulated substation components can carry rated continuous current at rated frequency without exceeding any of the temperature limitations in 5.1.1. The effect of solar radiation shall be considered in assigning the temperature rise to the equipment. IEEE Std C37.24-1986 governs how this factor is to be applied.

5.8.1.2 Conditions of test

Required conditions are as follows:

a) The equipment shall be in a new condition.

b) Temperature-rise tests shall be conducted three-phase if three phases are enclosed within one enclosure. For a single-phase design, single-phase tests shall be made and the current in the enclosure shall represent the most severe service condition.

c) Allowances shall be made for the heating effect of neighboring or adjacent assemblies by means of heaters or insulation.

5.8.1.3 Duration of rated continuous current tests

The rated continuous current test shall be continued until the temperatures of all components that carry continuous current in normal operation are substantially constant, as indicated by three successive readings at 30 min intervals.

5.8.1.4 Temperature measurements

Temperatures shall be measured by the methods described in IEEE Std 119-1974 and ANSI MC96.1-1982. The measuring device shall be located at the hottest spot. Measurements shall be made at junction points of insulation and conducting parts to ensure against exceeding temperature limits of the insulation. The sensor of the temperature-measuring device used for measuring apparatus temperatures shall be in intimate contact with the apparatus, and so insulated that it is not affected by ambient temperatures.

5.8.1.5 Ambient temperature

The ambient temperature shall be taken as that of the surrounding air. The ambient shall be between 10 °C and 40 °C, inclusive, so that no correction factors need be applied. The ambient temperature shall be determined by taking the average of the readings of three thermometers placed in locations unaffected by drafts, horizontally 305 mm (12 in) from the periphery of the enclosure, and approximately on a vertical line as follows:

a) One approximately level with the enclosure
b) One approximately 305 mm (12 in) above the enclosure
c) One approximately 305 mm (12 in) below the enclosure

5.8.1.6 Short-circuit current rating

The values shall be as described in 5.1.7.

Tests to demonstrate the required capabilities shall be made in accordance with the conditions specified in IEEE Std C37.09-1979 and ANSI C37.06-1987.

Three-phase enclosure designs shall be tested three phase. Single-phase enclosures shall be tested single phase unless otherwise agreed to by the manufacturer and the user.

These tests shall be made on single shipping sections and various other configurations of bolted, welded, plug-in, or otherwise jointed sections to verify the integrity of the GIS components as joined together. Tests shall be made on configurations providing the most onerous conditions.

Assemblies shall be tested such that specimens of all components and subassemblies of the design are subjected to the test.

5.8.1.7 Dielectric withstand tests

Three-phase enclosure designs shall be tested for each phase, with the other two phases and the enclosure grounded.

5.8.1.7.1 Power frequency

Power frequency voltage at the rated power-frequency withstand values shall be applied for 1 min between the main bus and ground and across all isolating gaps. All tests shall be made with high voltages in accordance with table 1, at minimum-rated gas density specified by the manufacturer.

5.8.1.7.2 Lightning impulse

Lightning impulse voltage at the rated BIL value (table 1) shall be applied between the main bus and ground and across all isolating gaps. The lightning impulse-type test circuit shall contain a spark gap between the high-voltage terminal of the impulse generator and the high-voltage terminal of the test piece. The spark-gap breakdown voltage shall be no greater than 25 kV and no less than 5 kV A resistor shall be connected from the high-voltage terminal of the test piece to ground. The discharge time constant of the test piece through this resistor shall be no greater than 0.1 s. At least 2 min shall separate each impulse application during the lightning impulse-type test using the above circuit. Otherwise, the test shall be conducted in accordance with IEEE Std C37.09-1979.

The purpose of the above test circuit is to ensure that the impulse generator does not impose small voltages on the test piece during charging of the impulse generator. Such voltages cause depletion of the negative SF_6 ions which are the primary source of initiatory electrons for SF_6 breakdown. The purpose of the waiting time of 2 min between impulse applications is to allow the ion concentration to approach equilibrium after being depleted by the electric field imposed during an impulse withstand or being enhanced by the breakdown processes which occur during an impulse breakdown. The time constant for approach to equilibrium is approximately 2 min.

5.8.1.7.3 Switching surge

Switching surge impulse voltage at the rated withstand value shall be applied between the main bus and ground and across all isolating gaps. Both positive and negative 250 by 2500 μs impulses are to be used. See IEEE Std C37.09-1979, ANSI C37.06-1987, and IEC 517 : 1990.

5.8.1.7.4 Partial discharge

All internal portions of the gas-insulated system shall be tested for partial discharge at 150% of rated maximum phase-to-ground voltage on the downward excursion of voltage from the power frequency withstand voltage. Extinction of the partial discharge must occur above the 150% point. Partial discharge tests shall be made using PD test apparatus with a sensitivity of 5 pC or better.

5.8.1.8 Electrical and mechanical life tests

Mechanical endurance tests shall be made on all circuit breakers, disconnects, and ground switches, in accordance with IEEE Std C37.30-1992 and IEEE Std C37.09-1979. This does not apply to fault-making ground switches.

Additional electrical and mechanical life tests shall be made to demonstrate life performance of bellows, elbows, or expansion joints used to compensate for thermally-induced movements, and to sliding electrical contacts used to tie electrically floating components to the conductor or enclosure.

Tests must ensure that all sliding contacts, sliding joints, bellows, and elbows with angular displacement or other means of compensating for thermally induced movements be tested such that electrical current, mechanical forces and movement, and temperature cycles over the extreme conditions are adequately simulated over the life of the equipment.

The tests and criteria of acceptance shall be subject to agreement between the user and the manufacturer.

Tests to demonstrate the switching capability of the circuit breakers, disconnect switches, and ground switches shall be made in accordance with IEEE Std C37.30–1992 and IEEE Std C37.09–1979. All switching devices fitted with mechanical interlocks shall be subjected to 50 cycles of mechanical operation to check the effectiveness of the interlocks. All interlocks shall be set to prevent operation of the switching device. One attempt shall be made to operate the switching device applying only normal operating forces and without adjusting the switching device or interlock.

5.8.1.9 Pressure tests

Pressure tests shall be performed on one sample of each component or assembly making up the substation in accordance with 5.2.1.7.

5.8.1.10 Weatherproof tests

If the equipment is to be installed outdoors, the design shall be subjected to weatherproof tests. Tests shall be agreed to between the user and the manufacturer, and shall simulate rain, ice, wind-driven snow, humidity, and other conditions as applicable.

5.8.1.11 Shipping tests

Subject to agreement between the manufacturer and the user, the manufacturer shall demonstrate that the equipment can be shipped from the factory to the site without being damaged. Methods of demonstration may include previous experience with similar equipment shipped by similar modes of transportation, shipping tests in which representative equipment is shipped, loaded, and unloaded, vibration tests to simulate shipping conditions, and weatherproof tests to check the adequacy of packing.

5.8.1.12 Internal arcing tests

Subject to agreement between the user and the manufacturer, tests shall be made to demonstrate that the equipment can safely withstand the effects of an internal arcing fault. Such tests shall demonstrate that the compartment that has the least likelihood of withstanding the pressure and temperature rise in the event of arcing shall be contained or safely vented (see 5.2). See IEC 517 : 1990.

5.8.1.13 Insulator tests

The thermal performance of each spacer insulator design shall be verified by subjecting five insulators to ten thermal cycles each. A thermal cycle is defined as the following:

a) 4 h at an ambient temperature of –40 °C
b) 2 h at room temperature
c) 4 h at an ambient temperature of +105 °C
d) 2 h at room temperature

After the test sequence, all spacer insulators shall meet all of the requirements of 5.2 and 5.8.2 item b) and shall have no visible cracks (see CENELEC EN 50 089–1992).

5.8.2 Routine tests

The following routine tests shall be performed at the factory on every unit following its manufacture:

a) Pressure test of cast and fabricated enclosures.

b) Gas leakage tests shall confirm the guaranteed leakage rates, including leakage tests across the gas barriers, if applicable.

c) Dielectric tests of auxiliary circuits.

d) Measurement of the resistance of the main circuit.

e) Tests for continuity of auxiliary circuits.

f) Tests on the resistors, heaters, coils, and interlocks in the control mechanism.

g) Operating tests on the auxiliary electrical, pneumatic, and hydraulic devices, at the limits of range of operating values, on all devices.

h) Timing tests on operating assemblies.

i) Stored energy system tests.

j) A power frequency withstand test shall be performed on each shipping section at the rated withstand voltage for 1 min (see table 1). A partial-discharge test shall be made in accordance with 5.8.1.7.4. Power frequency withstand and partial-discharge tests shall be performed after the section has undergone all indicated mechanical tests.

k) Tests on the gas density relay settings.

5.9 Field testing

5.9.1 Mechanical tests—Leakage

All compartments shall be filled with SF_6 to the normal pressure and leak tested to ensure compliance with the specified leak rate.

All field-assembled joints and interconnecting gas piping shall also be checked for leaks.

5.9.2 Operational tests

All operating mechanisms for the circuit breaker, disconnecting switches, grounding switches, and load break switches shall be checked for proper contact rod alignment and contact travel. All mechanical interlocks shall be tested.

All exterior mechanical position indicators shall be checked for proper adjustment and indication.

The sealed assembly shall be tested to ensure that the moisture content of the SF_6 gas is below the level specified by the manufacturer.

5.9.3 Electrical tests

The GIS grounding connections shall be tested for electrical continuity.

Resistance measurements shall be performed on all the bus connecting joints, circuit breakers, disconnecting switches, grounding switches, and load break switch contacts to verify proper contact alignment.

Because of the inaccessibility to live parts, it is not possible to measure the resistance of individual components. The resistance readings may be for several components in series. The vendor shall supply factory resistance values of the accessible components in series as a base for progressive testing in the field.

5.9.3.1 Dielectric tests

The minimum test procedure shall be a low-frequency (45–200 Hz) conditioning test at voltage levels specified by the manufacturer. The conditioning test shall be followed by a 1 min low-frequency withstand test at 80% of the rated low-frequency withstand of table 1. Other tests can be performed subject to user-manufacturer agreements.

5.9.3.2 Test conditions

Tests shall be made on each phase-to-ground. A three-phase enclosure design shall be tested with the enclosure and the other two phases grounded. Before dielectric tests are initiated, all power transformers, surge arresters, and voltage transformers (if applicable) shall be disconnected. The voltage shall be applied in steps and gradually raised as specified by the manufacturer to the full field test voltage level (see 5.9.3.1).

Occasional flashovers may occur during the conditioning. The acceptability of flashovers during conditioning depends on whether the flashover may have caused damage to an insulator. The likelihood of such damage is dependent on the voltage level, the length of bus duct connected to the voltage source, and the particular design characteristics of the insulator. If the equipment successfully withstands full field test voltage after a conditioning breakdown has occurred, it can generally be expected that no reduction in dielectric strength will occur in service.

Due to the restrictions of the test facilities, it may be necessary to isolate sections of the equipment and test each section separately. To do this may require that portions of the equipment are subjected to more than one test procedure. When the equipment being tested is connected to equipment which is in service, isolation and grounding shall be provided to ensure that the test voltage cannot cause service disruptions.

5.10 Shipment and storage

Each shipping unit shall be provided with impact devices, when applicable. Equipment shall be sealed and protected for outdoor storage.

5.11 Installation

Manufacturers shall provide detailed and specific installation instructions and drawings, and shall have experienced field service personnel available as agreed to between the user and the manufacturer.

5.12 GIS nameplates

Symbols on GIS nameplates shall be in accordance with IEEE Std 315-1975.

Nameplates of the following types shall be furnished in a convenient, central location to provide information for operation and maintenance:

a) One-line diagram nameplate
b) GIS ratings nameplate
c) Equipment nameplate
d) Nameplates for high-voltage cable terminations
e) Gas system nameplate

5.12.1 One-line diagram

The one-line diagram nameplate shall show the following:

a) A one-line diagram of the GIS
b) GIS nomenclature
c) Power transformers
d) Circuit breakers
e) Disconnecting switches
f) Interrupter switches (distinguished by interrupting capability)
g) Grounding switches (distinguished by fault closing capability)
h) Surge arresters
i) Voltage transformers
j) Current transformers
k) Cable terminations
l) Air bushings
m) Gas-oil bushings
n) Gas barriers
o) Manufacturer's type and serial number
p) Year of manufacture

When the installation is an expansion of an existing substation, the one-line diagram shall show and identify the existing equipment and the new equipment as specified by the user.

5.12.2 Ratings

The GIS ratings nameplate shall show the following ratings:

a) Maximum continuous voltage

b) System frequency

c) Maximum and minimum ambient temperature

d) Maximum continuous currents (at 40 °C ambient temperature) of equipment for which ratings are not shown on the nameplate described in 5.12.1 (if needed for clarification, current ratings shall be shown on the one-line diagram nameplate)

e) Rated lightning impulse level (BIL)

f) Power frequency for 1 min (factory test)

g) Switching surge (if applicable)

h) Short-circuit currents
   1) Symmetrical interrupting (rms)
   2) Short time (rms)
   3) Close and latch (rms and peak)

i) Total weight of gas at rated density

j) Nominal gas pressure at 20 °C (filling)

k) Recommended minimum operating gas pressure at 20 °C

l) Maximum acceptable gas pressure at 20 °C

m) Recommended moisture limits of gas insulation (ppmv)

n) Auxiliary voltages

o) Contract orders

p) Total weight of equipment

q) Alarm and trip pressures

r) Curves for SF_6 showing nominal alarm and filling pressures vs. temperatures

The ratings nameplate shall state to which of the GIS equipment the ratings apply.

5.12.3 Equipment nameplates

Serial numbers and other data that are not common to all units of a category of equipment shall be shown on the nameplates mounted on the equipment itself.

5.12.4 Nameplate for high-voltage cable terminations

The nameplate shall be mounted in a conspicuous location and the following information shall appear on the nameplate, as appropriate:

a) Manufacturer's name, type, and designation number
b) Insulation class (rated maximum voltage)
c) Rated lightning impulse level (BIL)
d) Rated cable fluid pressure
e) Maximum and minimum cable conductor size
f) Maximum and minimum cable insulation diameter
g) Rated switching impulse level (SIVVL)
h) Rated internal (SF_6) gas density (stated in pressure and temperature)
i) Maximum allowable force applied in any direction at the external terminal
j) Voltage tap, capacitance C1 and C2

5.12.5 Insulating gas system

The insulating gas system nameplate shall show the following:

a) Complete gas system
b) Gas density monitors
c) Pressure gauges
d) Interconnections between gas compartments
e) Valves on exterior piping

6. Bibliography

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