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IEEE Guide to Specifications for Gas-Insulated, Electric Power Substation Equipment

Sponsor

Substations Committee
of the
IEEE Power Engineering Society

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Abstract: Technical requirements for the design, fabrication, testing, and installation of a gas-insulated substation (GIS) are provided. Parameters to be supplied by the purchaser and the technical requirements for the design, fabrication, testing, and installation to be furnished by the manufacturer are discussed. Environmental conditions, general and specific equipment requirements, and a proposal data sheet form are provided to aid the user.
Keywords: gas-insulated substations, GIS, GIS design, GIS equipment, GIS installation

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Introduction

(This introduction is not part of IEEE Std C37.123-1996, IEEE Guide to Specifications for Gas-Insulated, Electric Power Substation Equipment.)

This updated guide is issued to aid users in developing and preparing specifications for gas-insulated substations and equipment; its intent is advisory. The guide covers parameters to be supplied by the user and technical requirements for the design, fabrication, testing, and installation to be furnished by the supplier. The user should revise any paragraph as appropriate, delete any paragraph that does not apply to his or her needs, and incorporate any details to make the specification conform to his or her standard practices and requirements.

Proposal data, provided in clause 7, should be completed by the user and by each bidding supplier in order to elicit uniform answers from all the providers and to facilitate technical proposal evaluation. The form in annex A is a simple way for the user to provide to the GIS supplier the principal constraining information that defines the GIS required. The form should be sent to the suppliers early in the planning cycle to obtain information regarding availability of equipment, typical physical arrangements and budget prices. The form does not need to have 'specification' attached. However, users are encouraged to ask suppliers to review the specification to be used in preliminary form and submit comments during the planning stage of the project.

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IEEE Guide to Specifications for Gas-Insulated, Electric Power Substation Equipment

1. Overview

1.1 Scope

This guide covers the technical requirements for the design, fabrication, testing, installation, and in-service performance of a gas-insulated substation (GIS).

The supplier should furnish all equipment and material necessary to provide the complete GIS as shown on the functional one-line diagram, which may consist of circuit breakers (CB), disconnect switches (DS), maintenance ground switches (MGS), fast-acting ground switches (FGS), voltage transformers (VT), current transformers (CT), SF_6-to-air bushings, SF_6-to-cable termination, buses, cable termination enclosures, transformer or reactor bushing enclosures, enclosed surge arresters, elbows, bellows, controls, cables for control, protection and metering, density monitors, platforms, special tools, and SF_6 gas for initial filling. All equipment and material shall be prefabricated, factory assembled, tested, and shipped in the largest practical assemblies.

Assembled equipment should be capable of withstanding electrical, mechanical, and thermal ratings of the specified system. All joints and connections should be able to withstand the forces of expansion, vibration, contraction, and specified seismic requirements without deformation, malfunction, or leakage. Equipment shall be capable of withstanding the specified outdoor or indoor environment.

Optimized arrangements, shown in annex A, are required to reduce installation time, provide ease of operation, minimize maintenance and repair prices, and facilitate future additions as described in the specifications. The user should identify space or area limitations for the GIS, driveway access, and any overhead clearance restrictions. Final arrangement shall be as mutually agreed to between the user and the supplier.

Field assembly maintenance, cost of operation, and capitalized cost of maintenance during equipment life will be considered in bid evaluations. To elicit a complete and uniform response from each bidder, proposal data is provided in clause 7.

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2. References

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

ASTM D2472–1992, Specification for Sulfur Hexafluoride.[1]

IEC 859:1986, Cable Connections for Gas-insulated Metal-Enclosed Switchgear for Rated Voltages of 72.5 kV and above.[2]

IEC 1129:1992, Alternating Current Earthing Switches—Induced Current Switching.

IEC 1639:1996, Direct Connections Between Power Transformers and Gas-Insulated Metal-Enclosed Switchgear for Rated Voltages of 72.5 kV and Above.

IEEE Std 100–1996, The IEEE Standard Dictionary of Electrical and Electronic Terms.[3]

IEEE Std 1300–1996, Guide for Cable Connections for Gas-Insulated Substations.[4]

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

IEEE Std C37.122–1993, IEEE Standard for Gas-Insulated Substations (ANSI).

IEEE Std C57.13–1993, IEEE Standard Requirements for Instrument Transformers (ANSI).

IEEE Std C62.11–1993, IEEE Standard for Metal-Oxide Surge Arrestors for AC Power Circuits (ANSI).

NEMA CC 1–1993, Electric Power Connectors for Substations.[5]

NFPA 70–1996, National Electrical Code® (NEC®).[6]

In the event of conflict between the referenced standards, the drawings of the user, and specified requirements, or between standards issued by different authorities, the more stringent requirements are to apply.

3. Definitions

The following definitions are applicable only to the subjects treated in this guide.

3.1 catastrophic failure: A failure of any portion of the GIS due to internal or external faults that results in sufficient damage to that portion of the GIS that it cannot be returned to service without major repairs.

[1]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959, USA.
[2]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.
[3]This standard will be available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855–1331, USA, in early Spring, 1997.
[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855–1331, USA.
[5]NEMA publications are available from the National Electrical Manufacturers Association, 1300 N. 17th St., Ste. 1847, Rosslyn, VA. 22209, USA.
[6]NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269–9101, USA.

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3.2 clearly discernable: Capable of being noticed easily without close inspection.

3.3 retransmit contacts: Auxiliary contacts on an annunciator that provide an output to a remote device to indicate that the annunciator has been actuated.

4. Conditions

4.1 Environmental

All apparatus should be capable of satisfactory operation in the following environments:

Indoor or outdoor:		
Elevation above sea level	_____	m
Maximum ambient temperature	_____	°C
Minimum ambient temperature	_____	°C
Humidity (average)	_____	%
Wind velocity	_____	km/h
Solar radiation	_____	W/m^2
Maximum ice loading	_____	mm
Maximum uplift	_____	N
Maximum impact	_____	N
Seismic:		
Horizontal force	_____	g
Vertical force	_____	g
Air quality:	_____	g
Special environmental considerations:	_____	g

Values are to be in accordance with IEEE Std C37.122–1993 .[7]

4.2 Equipment and services furnish by the user

Unless otherwise specified or agreed upon, the user should receive, install, and field test the apparatus specified herein. Installation and field testing of the GIS should be completed under the supervision of the supplier to ensure correct installation. Unless otherwise specified, the following equipment and services should also be furnished by the user:

a) Concrete foundations
b) Power transformers or reactors, including bushings
c) Surge arresters outside the GIS
d) The station ground grid, below ground, and vertical connection risers of adequate length

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

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e) Ac and dc auxiliary power to furnished equipment
   1) Rated dc service voltage _____ V
   2) Minimum dc service voltage _____ V
   3) Maximum dc service voltage _____ V
   4) Rated ac service voltage (three-phase) _____ V
   5) Rated ac service voltage (one-phase) _____ V
f) Hoist or crane
g) Supervisory control and data acquisition (SCADA) equipment
h) Conduit or troughs and wiring to supplier-furnished equipment
i) Gas handling equipment
j) Batteries and battery chargers
k) Protective relaying systems
l) Transmission-line dead-end terminations
m) Control and power cable trenches
n) Erection labor, with the supervision and assistance of the GIS supplier
o) Control house and related equipment or building in case of indoor installation, including crane, if applicable
p) Job-site unloading and storage
q) Field welding, if required, with the supervision and assistance of the GIS supplier
r) Test equipment, coordinated with the GIS supplier
s) Specific tertiary bus and other related equipment
t) High-voltage power cables and terminations
u) Anchor bolts and/or embedded steel, if part of foundation pouring

4.3 Equipment and services furnished by the supplier

The supplier should design, manufacture, test, deliver, and guarantee the following services as recommended by this guide:

a) The complete gas-insulated switchgear, including connections to power transformers and line exits with associated circuit breakers, disconnect and grounding switches, voltage transformers, and surge arresters.
b) All metal-enclosed gas-insulated buses for interconnecting various switchgear assemblies, including flexible joints to ensure service continuity during thermal cycling and vibration.
c) All cable connections, including SF_6 enclosures, terminator support structures, and mounting insulators should be as specified in IEC859 : 1986 and IEEE Std 1300–1996 .
d) All transformer and reactor bushing sulfur hexafluoride (SF_6) enclosures, complete with vibration dampers and/or alignment bellows, if required.
e) All coordination with power transformer, reactor, cable, and cable termination suppliers to assure proper electrical and mechanical interface, in accordance with IEC859 : 1986 and IEC1639 : 1996.
f) All necessary supports, platforms, stairways, and walkways, including fasteners to foundation. Final design of platforms and walkway systems is to be by mutual agreement between the user and the supplier.
g) All auxiliary equipment, for emergency control and local supervision, including interlocks; operating mechanisms; and control, monitoring and protective devices, installed in suitable cabinets.
h) All control cabinets with respective mimic buses, internal wiring, and terminations.
i) All wiring of devices and terminations internal to the switchgear and all shielded control cables (and associated raceways), above foundation, between the equipment and the GIS local control cabinets. All raceways and wiring furnished by the supplier are to be designed in accordance with the NEC®, with respect to raceway cable fills. Raceways and conduits shall be installed so as not to present a safety hazard to personnel servicing the equipment.
j) Ground buses and ground connection pads for connection to the ground grid.
k) Gas density monitors, pressure relief devices, and gas-filling connections.
l) New gaskets, sealant, and desiccant for permanent sealing of all field assembled joints and all access covers removed during assembly. No gaskets are to be reused for any permanent seal broken or disturbed in the field. If pressure relief devices are rupture disks or other self-destructive devices, then at least three spare discs and

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associated gaskets are to be provided and available during filling and testing of the equipment. Rupture disks and gaskets are also to be included as part of normal spare parts stock.

m) Initial filling of pneumatic devices, SF_6 gas, and hydraulic fluid, if required.
n) Any other equipment that is not specifically noted herein but that is necessary for trouble-free operation, installation, and maintenance of the GIS.
o) Technical direction for site assembly and testing by a competent service engineer. Indicate days included in the base bid and give a per diem rate for additional time.
p) Any special tools, lifting devices, and gas manifolds necessary for erection that should be retained by the user for maintenance purposes.
q) External surface preparation and coating, if specified. Color may affect the rating and the user must be informed in the proposal of the new rating. Sufficient amount of touch-up paint is to be provided.
r) Nameplates for each main component and operating device.
s) User may require a scale model of the GIS for use as a design and training aid.
t) Documents to be provided as required under 5.1, items a) through f).

5. General requirements

5.1 Information required with proposal

The proposal for a new or an addition to an existing GIS shall include general arrangement drawings and single-line diagrams, gas schematic diagrams, control diagrams, weights and dimensions, anchor requirements, appropriate technical data, the bill of material, and a description of system components.

The proposal should also include the following documentation:

a) Type test report, if required by the user.
b) Insulation coordination, transient recovery voltage (TRV), and electromagnetic transients program (EMTP) studies prices, if required by the user.
c) Seismic study price, if required by the user.
d) Grounding study price, if required by the user.
e) Typical factory routine test reports.
f) Drawings showing full details of locations where future expansion is to take place.
g) Documentation on installation procedure and sequence, operation, and maintenance of the GIS.
h) Data on allowable misalignment at the installation or required accuracy of foundations and anchors.
i) List of recommended spare parts, including price and delivery for normal and catastrophic failure conditions.
j) List and price of special tools, fixtures, and lifting devices required for installation, operation, and maintenance.
k) Availability and price of high-voltage test equipment, if required by the user.
l) List of previously supplied GIS facilities and their performance to date.
m) Estimated time required to install and to test the equipment.
n) User should indicate any limits on manpower available for installation that could have an affect on the supplier's time estimate. In absence of any limitations, the supplier time estimate should indicate manpower loading assumed plus any specific tasks that may require higher manpower loading than the majority of the installation.
o) Field service engineer price.
p) Training for personnel of the user, including price, duration, and material covered.
q) Filled-out data sheets provided in annex AA of this guide. Separate data sheets should be provided for each alternative proposal.
r) Listing of exceptions to and deviations from this guide and specific user requirements. All exceptions should be clearly and separately itemized. It should not be necessary for the user to examine the standard literature

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and documents of the supplier to determine the existence and extent of any exceptions or deviations from this guide.

s) Weight and dimensions of largest removable component (for use by the user in designing permanent hoist or crane).
t) Maximum weight of SF_6 gas in largest compartment. If suppliers gas barrier design requires that adjacent compartments have the SF_6 gas pressure reduced during maintenance, supplier should explain this and give the maximum amount of gas to be handled as a result.
u) Static and dynamic foundation loading for the circuit breaker.
v) A graph of enclosure and circuit breaker rupture pressure, design or safety pressure, working pressure, and coordination of pressure relief devices with these values.
w) Outline drawings with dimensions of all major components.
x) Data of corrosion protection (paint) system.
y) Voltage and current transformer magnetization and excitation curves.

5.2 Description

5.2.1 Station layout and equipment rating

The station layout and equipment rating shall be based on the single-line diagram furnished by the user. Depending on the station rating and the user's preference, single- or three-phase enclosures may be furnished. The user shall also provide the GIS electrical ratings and any special requirements, seismic requirements, or protective measures in particularly harsh operating environments.

5.2.2 Circuit breaker gas zone

The circuit breaker gas zone shall be independent from all other gas compartments and shall meet the rating requirements of IEEE Std C37.122–1993 and other applicable standards referenced in this guide.

5.2.3 Disconnect switches

Disconnect switches should be three-phase (or single-phase), manually or motor operated, and capable of interrupting the charging current of the connected GIS bus and associated components. Maintenance and fast-acting ground switches should be manual or motor operated. Each switch should be equipped with mechanism-actuated auxiliary switches for indication of the contact position. Visual inspection means may be provided, if specified, to observe disconnect and ground switch contact position, along with a mechanically connected external position indicator. Each switch should have provisions for mechanical locking against unwanted operation.

5.2.4 Electrical interlock schemes

Electrical interlocks or another suitable scheme should be furnished to prevent incorrect sequential operation or equipment malfunction that might result in equipment damage or personal injury. Electrical interlock schemes should be fail-safe to prevent loss of interlock function upon loss of control voltage.

5.2.5 Mitigating overvoltages

Proper grounding for mitigating overvoltages during disconnector operation shall be included.

5.2.6 Proper heater operation

Heaters (and thermostats, if specified), should be furnished as required in control cabinets and equipment housings to avoid condensation. Indicating lights may be specified to show proper heater operation.

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5.2.7 Single-phase/three-phase buses

A single-phase bus consists of two concentric tubes of high electrical conductivity and mechanical strength, with the inner tube being the conductor and the outer tube being the solidly grounded enclosure for each isolated phase. A three-phase bus consists of three inner tubes (the conductors) and a single outer tube (the solidly grounded enclosure for the bus).

5.2.8 Conductors

Conductors should be made of aluminum or copper tubing suitable for the specified current and voltage ratings. The enclosure should be aluminum or steel with all adjoining enclosures bolted or bonded together and grounded.

5.2.9 Standard manufacture

As much as possible, parts should be of standard manufacture with interchangeable parts and assemblies.

5.2.10 Pressure relief devices

Pressure relief devices, if required, shall be provided with a shield and be vented to provide a safe environment for field personnel and for equipment during operation. The bursting pressure of the relief device should be effectively coordinated with the rated gas pressure and the pressure rise due to arcing as described in IEEE Std C37.122–1993 .

5.2.11 Expansion

Expansion and installation alignment should be considered in the design of the bus and the enclosure. If required, expansion joints should be provided with compensators for the enclosure and sliding plug-in contacts for the conductor.

5.2.12 Support insulators

Support insulators shall be used to maintain the conductor and enclosure in the proper relation. Required are two types of support: insulators-barrier insulators that are employed to isolate gas compartments, and non-barrier insulators that allow the gas pressure to equalize.

5.2.13 Connections

Connections between adjacent conductor sections should be made by means of plug-in type contacts. Shields should be placed to capture metallic particles that may result from contact rubbing. Field welding of the conductor is not acceptable, except when required for special cases of extension, repair, or retrofit.

5.2.14 Weatherproof enclosures

Components outside the SF_6 environment shall be installed in weatherproof enclosures for outdoor installation.

5.2.15 Bolted, gasketed flange connections

Shipping sections should be joined in the field using bolted, gasketed flange connections of the enclosure. Flanged connections shall have a gas seal between the flange surfaces. A second seal ring, sealants, or other suitable means are required to protect the gas seal from the external environment. Connections, including bolts, washers, and nuts, should be adequately protected from corrosion and should be easily accessible with the proper tools.

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5.2.16 Field-welded connections

Where necessary, and agreed to by the user, field-welded connections may be used between major fixed components to permit length and angular adjustments to compensate for construction tolerances. Where field welding is used to join the enclosures, provisions should be made and described to preclude the entry of foreign materials into the gas space.

5.2.17 Design of supporting structures

Where required, structures to support the equipment, platforms, and walkways for operation and maintenance access to operating and monitoring devices should be designed to permit access without use of special devices or portable ladders. All structures, stairs, platforms, and walkways shall conform to the relevant occupational health and safety regulation.

5.2.18 GIS ground pad terminals

GIS ground pad terminals shall be located to permit proper connection to the station ground grid and to minimize external bus enclosure voltage gradient to a safe limit. All support structures and control cabinets are to be grounded.

5.3 Tests

The tests should verify that all components of the GIS perform satisfactorily, both electrically and mechanically, at the specified ratings. The tests should establish that production sections have been properly assembled and that they have essentially the same characteristics as those sections subjected to design tests.

5.3.1 Type test

The following type tests shall be performed prior to equipment delivery:

a) Impulse withstand voltage [basic impulse level (BIL) and switching impulse level (SIL), if applicable]
b) Power frequency withstand voltage
c) Circuit breaker and disconnect switch open-gap withstand voltage
d) Rated continuous-current carrying tests
e) Short-time current rating test
f) Mechanical operation tests
g) Pressure tests
h) Circuit breaker tests
i) Disconnect switching tests
j) Instrument transformer tests
k) Enclosed surge-arrester tests
l) Grounding switch tests

5.3.2 Production tests

Production tests should be made in the course of component assembly and at the complete or shipping assembly state. Tests should include, at a minimum, the following:

a) Circuit breaker test per IEEE Std C37.09–1979
b) Pressure test on all individual enclosures and barrier insulators
c) Gas leak tests of enclosure and barrier insulators, if applicable
d) Mechanical operation test
e) Low-voltage wiring test
f) Voltage drop measurement of the conductor and contacts

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g) Power frequency withstand voltage
h) Partial discharge test of insulators and/or shipping sections
i) Current transformer and voltage transformer tests
j) Functional tests on control and indication circuits

5.3.3 Field tests

The following field tests should be performed as a minimum requirement:

a) Gas leakage test
b) Operational test
c) Gas moisture measurement
d) Resistance test of conductor
e) Current transformer testing
f) High-voltage tests
g) Control and installation wiring checks
h) Inductive voltage transformer tests
i) Capacitive coupler test

5.4 Shipment and installation

5.4.1 Equipment and equipment storage

All equipment should be suitably packed and protected during shipment. Each shipping unit should be sealed in a clean, dry condition with leak-tight shipping covers securely mounted for shipment. All covers to be removed during installation should be clearly marked. Each shipping section should be carefully sealed and filled with dry gas to a slightly positive pressure to prevent the entrance of moisture and contamination. The supplier shall notify the user by placing temporary labels that state whether the shipping sections contain SF_6 or another type of dry gas under pressure.

Components requiring indoor storage shall be so identified. The supplier shall provide copies of complete, detailed, customized instructions for storage, installation, operation, and maintenance of the equipment. Long-term storage instructions should be provided, if specified. Because special conditions that may be required for long-term storage are easier to apply in the factory, the supplier should be informed of such requirement before shipment.

5.4.2 Technical guidance

A competent, experienced service engineer from the supplier should be present at the job site for technical guidance and direction throughout the installation and testing of the equipment.

6. Detailed requirements

6.1 Circuit breakers

Circuit breakers should be the SF_6 gas-insulated type, dead tank design, and with the ratings as specified.The breaker shall have ratings described in IEEE Std C37.122–1993 , and specific ratings in accordance with other applicable ANSI standards. The breaker shall be capable of performing the specific duty cycle without derating.

Each circuit breaker should be factory assembled, adjusted, and tested, and should be shipped as a complete single-phase or three-phase unit.

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The breaker should include a suitable operating mechanism to assure proper opening and closing and should permit checking adjustments and operating characteristics. The mechanism should be capable of reclosing within the time range specified in the standards. Independent pole operation, dual trip coils, and pole discrepancy tripping may be specified by the user. Noise-level requirements may also be specified by the user.

For outdoor applications, each breaker shall include a weatherproof control cabinet for housing the operating mechanism and all accessories. Necessary valves and connections should be provided to ensure ease in handling the SF_6 gas.

Each circuit breaker should be equipped with an operation counter. The preferred arrangement for this device is to operate only during the opening cycle. An indicator that shows the position of the contacts should be provided. All gauges, counters, and position indicators shall be readable by an operator standing near the equipment.

Closing resistors, when required, should meet the rated line-closing switching surge factor as specified in the applicable standards, or by the user.

6.2 Disconnect and grounding switches

6.2.1 Operating mechanisms

Disconnect switches should be three-pole, group-operated, or single-pole operated, no-load break, with one operating mechanism per three-pole or one operating mechanism per single-pole position. The user should specify manual or motor operation. Operating mechanisms are to be provided with position indication that may be color-coded, or the position may be spelled out.

Grounding switches should be three-pole, group-operated or single-pole operated, no-load break, with motor- or manual-operating mechanisms.

For motor-operated disconnect and grounding switches, the control should be electrically and/or mechanically uncoupled from the drive shaft when the switch is operated manually to prevent coincident power operation of the switch and the drive mechanism(s).

Each disconnect and ground switch should open or close only due to manual- or motor-driven operation. The switch blade should not move due to gravity or other means, even if a part fails. Once initiated, the motor mechanism should complete an open or close operation without requiring the initiating contact to be held closed.

Each disconnect switch and grounding switch should be furnished with electrically independent auxiliary switches. The auxiliary switches should indicate the position of the switch blades and should be provided so that the contacts can be adjusted to be fully engaged and in proper alignment when in the closed position. User should specify the number of “a” and “b” contacts.

6.2.2 Visual verification

Visual verification may be provided, if specified, for each pole of each disconnect switch and grounding switch to permit visual inspection of each switch blade position. External position indicators should also be provided. Inspection viewports should have removable covers to prevent damage of the actual viewport due to the elements or from abrasive action while cleaning the port for viewing.

6.2.3 User specifications

The user should specify any anticipated duty condition for the ground switches, including the interrupting and/or closing duty for ground switches, especially when connected to parallel transmission lines or similarly coupled

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systems; refer to IEC 1129 : 1992. This duty cannot normally be performed with a standard ground switch and may require a special design.

The user should specify the expected disconnect switch operating capability in situations where a disconnect switch can be operated with out-of-phase conditions, such as synchronizing generators or an inductive potential transformer on the load side of the switch.

6.2.4 Access

Suitable means of access should be provided in each disconnect-switch and grounding-switch housing and mechanism for repair and/or maintenance of contacts.

6.2.5 Low-voltage test provision

A low-voltage test provision may be supplied with a grounding switch to permit test voltages of up to 10 kV (optional 2.5 kV) and up to 200 A to be applied to the conductor without removing SF_6 gas or other components, except for ground shunt leads.

6.2.6 Operation mode specification

The following operation modes should be specified for special grounding applications:

a) Fast-acting for cable grounding
b) Fault initiating (fast-acting)
c) Current-interrupting capability and recovery voltage for use with parallel transmission lines

6.3 Gas system

6.3.1 Furnishing the GIS

The GIS shall be furnished, if so specified, with sufficient SF_6 gas to pressurize the complete system in a sequential approach, one zone or compartment at a time, to the rated nominal density. An additional quantity of gas should be furnished as specified.

The SF_6 gas should conform to ASTM D2472-1992. Recycled SF_6 gas that conforms to specifications mutually agreed upon by the user and the equipment supplier may also be used.

6.3.2 Reuse or recycling of removed gas

The supplier should provide guidelines or recommended practices for the reuse or recycling of SF_6 gas removed from the equipment. These guidelines should be consistent with current industry practices, as they pertain to the effect of SF_6 on global warming; i.e., SF_6 gas should be reused and recycled whenever possible, and never be unnecessarily released into the atmosphere.

6.3.3 GIS enclosure

The GIS enclosure should be divided into several sections separated by gas-tight barrier insulators. Each section should be provided with the necessary piping and valves to allow isolation, evacuation, and refill of gas without evacuation of any other section. Location of gas barrier insulators is to be clearly discernable outside the enclosure by a band of distinct color normally used for safety purposes.

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6.3.4 Gas schematic diagram

A gas schematic diagram should be submitted for approval. It should include the necessary valves, connections, density monitors, gas monitor system and controls, indication, orifices, and isolation to prevent current circulation. Means of calibrating density monitors without de-energizing the equipment should be specified by the supplier.

6.3.5 External fixtures

The external fixtures should be made of corrosion-resistant material and should be capped where required.

6.3.6 Monitoring and maintenance

For the purpose of gas monitoring and maintenance, the GIS should be divided into the following individually monitored zones:

a) Each power circuit breaker
b) Additional zones as mutually agreed upon by the user and the supplier

6.3.7 Single-phase bus construction

For single-phase bus construction, single-phase or three-phase gas pressure and density monitoring should be specified.

6.3.8 Leakage rate

The leakage rate of SF_6 gas from an individual gas compartment shall not exceed 1% per year. The total leakage rate from the GIS system shall not exceed 0.5% per year.

6.3.9 Alarms

Each gas zone should be furnished with a gas monitoring device capable of signaling two adjustable, independent alarms. The user should specify the signaling requirement as it pertains to the user's protection and control system. Typically, the signaling is done by two sets of adjustable, electrically-independent contacts that operate at the alarm levels as follows:

a) First alarm—refill gas density normally 5–10% below the nominal fill density
b) Second alarm—minimum gas density to achieve equipment ratings

In special cases determined by the supplier, a third stage with a set of contacts may be necessary in certain areas.

6.3.10 Connections

Provisions should be made for connecting density relay, the service cart, and moisture instrumentation to each one of the gas sections.

6.4 SF_6-to-air bushings

SF_6-to-air bushings may be used for connections between conventional overhead transmission lines and GIS, between the transformer or reactor, and GIS equipment, or other locations specified by the user.

Each bushing should be constructed of commercial-grade porcelain or an acceptable substitute, with all surfaces free from imperfections. The color specified by the user should be gray or brown.

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Bushing connections to an overhead line or transformer lead should be NEMA CC 1-1993, standard four-hole aluminum pad.

Each porcelain component or nonceramic bushing that has an internal pressure shall comply with IEEE Std C37.09-1979 .

6.5 Cable connections

If required, SF_6 enclosures for cable terminations should be provided for connecting the power cable to the GIS connection.

The cable connection enclosure should be proportioned to permit adc field test of the connecting cable and should provide means to permit such testing. If necessary, it shall be possible to connect a test bushing. The pothead should be equipped with a removable link to permit separate cable and GIS high-voltage tests.

The SF_6 cable enclosure and connection support structure should be equipped with provisions for isolating the cable sheath or pipe to permit cathodic protection of the cable system. (See IEC 859 : 1986 and IEEE Std 1300-1996 .)

To ensure the effectiveness of the corrosion-protection in handling power frequency fault current within the GIS, the user and the supplier should coordinate placement, ratings, and testing of corrosion protection installation.

6.6 Transformer and reactor connections

Enclosure adapters may be required to connect the SF_6 bus directly to the SF_6-to-oil transformer bushing, bolting directly to a flange on the bushing, and totally enclosing the insulator and live parts in the SF_6 environment. The adapter should have a removable cover and removable bus link to permit disconnecting the transformer from the bus, testing of the bus or transformer separately, and removal of the transformer, if required.

The bus enclosure may be insulated from the transformer tank to minimize circulating currents through the transformer tank. The bus connecting the transformer to the GIS may also contain a bellows assembly and flexible conductor connection to minimize vibration transfer from the transformer. Alternatively, a flexible element may be provided on the transformer side of the SF_6-to-oil bushing. To permit alignment of the bus and the bushing, the user should assign responsibility to the GIS supplier to coordinate the designs of the interface. (See IEC 1639 : 1996.)

6.7 Current transformers

Each current transformer should be provided so that the enclosure current does not affect the accuracy or the ratio of the device or the conductor current being measured. Provision shall be made to prevent arcing across the enclosure insulation.

Current transformer secondaries shall be terminated to shorting terminal blocks. It should be possible to test each current transformer without the removal of gas. The current transformer location, polarity, ratios, and accuracy shall be as specified and in accordance with IEEE Std C57.13-1993 .

6.8 Inductive voltage transformers

6.8.1 Dry-type, encapsulated, or SF_6 insulated

Each voltage transformer should be dry-type, encapsulated, or SF_6 insulated, and should have the following information specified:

a) Number of secondary windings
b) Number of taps in each secondary winding

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c) Ratio of primary voltage to each secondary winding voltage
d) Thermal rating of each secondary winding
e) Thermal rating of primary winding
f) Compensating winding

6.8.2 Accuracy classification

The accuracy classification at power frequency and at the specified secondary voltage should be 0.3 at burdens of W, X, Y, Z, and ZZ, as stated in IEEE Std C57.13-1993. Burdens may be divided in any proportion between the secondary windings, but for accuracy classification the total burden on both windings must not exceed W, X, Y, Z, or ZZ. Thermal ratings and burdens should be coordinated with the protection system.

6.8.3 Construction

Transformers should be of either plug-in construction or the disconnect-link type, and be attached to the gas-insulated system in such a manner that they can be easily disconnected while the system is being dielectrically tested. Alternately, a voltage transformer designed so that it does not have to be disconnected during dielectric testing may be specified. The metal housing of the transformer should be connected to the metal enclosure of the GIS with a flanged, bolted, and gasketed joint so that the transformer housing is grounded to the GIS enclosure.

6.8.4 Covers and shields

Special covers and any necessary corona shields should be supplied so that the system can be pressurized and dielectrically tested after removal of the transformer.

6.8.5 Primary and secondary terminals

Primary and secondary terminals should have permanent markings for identification of polarity, in accordance with IEEE Std C57.13-1993 .

6.9 Metal-enclosed surge arresters

Arresters should be of the voltage rating called for in the detailed specifications. IEEE Std C62.11-1993 may be used as a reference. Arresters should be of either the “plug-in” construction or the disconnect-link type and be attached to the gas-insulated system in such a manner that they can be readily disconnected from the system while the system is being dielectrically tested. The metal housing of the arrester should be connected to the metal enclosure of the GIS with a flanged, bolted joint.

The ground connection should be sized for the fault level of the GIS. It should be insulated from the GIS-enclosure and grounded externally to permit periodic maintenance and monitoring of the leakage current.

If the arresters are not equipped with removable links, special covers and any necessary corona shields should be supplied so that the system can be pressurized and dielectrically tested after removal of the arrester.

Access to the arrester ground connection, when it is provided with means for leakage current monitoring should not be obstructed.

6.10 Capacitor voltage couplers

Suitable capacitive voltage couplers can be furnished to provide for specialized measurements, such as ultra-high-frequency partial discharge and diagnostic monitoring.

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Capacitive voltage couplers designed for partial discharge measurements do not normally have to be disconnected from the equipment during high potential testing.

A voltage test instrument may be specified for indicating the presence of voltage on the conductor system. This is accomplished by measuring capacitive charge on a ground electrode. If this feature is desired, specification should include the following phrase: “Provisions for the attachment of a voltage instrument.”

6.11 Local control cabinets

6.11.1 Control cabinet

The supplier should furnish one local control cabinet for each circuit breaker (or specified sets of line terminals). Each cabinet shall be completely fabricated, wired, assembled, and tested at the factory. Each cabinet furnished should be fully equipped and completely wired to the terminal blocks for termination of circuit breaker and switch control instrument transformer leads, indication, and gas alarm cables.

6.11.2 Cabinet guidelines

In general, each cabinet should contain the following equipment for control, indication and protection of switches, circuit breakers, and associated components:

a) One control switch for each three-phase circuit breaker.
b) One remote-local switch for each three-phase circuit breaker.
c) One open-close control switch for each motor-operated grounding switch.
d) One open-close control switch or push-button for each motor-operated grounding switch.
e) One or two red light-emitting diodes or mechanical semaphore and one green for each circuit breaker, each disconnect and grounding switch, or contact position indication on the mimic diagram.
f) Control switches for ac and dc supply to each compartment.
g) A mimic diagram showing connections of all furnished equipment and showing location of all gas zones.
h) An annunciator panel with retransmit contacts.
i) Terminal blocks and terminations for each gas density relay.
j) Terminal blocks and terminations for electrical interlock contacts.
k) Terminal blocks and terminations for alarm and miscellaneous remote-control circuits.
l) Terminal blocks and terminations for all instrument transformer leads. A lead should be installed and terminated for each tap of a multi-ratio current transformer and all secondary winding taps for voltage transformers.
m) Terminal blocks and terminations for all required spare contacts.
n) Terminal blocks and terminations for the external control, instrumentation, and protection of the user.
o) A total of 10% spare terminal blocks.

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7. Proposal data

7.1 Drawings

Time after notification of award when the following drawings and data will be submitted (in weeks):	**User requirements**	**Supplier proposal**
General arrangement drawings		
Structural plan and details		
Foundation loadings for all GIS equipment and supporting structures		
Physical detail drawings (shipping unit)		
Electrical schematic diagrams		
Wiring diagrams		
Gas schematic diagrams		
Grounding arrangement and ground bus details		
Erection drawings		
Dimensional tolerances, outdoor/indoor:		
X		
Y		
Z		

7.2 Weights (kilograms, unless otherwise noted)

	User requirements	**Supplier proposal**
Circuit breaker 1P or 3P*		
Disconnect switch 1P or 3P		
Grounding switch 1P or 3P		
Grounding switch IP or 3P		
Voltage transformer 1P or 3P		
SF_6-to-air bushing 1P		
Surge arrestor 1P		
Longest section of interconnecting bus 1P or 3P		
Interconnecting bus elbow 1P or 3P		
Interconnection bus tee 1P or 3P		
Weight of the heaviest piece of equipment to be handled during construction (name item)		
Estimated total weight of all structural steel		
Total estimated weight of all items		

*1P=single-phase; 3P=three-phase

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7.3 General technical data

	User requirements	Supplier proposal
Rated service voltage (kV rms)		
Rated maximum voltage (kV rms)		
Rated frequency (Hz)		
Rated continuous current (A)		
Bus (A rms)		
Terminal (A rms)		
Rated short-circuit current (kA rms)		
Short-time current duration (s)		
Peak withstand current (close and latch) (kA rms)		
Withstand voltages:		
Power frequency (kV rms)		
Full wave impulse (BIL)		
Switching impulse (SIL), if required		
Maximum acceptable moisture level:		
Circuit breaker (PPMV)*		
Compartments where arcing is expected (PPMV)		
Compartments where arcing is not expected (PPMV)		

*PPMV= Parts per million per volume

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7.4 Enclosure and conductor (for each rating)

	User requirements	Supplier proposal
Inductance (H/m)		
Capacitance (pF/m)		
Resistance:		
Enclosure (Ω/m)		
Conductor (Ω/m)		
Surge impedance (Ω)		
Weight of gas for largest gas zone (kg)		
Length of bus sections (m)		
Bus enclosure data (for each rating)		
Type of material		
Outside diameter (mm)		
Wall thickness (mm)		
Internal SF_6 GIS pressure at 20 °C (kPa)		

7.5 Circuit breakers

	User requirements	Supplier proposal
Voltage range factor		
Rated continuous current (A rms)		
Rated short-circuit current (kA rms)		
Rated short time current duration (s)		
Rated peak withstand current (closing and latching) (kA rms)		
Rated interrupting time (ms)		
Rated reclosing time (ms)		
Rated permissible tripping delay (s)		
Rated capacitor switching current (A rms)		
Rated operating duty cycle		
Type of operating mechanism		
Breaker operating time for rated control voltage and pressure		
Opening time from energizing of trip coil to contact parting (ms)		

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	User requirements	Supplier proposal
Closing resistors (if applicable):		
Ohmic value of closing resistors per phase (Ω)		
Insertion time during closing (ms)		
Gas pressures		
Pressure at 20 °C (kPa)		
Maximum foundation loading during operation:		
Horizontal (N)		
Vertical (N)		
Motor capacity		
Number and type		
Power of each (W)		
Voltage and number of phases (V)		
Current, start/run (A)		
Total heater power per three-pole breaker (W)		
Control circuit:		
Rated dc control voltage (V)		
Closing voltage range (V)		
Maximum closing current (A)		
Tripping voltage range (V)		
Maximum tripping current (A)		
Number of trip coils per breaker pole		
Number of operations before the breaker must be removed from service for maintenance inspection		
No-load mechanical		
Full load non-fault		
Rated short-circuit current		
Expected number of hours required to perform a com- plete maintenance inspection of one breaker (including gas handling time)		
Maximum guaranteed noise level, during operation, at a point 100 ft from the breaker (dB)		
Number of breaker operations without recharging		
Number of full reclosing operations without overheating the closing resistors (specify the closing duty for the thermal rating)		

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7.6 Disconnect switches

	User requirements	Supplier proposal
Rated full-wave impulse withstand voltage:		
Across the open gap (kV peak)		
Power frequency—1 min withstand voltage:		
Across the open gap (kV rms)		
Number of switch-operating-mechanism operations before internal visual inspection or servicing		
Maximum control voltage (Vdc)		
Minimum control voltage (Vdc)		
Current, start/run (A)		
Maximum opening current (A)		
Maximum closing current (A)		
Heater power per three-pole switch (W)		
Main current-carrying contact material		
Base material and specification		
Contact insert		
Plating material		
Control data for operating mechanism		
Operating time (s)		
Maximum charging current interrupting (A)		

7.7 Grounding switches

	User requirements	Supplier proposal
Rated peak withstand current (close and latch) (kA rms)		
Number of the mechanical operations before internal visual inspection or servicing		
Number of closing operations into energized bus without damage		
Ground switch interrupting capacity, if specified and agreed (A)		

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7.8 Voltage transformers

	User requirements	Supplier proposal
Name of the supplier		
Applied test voltage (kV rms)		
Power-frequency field test voltage with VT connected (kV rms)		
Ratio of high-voltage to low-voltage windings		
Thermal rating of each secondary winding (VA)		
Thermal rating of the primary winding (VA)		
IEEE Std C57.13-1987 accuracy classification		
List burdens for which the above accuracy classifications apply		
Table of current versus time for back-feeding capacitive current during GIS field tests		

7.9 Current transformers

	User requirements	Supplier proposal
IEEE Std C57.13-1993 accuracy class		
Ratio in terms of primary and secondary current ratings		
Continuous thermal current rating factor		
Secondary winding insulation class		
Are all current transformers external to the GIS enclosure? (Yes/No)		
Are CTs split-core type? (Yes/No)		

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7.10 Gas-to-air bushing

NOTE — Special BIL and SIL requirements may be specified for the bushing.

	User requirements	Supplier proposal
Name of the supplier		
Type designation of the supplier		
Material		
Rated power frequency withstand		
Dry—1 min (kV rms)		
Wet—10 s (kV rms)		
External strike distance:		
Phase-to-ground (mm)		
Phase-to-phase (mm)		
External creep distance (mm)		
Cantilever strength (N · m)		
Acceptable terminal load (N)		

7.11 Gas system

	User requirements	Supplier proposal
Total quantity of SF_6 gas required with the original equipment (kg)		
Total quantity of SF_6 gas required per breaker (kg)		
Guaranteed maximum SF_6 gas leakage rate from the complete GIS (kg/year)		
Number of gas monitoring systems included with the equipment		

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7.12 Gas-to-cable connection

	User requirements	Supplier proposal
Cable type		
Cable size		
Cable ampacity		
Cathodic protection isolation		
Termination type/supplier drawing		

7.13 Gas-to-transformer connection

	User requirements	Supplier proposal
Transformer supplier		
Ampacity		
Gas-to-oil bushing type/supplier drawing		
Circulating current isolation		

7.14 Enclosed surge arrestor

	User requirements	Supplier proposal
Supplier		
Type		
Duty-cycle voltage rating (kV)		
Maximum continuous operating voltage rating (kV)		
Discharge counter		
Leakage monitoring		
Enclosure diameter (mm)		

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Annex A

(informative)

GIS budget inquiry form

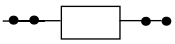
To _____ Date _____ FAX #_____

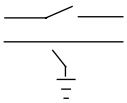
System voltage kV rms: _____ Project name: _____

Interrupting rating kA: _____ Location:_____

Number of circuit breakers _____ Number of connections _____

One-line schematic diagram:


Circuit breaker, CTs


Disconnect switch
Ground switch


SF6 Air bushings


Cable connection


Direct transformer connection-SF6—Oil


(3) Voltage transformers with # of phases

NOTES:

_____
_____
_____
_____
_____

Site information: Show approximate size and shape.

Indoor ☐ Outdoor ☐

NOTES:

_____
_____
_____
_____
_____
_____
_____
_____

Reply to: _____ By: _____

FAX #: _____ Expected in-service date: _____

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Annex B

(informative)

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