



Design Review of Gas Insulated and Hybrid Gas Insulated Switchgear

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Abstract

This paper highlights overall process of design review, the challenges faced during the process and points observed to capture in revised technical specification. Also, it covers the advantage of adoption of this method by power utility for improving quality of product over the period.

Keywords: Gas Insulated, Manufacturing quality Plan (MQP), Radio Interference Voltage (RIV), Switch Gear, UHF Sensors

1. Introduction

Global industrialization and increasing population results in rise of demand for quality and uninterrupted power supply. For this, substation equipment has to be made more efficient and reliable to cope up with increasing demand. But as we know with shortage of geographical area needs creation of compact but efficient power supply medium. Gas/Hybrid Gas insulated substation is the right solution to such problems.

In Gujarat, power requirement has grown steadily in all segments and reached a peak demand of 18424 MW in June 2019 against 12348 MW in 2012–13. In many locations, GETCO has no option other than Gas insulated substation for new substation and Hybrid gas insulated switchgear technology in case of uprating and expanding of existing substation due to limited time frame and space constraint.

In such situation, the evaluation of technical bid and design review after post bid become more important to understand what has been offered whether meeting with requirement of technical specifications, guaranteed technical particulars, applicable standards, etc.

GETCO have adopted unique design review methodology for Gas and Hybrid gas insulated switchgear which comprises design verification of successful bidders (Drawings, type tests/ calculations, GTP/technical data, MQP/FQP) and Inspection at OEM factory.

2. Design Review

Design review is a planned exercise to ensure that proposed design will be meeting the requirements of applicable standards as well as technical specification, the contract, quality and safety requirement. The emphasis of design review is to establish that what is being offered fits for the purpose in all respect for the intended performance during service life. Also, to ensure that the manufacturer uses proven materials, process, design tools and methodology to meet all specified requirements.

During design review the drawings, Guaranteed Technical Particulars /data sheet, type test reports and Manufacturing Quality Plan (MQP) are being scrutinized to ensure that offered design complies with contract specifications.

2.1 Technical Particulars (GTP)

All required technical data furnished by manufactures in prescribed format of GTP shall be thoroughly evaluated and no technical deviation shall be allowed.

The data shall contain all information viz. type and designation given by manufacturer, rating, C/s area of contacts, clearance, weights, etc. for the offered items in line with submitted type test reports, specifications and relevant standard.

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2.2 Drawings

The contract drawings shall include all essential information of equipment to ensure that equipment being planned for manufacturing meets the guaranteed technical particulars as per order, type test reports and functional requirements as per customer specification. Hence for better clarity and understanding of drawing, GETCO have initiated design review practice.

The following contract drawings and documents for **GIS/HGIS switchgear** are asked to be submitted by supplier in the event of order and same is verified with check list prepared as per experience and major points observed during scrutiny for various projects.

List of Drawings /documents for approval of GIS:

1. GAS Single line coloured diagram (GSLD)
2. General Arrangement drawing (Plan View) of GIS in GIS room
3. Elevation and Section drawing
4. SF6 to air bushing with terminal connector
5. LCC layout and Schematic drawings
6. Bus-duct drawings/ Cable Sealing Arrangement drawings
7. Nameplate drawings for all the components
8. Gas Volume data (Enclosure wise and bay wise)
9. Detail view of all the components as per BOQ/SLD
10. Contact Assembly for CB, DS, ES, FES, etc.
11. Mechanisms for CB, DS, ES, FES, etc.
12. Secondary boxes of CT and PT
13. Bus - bar sizing with Expansion and contraction calculation
14. Seismic calculation and Structure span calculation
15. Calculation of voltage rise of enclosure (Step and touch potential)
16. Calculated point to point resistance for each assembly
17. Gas system installation procedure
18. Design Calculations for Bus-bar sizing, Short circuit forces and vibration on Bus-bar and each equipment, thermal stability and losses.

	A. General Check Points	B. Check Points for GA Drawing
1	Study BOQ and tender SLD to decide type of bays and no. of each bays.	Rated voltage, frequency, withstand voltages, BB current, STC. breaking current, Control voltage, CB motor voltage, Iso./ES Motor voltage, heater voltage, Rated Peak withstand current, Insulation withstand voltage across open isolators, PD at 1.1XUn, SF6 pressure for CB (Rated, Alarmed, Lockout), SF6 pressure for other compartments (Rated, Alarmed), Total no. current bays and future bays, Acceleration due to gravity (Horizontal and Vertical)
2	Study MOM and pre bid query	Name of each equipment, Quantity, Weight/each, SF6 quantity/each
3	Check all the ratings from BOQ and same is matched with specifications.	Item, Manufacturer, Rating, Model, Application, Type of mechanism (Manual, Spring, Motorized etc.)
4	All the type tests must be matched with ratings	Rated duty cycle for CB, Annual Leakage rate, Max. and Min. ambient temperature, Bus transfer switching capacity
5	Match model no. for each module from TTR and drawings.	Sr. No., Description of parts, Qty per bay, Material, Thickness of housing, size (Flange to flange)
6	Check all equipment arrangement as per tender SLD.	Each conductor current rating, material, cross section area with current density
7	Confirm that CB is at Bus-1 side and CT at Bus-2 side in Bus-coupler module.	Future extension provision for first and last bay
8	Check all polarities direction as per PSLD. (Generally P1 at bus side).	Grounding arrangement with detail
9	CT secondary earthing provision must be available at both side i.e., S1 and S2. (Generally S2 side earthing is done for bus-coupler bay and for rest, it is done at P1 side).	PD sensor, PRD, bellow drawings, GAS monitor

10	Confirm location and sequence of all the CT cores from approved PSLD.	Insulator- Gas pass and Gas tight detailed drawing with provision for earthing continuity
11	Check the direction of ES which will decide which portion will be earthed when ES is closed.	Contact Resistance Measurement overview and declared values between accessible parts (especially in PT bay)
12	Cable Sealing Arrangement shall be for 3 cables in case of line (630 sq. mm three nos. of cable i.e., one cable per phase) and same shall be for 9 cables in case of transformer (630 sq. mm nine nos. of cable i.e., three cables per phase)	Elevation, Plan and side view with all the dimensions including overall dimensions and clearances from ground
13	Check the direction of outgoing bus duct i.e., direction of conductor going to yard with respect to building (Left side or right side)	Major points for GA: SF6 gas density relay, SF6 gas filling points, PRD, PD measurement points, Desiccant material, Earthing points, Future extension provision, Gas equalization pipe (Not allowed), Position Indicators
14	Check the module type w.r.t phase wise enclosed or all phase enclosed as per specifications.	Match arrangement of gas compartments with Gas SLD.
15	Major points for GA: SF6 gas density relay, SF6 gas filling points, PRD, PD measurement points, Desiccant material, Earthing points, Future extension provision, Gas equalization pipe (Not allowed)	Crane capacity should be greater than total weight to be lifted
16	“Considering feasibility of 66 KV power cable terminations at Line bays and transformer bays, M/s Sterling and Wilson to arrange extension of bus ducts if any required for 66 KV GIS modules”- This note shall be checked.	Location of CSD in case of 400 kV class modules

17	Position of Bus-1 and Bus-2 in GA and Schematic drawings. (Especially in Hybrid or existing substations where extension is proposed)	Check for requirement of tables or ladders for manual operation of CB/Iso/ES
18	Nomenclatures in GA drawings, Gas SLD and Schematic drawings.	Pressure Relief Device: Operating values and direction of gas relief
20	Crane capacity should be greater than total weight to be lifted	PD sensor location and provision detail
21	Gas volume diagram along with spare gas quantity	CB maintenance direction
22	Spacing in line with Tender layout and enough spacing for breaker maintenance	Galvanizing of structures

2.3 Type Tests (For GIS and Hybrid GIS)

GETCO technical specification calls for submission of following type test reports from NABL accredited laboratory and not older than ten years.

1. Tests to verify the insulation level (Lightning impulse, switching impulse and power frequency withstand test with PD) test on complete GIS module.
2. Dielectric tests on auxiliary circuits.
3. Tests to prove the Radio Interference Voltage (RIV) level.
4. Tests to prove the temperature rise of any part of the equipment and measurement of the resistance of the main circuit.
5. Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short time withstand current.
6. Tests to verify the making and breaking capacity of the included switching devices. i.e.
 - i. Basic Short circuit duty tests (T10, T30, T60, T100a, T100s)
 - ii. Short line fault test (L60, L75, L90)
 - iii. Single phase test
 - iv. Out of phase making and breaking test
 - v. Capacitive current switching test
 - vi. Shunt reactor current switching test (For 220kV and 400KV Class)

7. Tests to prove the satisfactory operation of the included switching devices.
8. Verification of the degree of protection of the enclosure.
9. Gas tightness tests
10. Additional tests on auxiliary and control circuits.
11. Tests to prove the strength of enclosures
12. Electromagnetic compatibility tests (EMC).
13. Tests on partitions.
14. Tests to prove the satisfactory operation at limit temperatures.
15. Tests to prove performance under thermal cycling and gas tightness tests on insulators.
16. Tests to assess the effects of arcing due to an internal fault.
17. Tests on solid dielectric components (operating rods, spacers, etc.)
18. Seismic test/ Calculation
19. Test on Auxiliary switches (Electrical and Mechanical Endurance, Heat run, IR and HV test)
20. Tests on CTs and PTs (On Primary and secondary) as per IEC 61869
21. Test on surge arresters
22. Test on control switching devices/PIR

Note: Tests specified in Sr. no. 11 to 17 are not applicable to Hybrid GIS.

2.3.1 Important Parameters to Cover in Type Test Report

The result of all the type test shall be recorded in reports containing sufficient data to prove compliance with the specification/standard and sufficient information shall be included so that the essential parts of switchgear and control gear can be identified.

Hence following Information for identification of specimen under type test is required to verify from test report in line with IEC 62271-203 to have full picture of offered item.

1. Manufacturer
2. Type designation and serial number of tested switchgear
3. Characteristics of GIS/HGIS
 - Number of poles/type (single phase /Three phase)
 - Installation (indoor or outdoor)
 - Rated voltage, current and frequency
 - Rated insulation level
4. Characteristics of the operating mechanism and associated equipment
 - Rated peak and short-time withstand currents
 - Rated short-circuit making and breaking current
 - TRV and time constant
 - First pole to clear factor
 - Operating sequence (0-0.3s-CO-3min-CO)
 - Line and cable charging current
 - SF6 gas pressure for insulation and interruption
 - Extended mechanical endurance class M1 or class M2
 - Service conditions, including minimum and maximum ambient air
 - Bus-transfer current switching (disconnections only)
 - Induced current switching (line earthing switches only)
5. General details of the supporting structure
6. Sufficient outline drawings and data schedule to represent the switchgear and control gear tested
7. Detailed drawings of Parts of main circuit and associated components
8. Test arrangement.
 - a. Test set up
 - b. Circuit diagram
 - c. Testing equipment etc.
9. Test Parameters
10. Number of make and break switching operations.
11. Statement of behavior of equipment during each test
12. Details of any parts renewed or reconditioned during the tests
13. Photograph showing condition of equipment before and after the test
14. Oscillographs.
15. Conclusion

Following criteria are also required to be considered while scrutinizing type test report of GIS/HGIS as per guideline of IEC-62271-203 and 205.

- All dielectric tests should be carried out on one switchgear only.
- All the type tests shall be carried out on maximum of four specimens.
- If any special type test requested by user, additional test samples may be used.

2.3.2 Issues/Discrepancies Observed in Type Test Reports

While evaluating drawings with respect to type test reports, following points are generally observed:

1. Incomplete Details/Data/Drawings in Type Reports

Type test reports submitted without required drawings, test set up, oscillographs, and conclusion. Many times the drawings not cover relevant data.

2. Temperature Rise Test Report

- Test reports without indicating materials and cross sectional area of each current carrying part.
- Test not carried out on complete GIS/HGIS bay or detail of each equipment not shown in report.

3. Dielectric Test Report

- Drawing without indicating make and technical particulars of insulators used or indicate multiple makes of insulator instead of actually provided during test.
- Test not carried out on complete GIS/HGIS bay

4. Mechanical Load Test

- a. The report submitted without complete details of operating mechanism.
- b. Maximum current drawn by the motor for closing and opening operation not indicated.
- c. Power consumption before and after the test not measured.
- d. Detailed drawing of mechanism box not submitted.

5. Degree of Protection Test

Details of gasket i.e. Material, Size and profile by which dirt and moisture ingress prevented is not shown in drawing. Offered gasket not matching with that used in type test.

6. Lower Rating/Other Class Type Test Report

Report submitted for different type / different gas pressure or deferent type designation.

7. All the Type Tests Not Being Carried Out on the Same Unit

All dielectric tests, duty cycle tests, mechanical and environment test should be carried out on same unit as per grouping of tests as per IEC but sometimes it is found that tests of same group carried out on different units. e.g. RIV and corona test carried out on different unit then Lightning Impulse voltage withstand test and High voltage power frequency withstands test. which shall not be allowed.

8. Sometimes, laboratory indicates that reports are conforming to requirement and simultaneously observations are made in detailed report, which create ambiguous situation.

2.4 Manufacturing Quality Plan (MQP)

To ensure the manufacturing process as per relevant standard for better quality and performance, GETCO has followed practice of reviewing MQP during proto and final acceptance.

Submitted MQP is evaluated on the basis of following major categories.

1. Raw material quality plan
2. In process Quality Plan
3. Routine test
4. Acceptance test
5. Packing and Dispatch

2.4.1 Routine/Acceptance Test

During manufacturing and on completion, all equipment shall be subjected to the Routine tests as laid down in IEC Standard IEC 62271-203. All the acceptance tests shall be carried out in presence of GETCO representative on complete bay of GIS for each type of modules.

GETCO has specified following tests as acceptance of material.

1. Dielectric test on the main circuit.
 2. PD test
 3. Tests on auxiliary and control circuits.
 4. Measurement of the resistance of the main circuit.
 5. Tightness (leakage) test.
 6. Design/ visual checks and Functional tests
 7. Gas quality verifications
 8. LCC – Complete functional and interlock test as per approved drawings with LCC duly connected to respective Bay GIS module in all respect.
- IR test and HV test

- 9. Test on CTs /PTs and surge arrester
- 10. Test on control switching devices/PIR if applicable

2.5 Review of Technical Specification

Various class GIS are purchased for new projects and HGIS for renovation and modernization purpose. We have learnt lot from each of supplier design and problems faced in actual operation and based on that, modified and upgraded the specifications are prepared to reduce operational difficulties, increase longevity, higher durability etc. Accordingly, modifications are adopted in the technical specifications and some special requirements incorporated are here in:

1. Provision of adequate number of UHF sensors in the offered GIS for PD Monitoring.
2. To Limit the effects of an internal arc the switchgear shall be suitably divided in to arc and gas proof compartments preferably.
 - Bus bar together with bus bar isolator and earthing switch
 - Circuit breaker
 - Line dis-connector and earthing switch
 - Instrument transformers
3. Irrespective of bus bar design, provision is to be made available for isolation of individual/affected bay without disturbing adjacent bay
4. Provision for extension in the future on both end.
5. Arrangement of section barriers/insulator with bus conductor shall be such that there shall not be any requirement for removal of adjacent bay while replacing of gas barriers.
6. The electrical connections between the various gas sections shall be made by means of multiple contact connectors (plug-in type) so that electrical connection is automatically achieved when bolting one section to another. Field welding of conductor and continuous bus conductor is not acceptable
7. Minimum mass of zinc coating for Galvanizing shall be 900 gm/square meter instead of 610 gm/square meter.
8. Added following features in LCC:
 - Contact rating of each Control switch shall be matched with respective switchgear DC load requirement.

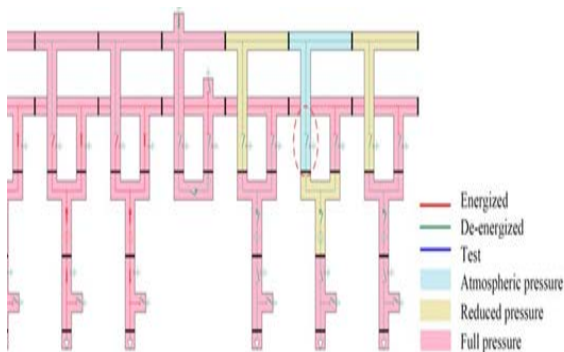
- Each Control switch / Interposing relay / other component utilized in scheme shall have at least one set of spare contact which are utilized in scheme over and above all the interfaces of Local as well as Remote.
9. For better clarity specified contacts for SCADA in specification
 10. Added following tests in type test /routine and acceptance test list.
 - a. Gas quality verifications. (Routine and acceptance test)
 - b. Test on CTs and PTs
 - c. Test on surge arrester
 - d. Test on control switching devices/PIR.
 11. Added following service Continuity criteria in case of GIS equipment maintenance for better clarity.

Table 1. GIS Equipment Maintenance

Type of GIS Equipment Maintenance	Requirement
(1) Bus bar dis connector	Only the affected feeder and the bus bar to which the affected bus bar DS is connected can be shutdown. The other bays (including those adjacent to the affected bay) shall still be energized.
(2) Circuit breaker	Only the affected feeder can be shutdown. Both bus bars shall still be energized.
(3) Current transformer	Only the affected feeder can be shutdown. Both bus bars shall still be energized
(4) Earthing switch next to the bus bar DS	Only the affected feeder and one bus-bar (in case of internal fault) can be shutdown.
(5) Extension	The gas buffer/dummy compartment (if required dis-connector with dummy compartment) shall be provided at both the ends of each bus in order to maintain the service continuity of the bays. <ul style="list-style-type: none"> - The additional bays shall be tested separately before connecting to main GIS set up.

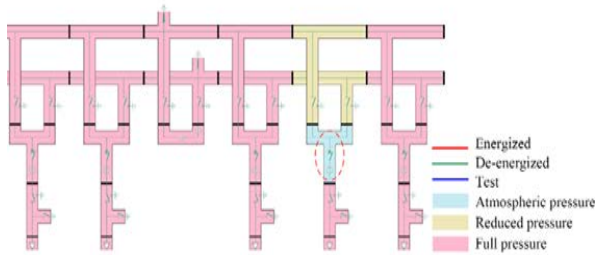
2.5.1 Service Continuity Criteria

2.5.1.1 DS/DES maintenance –Service Interruption



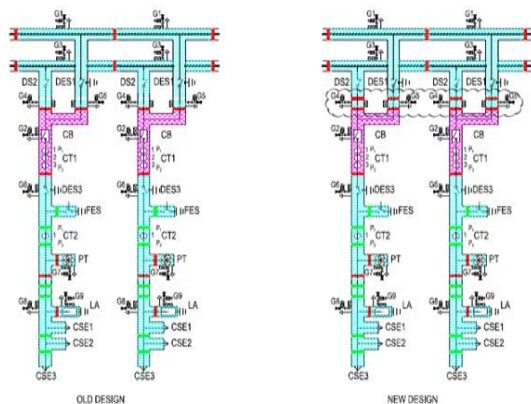
Service interruption of a typical GIS design when dismantling a busbar disconnecting switch

2.5.1.2 CB Maintenance – Service Interruption



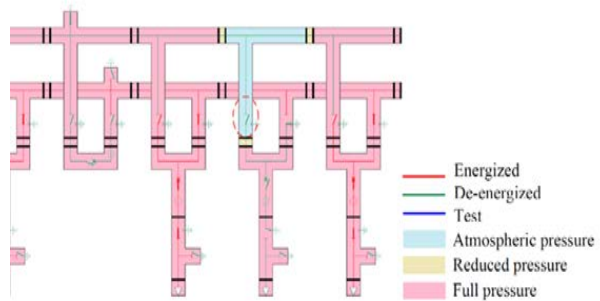
Service interruption of a typical GIS design when dismantling a circuit breaker

2.5.1.3 Design Modification by GIS OEM w.r.t. Service Continuity Criteria for DS/DES



Considering past experiences of GIS design review, OEM has proposed change in design to meet for GIS service continuity criteria.

2.5.2 Design Modification proposed w.r.t. Service Continuity Criteria for Full Bay Maintenance Without Adjacent Bay Shutdown



3. Conclusion

Proper understanding of specifications and standards implemented during technical bid scrutiny, design review, FAT and SAT can support to improve product quality, higher reliability, higher safety, flexibility, less maintenance, easy operation and helps us to reduce overall project delivery. Hence, to bring all the bidders at par, it is required to evaluate all bids with common format for the all the attributes of technical specification requirement. Therefore, GETCO has adopted process of design evaluation at bid stage and design review during order execution.

Above practices helps GETCO in faster scrutiny of technical documents and reduction in procurement time cycle as per our specification. It also helps in improving quality of product over the period. The experience shared in this paper would be useful for other utilities also.

4. Acknowledgement

We are very much grateful to the GETCO management for kind support, guidance and granting permission to publish this paper.

5. References

1. IEC 62271-100 HV AC Circuit breaker.
2. IEC 62271-300 HV Circuit breaker- Gas insulated metal enclosed switchgear for rated voltage above 52 kV.
3. IEC 62271-205 HV Circuit breaker- Compact switchgear assembly for rated voltage 52 KV.
4. GETCO specification for GIS and HGIS.