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# Practical Guidance for the Renewal of Gas Insulated Substations

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## SUMMARY

Gas Insulated Switchgear (GIS), like any other electric utility equipment, must meet the performance and reliability standards of the electric transmission system to which it is connected. A station may need to be replaced when its rated capacity is exceeded, the reliability drops to unacceptable levels, or the equipment can no longer be maintained due to obsolescence. Replacements or renewal projects involving GIS are unique and therefore require special attention. These sorts of renewal projects with GIS offers some particular challenges due to its compact, flange connected and gas filled construction. This paper gives practical guidance for proper planning of a renewal project where GIS is part of the solution. The concerns addressed include physical design planning including GIS interfaces between existing and new equipment, maintaining both safety and dielectric capability when working with gas-filled compartments, outage planning, and high voltage dielectric testing planning. The focus is to establish the fundamental understanding necessary for successful project execution. Experience gathered from over 20 GIS renewal projects is given to users facing a GIS renewal project.

## KEYWORDS

GIS, Gas Insulated Switchgear, Gas Insulated Substation, Service Continuity

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## Introduction

Gas Insulated Switchgear (GIS), like any other electric utility equipment, must meet the performance and reliability standards of the electric transmission system to which it is connected. A station may need to be replaced when its rated capacity is exceeded, the reliability drops to unacceptable levels, or the equipment can no longer be maintained due to obsolescence. Replacements or renewal projects involving GIS are unique and therefore require special attention. Although the number of GIS users is increasing those experienced in replacing or renewing GIS are still few. Herein we offer some fundamental instruction and guidance on the implementation of this type of renewal project. Our Mitsubishi Electric Power Products Inc. (MEPPI) experience comes from more than 20 of these types of renewal project in North America since our company's inception in 1987.

| Original Manufacture | Number of Renewal Projects |
|---|---|
| ABB 245kV | 1 |
| ABB 550kV | 1 |
| Alstom 145kV | 2 |
| Alstom 345kV | 2 |
| BBC 245kV | 1 |
| BBC 550kV | 1 |
| Hitachi 550kV | 1 |
| ITE 145 | 1 |
| ITE 245kV | 4 |
| ITE 345kV | 3 |
| Westinghouse 245kV | 2 |

*Table 1: North American GIS renewal projects involving GIS replacement performed by Mitsubishi Electric Power Products, Inc.*

We trust that the guidance we provide here will help you plan and execute all phases of your next transmission station renewal using GIS.

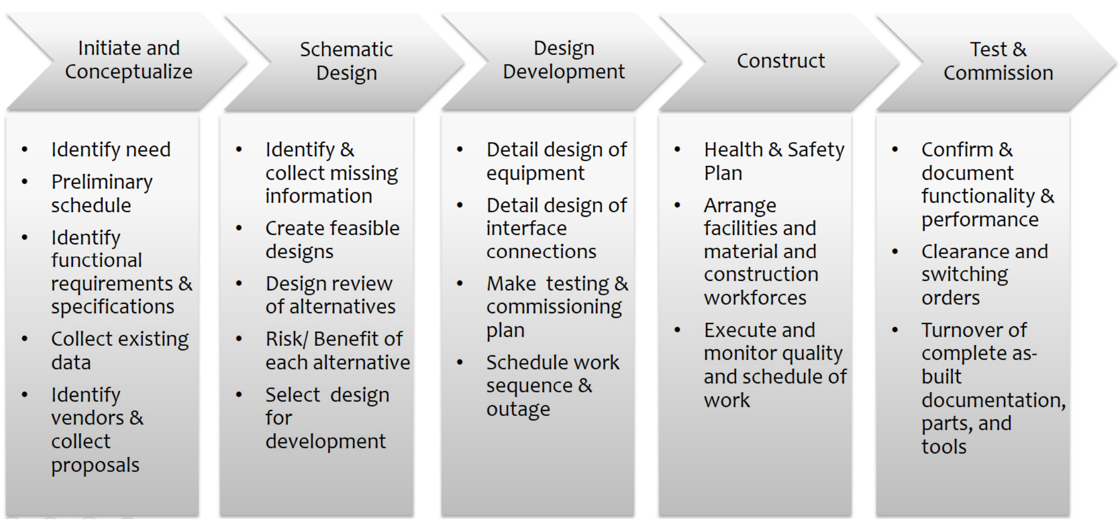


*Figure 1- Project phase diagram*

We will focus on the following basic concerns faced on each project of this kind: documenting existing conditions and visualizing new equipment design, interfacing to existing GIS, maintaining dielectric capability and safety when working with SF6 filled compartments, outage concerns, and high voltage testing concerns.

## Documenting existing conditions and visualizing new equipment design

As-built equipment layout or "physical" drawing records are a convenient starting point for initial designs. However, developing a complete picture of surrounding equipment like equipment platforms, control cable raceways, and any existing adjacent structures is equally useful. The chance of finding reliable dimensioned drawings with these data is very unlikely. Fortunately advances in surveying tools allows for the complete 3D mapping of the primary equipment and all surrounding structures of the substation area in a single day. These 3D survey data consists of millions of accurately place points in a point cloud that represents all these structures (enabling location to better than 3mm (1/8 inch)). These point cloud data can be directly imported into the CAD model for the new equipment to visualize and plan the new construction. Also with these CAD models, critical dimensions such as phase-phase and phase-to-ground clearances are easily confirmed, even to the existing station structures and conductors.

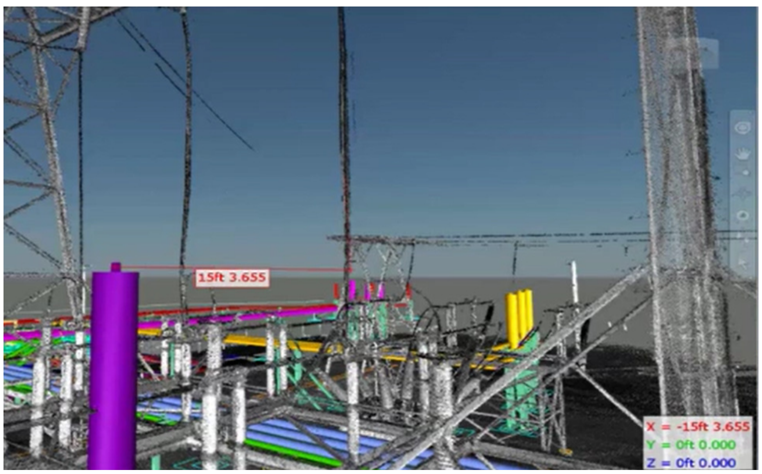


*Figure 2-Measuring clearances from designed GIS to existing conductors*

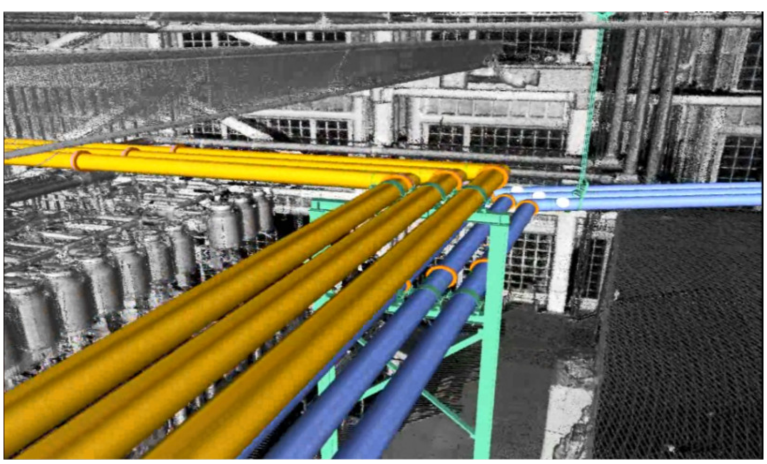

*Figure 3-Model of new gas insulate bus through existing substation interference check*

Once the design is modeled for both the existing equipment and the new equipment the replacement plan can be easily seen, material movement logistics can also be established. During equipment removal, existing material is often cut into smaller pieces to facilitate removal. However, proper planning for the new equipment shipping dimensions may need to consider certain physical constraints of the workspace. This was the case of one of our recent GIS installations near Boston, MA. The circuit breaker positions had to be broken down from their factory-tested size to a size that would fit through the small hatch available in the substation and then reassembled. Identifying these sorts of limitations in the existing facility will allow the proper design. Similarly, the capacity of the lifting equipment will set the constraints for the mass of the single shipping unit in an existing station.

*Figure 4-Lifting GIS breaker unit through floor hatch*

*Figure 5-Reassembling breaker position in the final position*

## Interfacing

During the renewal installation there is often a need to have new equipment connected to the old equipment to allow for the least amount of disruption to the transmission system. Establishing this interface is one of the most critical planning steps. These interface points at the GIS flanges have to be located very accurately, within 2 mm. Often times the design of this interface is straightforward when details of a flange and conductor interface is known; we can simply design and make the mating parts. Industry standards such as IEEE Std. C37.122.6, *IEEE Recommended Practice for the Interface of New Gas-Insulated Equipment in Existing Gas-Insulated Substations Rated above 52 kV,* offer complete guidance on the data that is necessary to collect to design these interfaces to existing GIS. However, sometimes these data are not available on existing drawings. So what do we do in these cases? Perhaps the same parts or mating parts are available in crates as spares. If they are, measurements of these parts may provide the required data. In other cases, an outage is necessary to disassemble the existing equipment to make the required measurements. Another option when the conductor detail is well known is to cut into the existing bus and field weld a new flange to mate to the new gas insulated bus. When cutting the bus enclosure the utmost care and proper cutting tools are used (a pipe cutter, not saw) so that particles are not introduced in to the bus. It is possible, and preferred to make this new flange and conductor adapter in such that when the replacement is complete none of the old parts remain but only new. This temporary adapter is discarded along with the other old equipment.

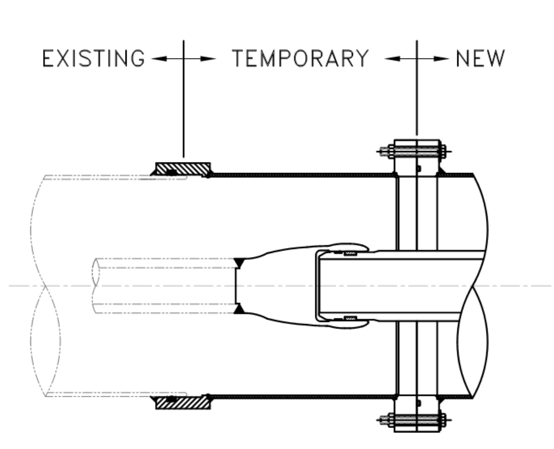


*Figure 6-Field welded temporary interface piece*

**Maintaining Dielectric Capability and Safety when working with SF6 filled components**

Planning of the most appropriate interface location involves examining the physical flange design and also the gas system design. When the gas system is understood an evaluation of the parts which will become nonfunctional when the insulating gas is removed can be made. The gas system or gas schematic diagram is the drawing that describes how the devices are divided into different gas compartments. This must be related to the physical equipment and the locations for these gas barrier insulators must be established. This is because safety must be established in two areas: worker protection from electrical hazards and worker protection from physical hazards. To protect from electrical hazards the work areas must be isolated and grounded. The bus conductor in gas insulated switchgear is typically not accessible, therefore maintenance ground switches are provided to ground those conductors which can be isolated but are not accessible. The grounding function does not require an insulating gas for its operation but the isolation function does require that the isolating device have sufficient dielectric capability. The dielectric capability of a GIS disconnect switch or isolation link is only available when the pressure of the gas compartment containing this isolation device is above its minimum functional pressure.

Safety precautions and rules are used to prevent any injuries to a worker that could be caused by the rupture of a pressurized gas barrier. A gas barrier can rupture when it is significantly stressed or impacted (like that caused by a drop of a tool). To protect the worker, typically not more than one-half an atmosphere of pressure is allowed on the opposite side of a gas barrier which is in close proximity to the work.

A diagram of the outages required because of these electrical and physical safety rules can be seen below. The outage caused by these physical safety rules for pressurized compartments, particularly those cause by the partially filled gas compartments in *figure 7,* often are overlooked by those without experience.

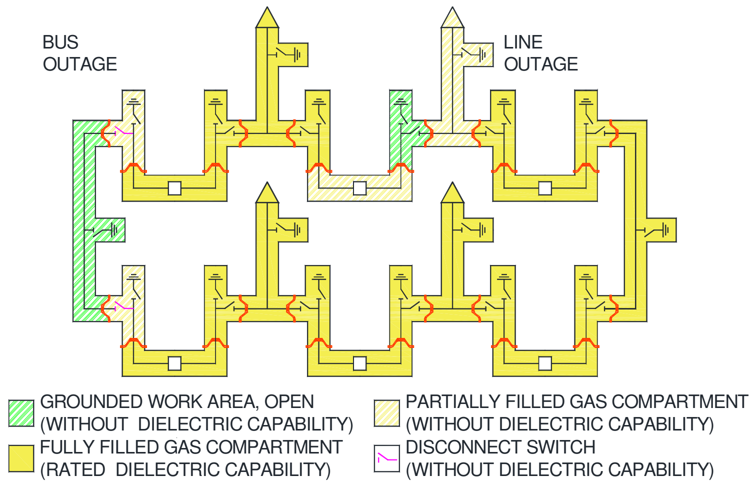


*Figure 7-Diagram showing outage areas required for work*

## Outage planning

Typically, outages on the transmission system have to be scheduled months in advance and usually when load is lower. For example in the Northeast United States where there is a high summer and winter peak power demand outages are usually scheduled during the spring or fall months.

Pre-outage work includes assembling and staging all required parts and work crews, construction and test equipment and facilities, and planning the step-by-step sequence of events onto the schedule. The durations needed to reclaim and fill SF6 gas must also be included in the planning. Effective risk management often includes planning for restoration of service until such time that there is an irreversible modification to the existing equipment or when proceeding with the replacement work is less risk and less time duration than reverting to the previous configuration.

## High Voltage Test Level and Testing Point

GIS standards recommend the field high voltage withstand test be performed at 80% of the low frequency high voltage withstand test level specified for the routine factory test. However, there are conditions where users would be concerned that this level would overstress existing GIS equipment, especially when the equipment is quite old. In these cases the equipment owner will usually recommend that the existing GIS be tested a lower voltage. One of our recent projects it was agreed to use a voltage of only 60% of the standard factory test voltage when the test included portions of the old switchgear. The area of these sorts of reduced voltage tests should be limited to the smallest amount of bus possible. Other new buses that can be isolated from the existing equipment should follow the standard test values. The design of the new equipment can plan for testing from locations that will be most convenient for applying the test. These test points can also be located to minimize outages required to perform the high voltage withstand test. The reason that there may be outages required for testing is due to the fact that the GIS disconnects or isolating links are not designed to isolate with system voltage on one side of the gap and test voltage on the opposite side of the gap. Standards recommend that two isolation gaps be provided between the system voltage and the test voltage and that bus between the gaps be grounded.

## Conclusion

As the GIS equipment infrastructure ages we will be faced with the challenge of renewing these stations. Equipped with lessons learned from experience, we can confidently plan, design, execute and manage these renewal projects in way that expands or extends the reliable performance and has minimal impacts on electric service continuity.