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B3-118

CIGRE 2014

115 kV GIS Design Criteria Considering Service Continuity

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Abstract

Nowadays, the electric power industry is fundamentally driven by the increased demand for electricity. The growth in the use of electrical appliances in industrialized countries leads to the need for a new construction or uprate of the transmission lines and substations. Substations, the backbones of the power supply, are designed based on the factors such as size, location, service behavior, efficiency and availability of the substation. Whether the substation is newly constructed or renovated from the existing one, it depends on the following aspects which are technical, economic and environmental perspectives.

Recently, Gas Insulated Substation (GIS) has gained more and more attention from the utilities due to its high availability. Since the electrical equipment is gas insulated and hermetically sealed, the impact of contamination leading to failure is significantly low and thus the maintenance schedule can be prolonged. As a result, GIS is advantageous in terms of long-term operational and maintenance costs. Another important and attractive feature of GIS is its compact dimension. With GIS, the space required for construction and installation can significantly be reduced, half of that required for Air Insulated Substation (AIS). This leads to a feasible solution for the renovation of an aged substation with limited space. Typical GIS design of the manufacturer may not fulfill all design criteria set by the utilities. Consequently, it has to be properly customized.

For EGAT design criteria, GIS should be designed to maximize the service continuity and personnel safety during both normal operating and maintenance conditions. During maintenance, the service continuity of GIS can be interrupted. The maintenance procedure for GIS is much more complicated compared to that of AIS. It includes gas work, procedures for dismantling the equipment to be inspected, and high-voltage test prior to re-energization. Therefore, an inappropriate design of GIS can cause danger to the personnel as well as inconvenience and a long shutdown period during maintenance.

This paper presents the design criteria for EGAT's 115 kV GIS to meet the maximum service continuity. For this purpose engineering, installation and maintenance perspectives as well as standard products are taken into account during design. The example and related discussion presented here are based on the actual design study for EGAT's 115 kV GIS. In summary, to improve the service continuity of GIS, the proposed GIS design requires additional gas buffer compartments and disconnecting switches for bus separation. The addition of gas buffer compartments has two main purposes. First, it serves as a safety barrier during the maintenance so that the bays adjacent to the affected bay do not have to be de-energized. The other is to enable future extension for GIS without interruption of power supply. The additional disconnecting switches installed at the main bus are mainly used to sectionalize the GIS into subsections during the high-voltage test prior to re-energization. Only the subsection where the high-voltage test is applied has to be de-energized, while the others are unaffected, i.e. they can still be energized at system voltage.

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1. Introduction

Nowadays, electricity has become one of the fundamental needs and an essential driver for the ecomomic growth in both business and industrial sectors. Therefore, this raises a requirement for a reliable and secure electrical transmission system, i.e. capable of supplying and transmitting electrical power with good service continuity and minimum interruption. There are several reinforcement methods for the transmission system. One of them, i.e. the use of Gas Insulated Substation (GIS) will be discussed in details in this paper. GIS can offer high reliability due to the fact that the electrical components are completely encapsulated in the gas tanks. They can be almost perfectly protected from harsh environment, e.g. heat, humidity, high pollution, etc. This results in a low failure rate of the equipment and a long operational life-time. Hence, utilities or owners can radically reduce operation and maintenance costs.

This paper is organized in the following sequences. Section 2 presents a current status of GIS in EGAT including its roles and applications. Section 3 provides a detailed description of service continuity and Maintenance Repair & Extension (MRE) concepts and elaborates how EGAT adopts and integrates them into its new GIS design. Section 4 presents a GIS project which applies the new GIS design concept. Finally, conclusions are given in Section 5.

2. EGAT's GIS

As of 2013, EGAT has nearly 300 substations at the voltage level ranging from 115kV to 500kV, 23 of which are GIS. A number of GIS projects are in execution. The main advantage of GIS is its high reliability, and compactness. The latter is a crucial factor that makes GIS become a common solution to the limited construction space. Finding a land for contructing a substation is very difficult particularly in urban and suburb areas. Moreover, people nowadays have strong environmental concerns, i.e. using a large area for constructing a substation may not be acceptable. This constraint really poses a challenge to EGAT and brings about a need for GIS to be applied for both construction of a new substation with limited space and renovation of an aged substation.

3. Service Continuity and MRE Concept

To ensure efficient and reliable use of GIS, the service continuity should be considered in the engineering design. Unlike an air-insulated substation (AIS), the procedures for the maintenance of GIS are more complicated as they include gas work, dismantling compartments for the equipment to be inspected or repair, and dielectric test prior to re-energization. An inappropriate design of GIS can cause danger to personnel as well as inconvenience and a long shutdown time during maintenance. Hence, it is important for the engineering and maintenance staffs to work closely in order to finalize the design that satisfies the requirements from both parties.

3.1. Maintenance Repair and Extension, MRE Concept

The MRE concept is described in Annex F of IEC62271-203 Edition2 Year 2011-09 standard [1]. It provides a guideline and good references for maintenance, repair, and extension of GIS. The procedures associated with these activities may affect the service continuity of GIS. These procedures depend on the maintenance protocol which varies from utilities to utilities. Strict protocols can pose a significant impact on the service continuity. For instance, during repair, to access the equipment to be repaired, it is necessary to de-gas the gas compartment containing the equipment to be dismantled for repair to an atmospheric pressure, and lower the adjacent gas compartments to a reduced pressure. It should be ensured that when at reduced pressure condition, the equipment within the reduced pressure compartment will be taken out of service to avoid a risk of internal flashover when energizing at the system voltage.

Another maintenance procedure that can adversely affect the service continuity of the GIS is the dielectric test. Generally, the test voltage is almost twice as high as the system voltage. Attention should be paid to the disconnecting switch as it cannot withstand the voltage difference between its terminals when one is at the system voltage and the other is at the test voltage. With this regard, a general rule for the test procedure is that there shall be two gaps between the test and system voltages and grounding between the gaps as shown in Fig. 1.

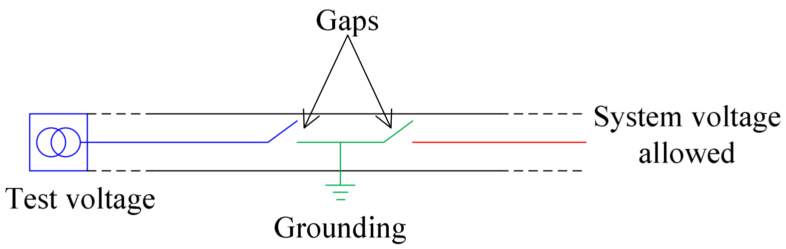

Fig. 1 Gap and grounding requirement for dielectric test

3.2. Approaches for improving the GIS service continuity during maintenance and extension

This subsection elaborates several design approaches for improving the service continuity of GIS focusing on GIS with Double-bus-single breaker bus scheme. There are several design approaches to mitigate the service interruption, e.g. a passive bus design, addition of the partitions, addition of the isolating links, etc. They will be described in the following.

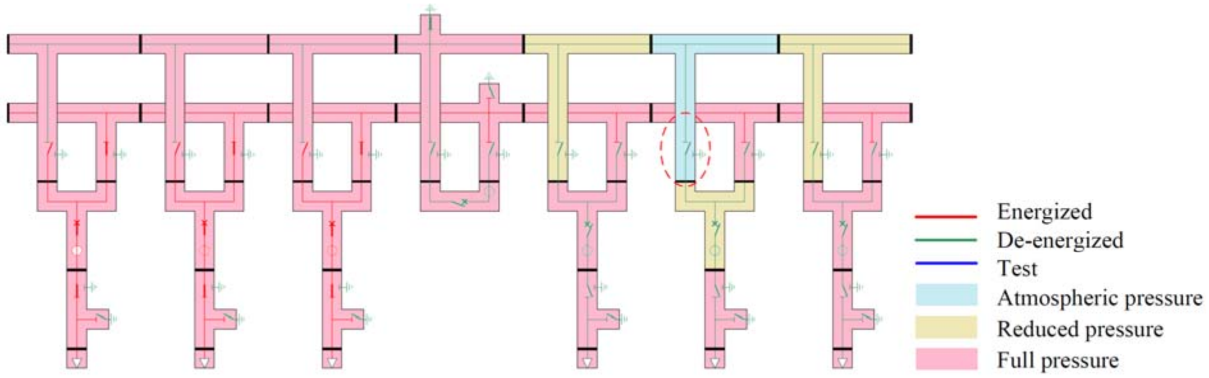

Fig. 2 Service interruption of a typical GIS design when dismantling a busbar disconnecting switch

Figure 2 shows how the service is interrupted for a typical GIS design when dismantling a busbar disconnecting switch. To access the busbar disconnecting switch, the pressure of the gas compartment containing the busbar disconnecting switch is lowered to an atmospheric pressure as indicated in blue in Fig. 2. For EGAT maintenance protocol [2,3], for safety reasons, the pressure of the adjacent gas compartments is also lowered to a reduced pressure as indicated in yellow in Fig. 2. It should be noted that the adjacent feeders have to be shutdown; otherwise, one terminal of the disconnecting switch in the gas compartment with reduced pressure has to withstand the system voltage ; hence, a risk of internal flashover.

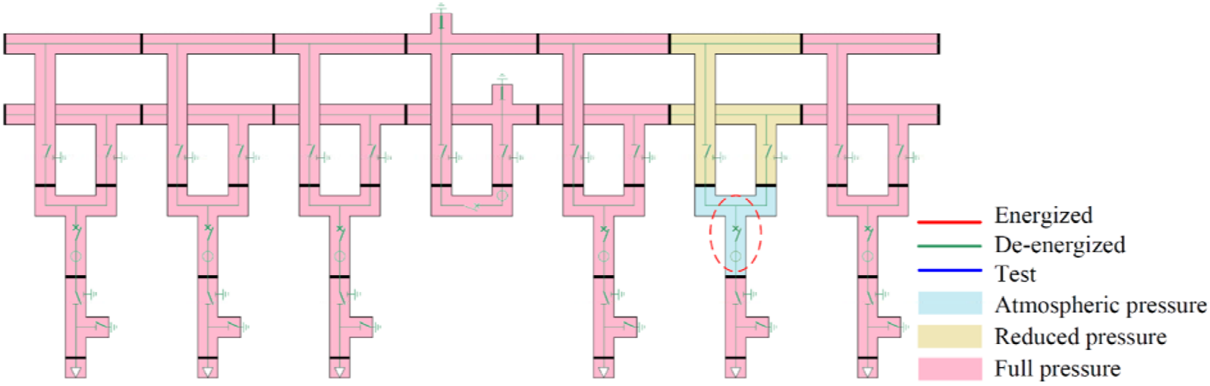

Fig.3 Service interruption of a typical GIS design when dismantling a circuit breaker

A more severe case is depicted in Fig. 3 when dismantling a circuit breaker. With the same dismantling procedure applied, both busbars have to be de-energized; hence, this causes the entire substation to be out of service.

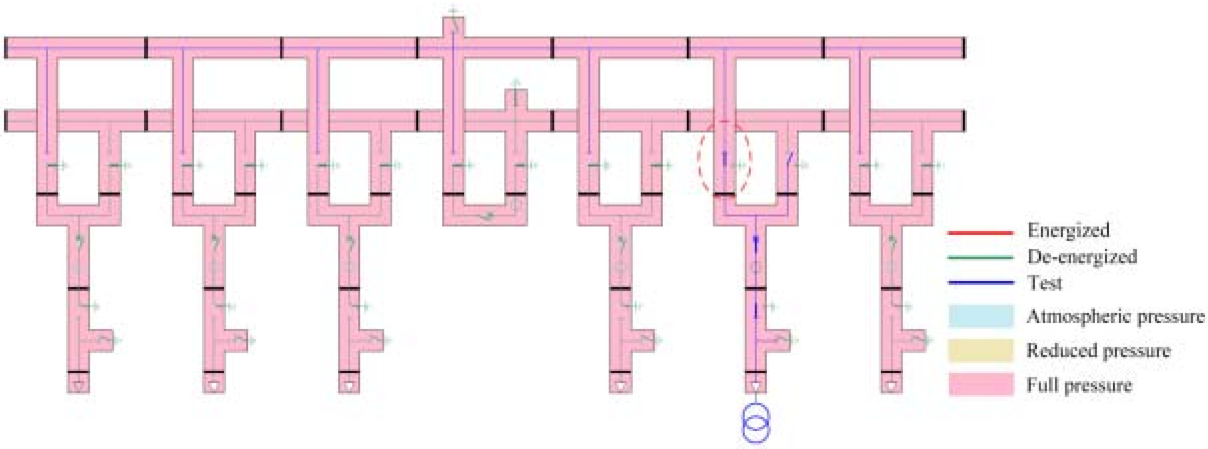

Fig. 4 Service interruption of a typical GIS design during dielectric test

A typical GIS design also encounters an interruption during dielectric test. Figure 4 shows a dielectric test for the busbar disconnecting switch in CLOSE position. It is clear from Fig. 4 that it is not possible for a typical GIS design to meet the gap and grounding requirement, i.e. causing a shutdown of the entire substation. Although the test usually takes 3 hours to complete (including the set-up), such interruption should be avoided in the critical areas where the entire substation shutdown is not permitted.

The passive bus design is achieved by separating the gas compartment of the busbar from that of the busbar disconnecting switch, i.e. by means of adding partitions. The passive bus design helps avoid the interruption during dismantling as shown in Fig. 5. This is possible because the gas compartments of the adjacent feeders are still at the rated pressure; hence, the equipment within can withstand the system voltage.

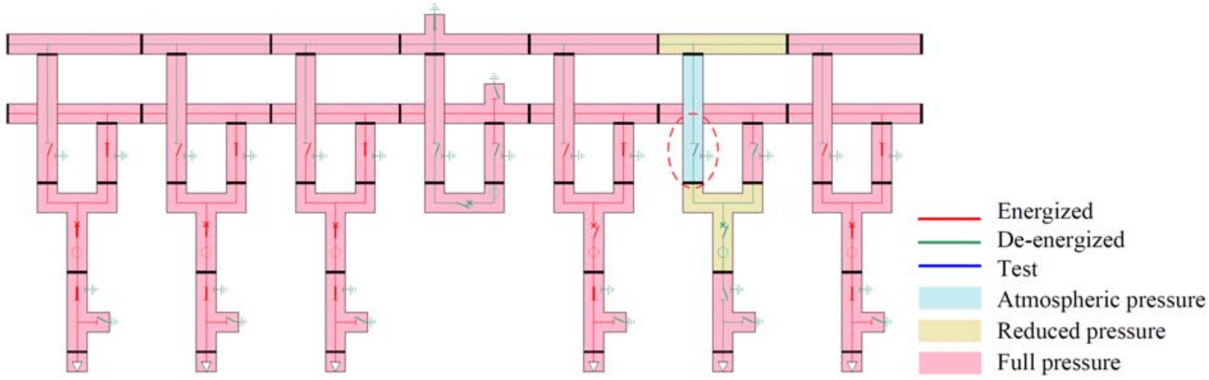

Fig.5 Passive bus design during repair

However, the passive bus design is not useful during dielectric test. As depicted in Fig. 6, the entire substation has to be out of service because it is not possible to meet the gap and grounding requirement. It is important to note that the passive bus design for the 115 kV GIS may not be possible for some manufacturers. Thus, the passive bus design seems not to be the best solution for EGAT.

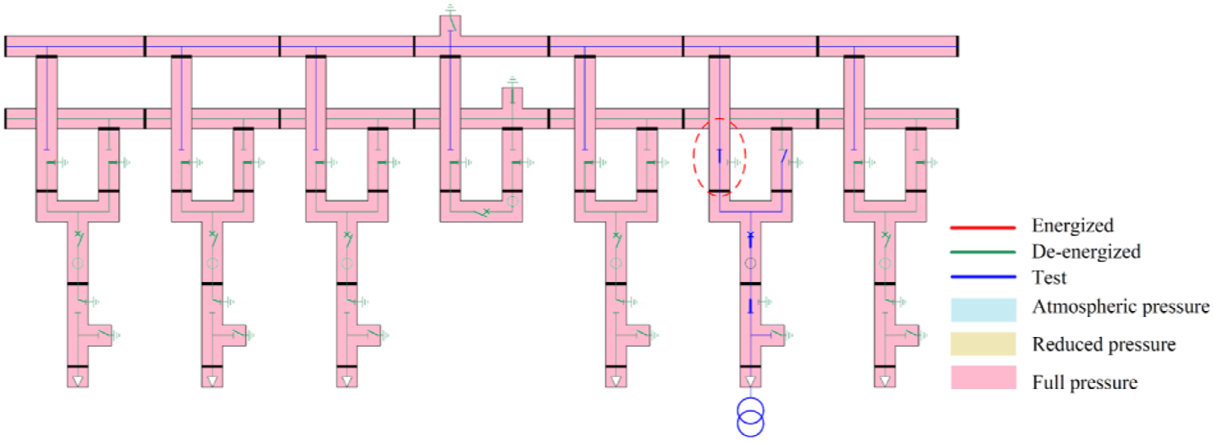

Fig. 6 Passive bus design during dielectric test

Another mitigation technique to reduce the interruption during repair is the addition of gas buffer compartment. It is simply formed by partitions. These additional partitions are common to most manufacturers and do not cause any significant change to the GIS design. Figure 7 illustrates the suitable location to insert the gas buffer compartments and how they work to increase the service continuity. With the gas buffer compartments inserted between the bays and behind the busbar disconnecting switches, it is possible to dismantle the busbar disconnecting switch without the interruption. The reduced pressure compartments are confined to these buffers, making it possible to keep the adjacent feeders in service.

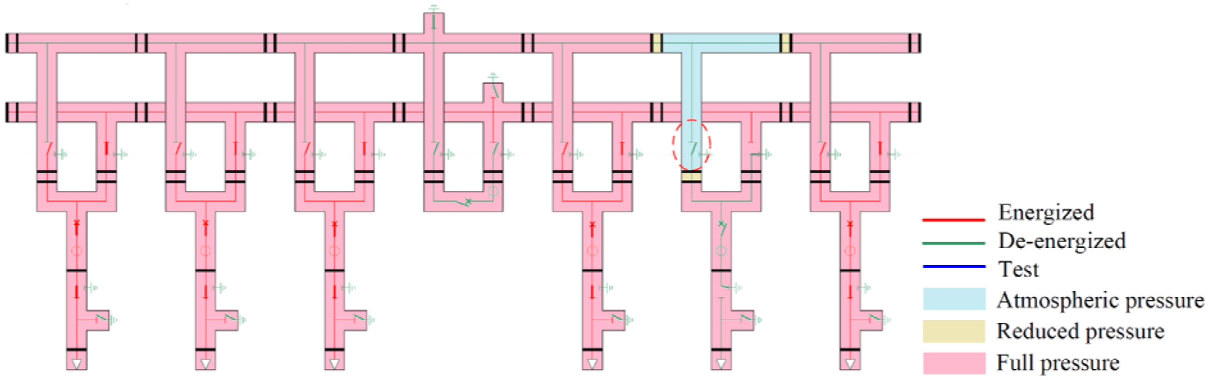

Fig. 7 GIS with gas buffer compartment during repair

Nevertheless, the gas buffer compartment is not useful during dielectric test in case of the failure of the disconnecting switch and/or the circuit breaker. All feeders still have to be shutdown as shown in Fig. 8. Therefore, the design concept to add only the gas buffer compartments is applicable for a substation in which an entire substation shutdown for a short time is acceptable, but not for an important substation where high reliability is required.

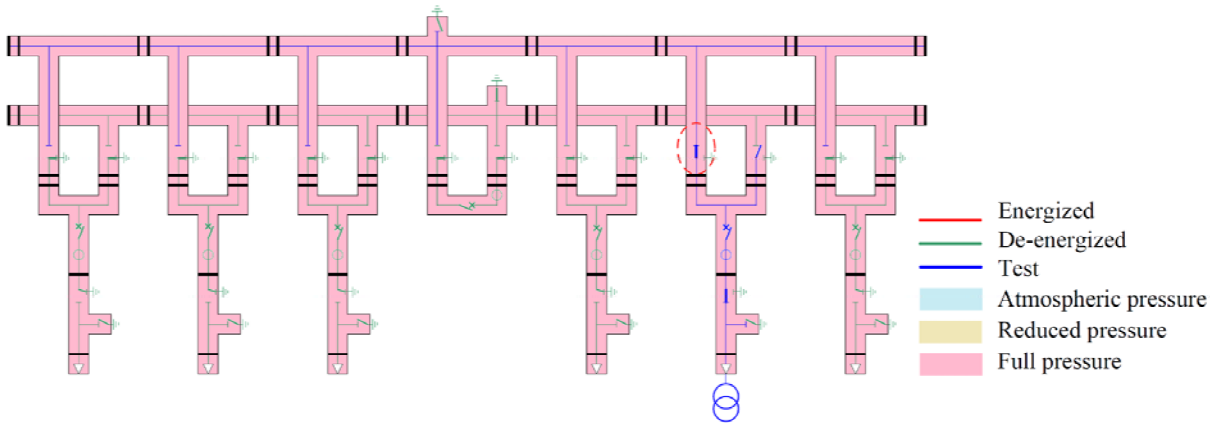

Fig. 8 GIS with gas buffer compartments during dielectric test

It can be seen so far that the main problem during dielectric test is a lack of required gaps and grounding. Therefore, this calls for additional gaps to be put into GIS at the right location that helps reduce the service interruption. After meticulously reviewed, the suitable location for the additional gap is at the middle of the busbars as depicted in Fig. 9. For this purpose, the disconnecting switch is used to provide the required gap and sectionalize the substation into two sections. It is evident from Fig. 9 that during the dielectric test, all feeders in the section of the affected bay have to be shutdown while those in the other section remain in service. For EGAT, the transmission system is designed with N-1 criterion. The shutdown of one section of a substation does not affect the system operation because the other section has an adequate capacity to handle the same amount of power. This GIS design option is applied to an important substation.

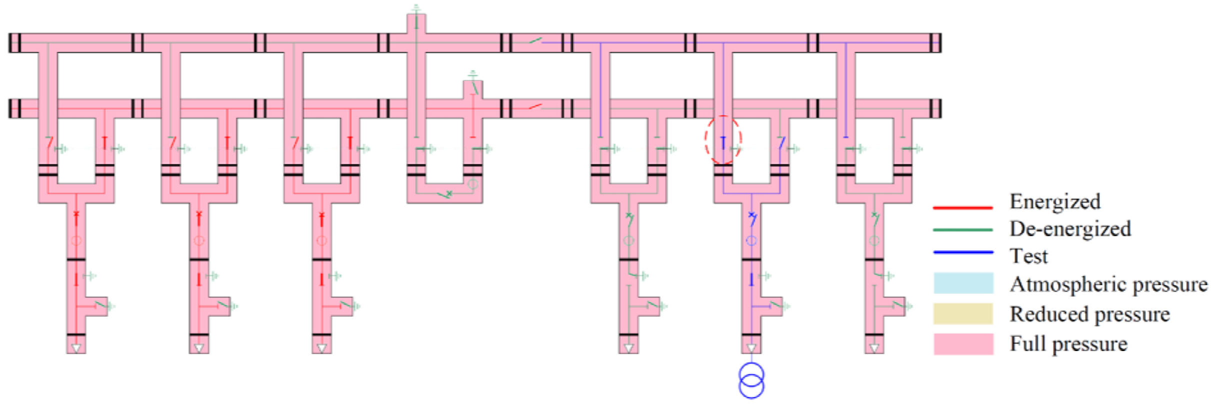

Fig. 9 Gap provided by the busbar sectionalizing disconnecting switch

Another important consideration to be taken is the future extension. Although it should be well known from the system planning study, the long life cycle of GIS, typically 40–50 years, seems so far in the future that there will be a high degree of uncertainty. In the past design, the service of the bay adjacent to the extension point has to be interrupted during connecting the new bay to the existing GIS. Therefore, the interruption is minimized by the addition of gas buffer compartments at the ends of the GIS busbars. Figure 10 shows how these additional gas buffer compartments help provide a buffer during busbar extension, as a result, the adjacent bay can be at the rated pressure and remain in service. Moreover, the dielectric test shall be performed on the new bay separately before connecting to the existing GIS. This is acceptable because there is no switching equipment directly connected at the extension points.

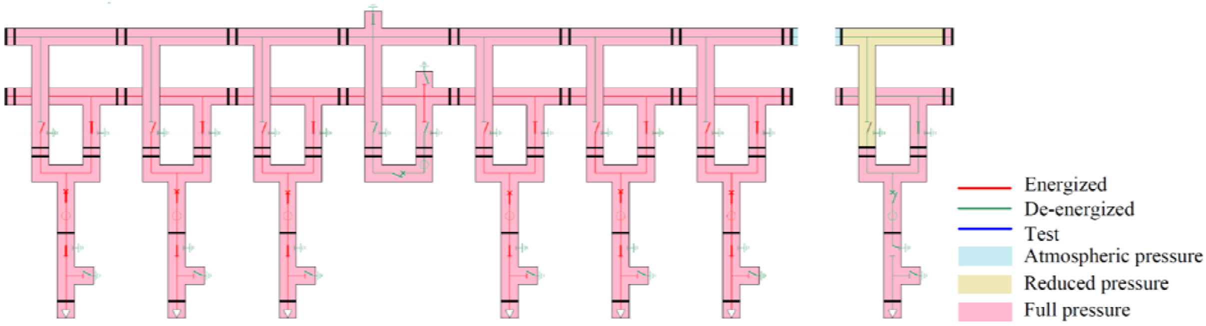

Fig. 10 Additional gas buffer compartment at the ends of the busbars used for extension

3.3. Service Continuity Criteria for EGAT's GIS

In general, the service continuity of GIS depends on several factors, i.e. a single-line diagram (i.e. substation design), GIS designs, e.g. a passive bus design, the use of partitions to form a gas buffer compartment as previously mentioned. Considering them all together would result in too many combinations, some of which may not be applicable for some GIS manufacturers. As a result, it is more reasonable and convenient to state what EGAT requires through a set of service continuity criteria. These criteria are a result of close discussion among several related departments and GIS manufacturers in order to ensure that these criteria are reasonable, practical and clearly reflect the requirements. The service continuity criteria for Double-bus-single-breaker bus scheme GIS are summarized in Table 1.

Table 1 EGAT's service continuity criteria for Double-bus-single-breaker (DB-SB) GIS

<table>
<tr><td colspan="3">Repair state</td></tr>
<tr><td>-</td><td>Busbar disconnector (Busbar DS)</td><td>Only the affected feeder and the busbar to which the affected busbar DS is connected can be shutdown.
The other bays (including those adjacent to the affected bay) shall still be energized.</td></tr>
<tr><td>-</td><td>Circuit breaker</td><td>Only the affected feeder can be shutdown.
Both busbars shall still be energized.</td></tr>
<tr><td>-</td><td>Current transformer</td><td>Only the affected feeder can be shutdown.
Both busbars shall still be energized.</td></tr>
<tr><td>-</td><td>Earthing switch next to the busbar DS</td><td>Only the affected feeder and one bus-bar (in case of internal fault) can be shutdown.</td></tr>
<tr><td>-</td><td colspan="2">In case that any other equipment in the bay fails, only the affected bay can be shutdown.</td></tr>
<tr><td colspan="3">Dielectric test</td></tr>
<tr><td colspan="3">Both busbars in the section* where the affected equipment is can be shutdown.
All feeders in the other sections shall still be energized.

* The DB-SB GIS substation shall be sectionalized by DS as shown in the single-line diagram.</td></tr>
<tr><td colspan="3">Extension</td></tr>
<tr><td>-</td><td colspan="2">The gas buffer compartment shall be provided at the end of each bus in order to maintain the service continuity of the bays adjacent to the extension point during busbar connection.
All the existing feeders shall still be energized.</td></tr>
<tr><td>-</td><td colspan="2">The additional bays shall be tested separately before connecting to the existing GIS.</td></tr>
</table>

4. First EGAT 115kV GIS Designed with Sevice Continuity Critria

This section presents the first 115kV GIS, Hua Wai substation, which is implemented with EGAT service continuity criteria. The substation is located in Nakhon Sawan province, and has a total of 5 feeders. The single line diagram is depicted in Fig. 12, which is similar to that of Fig. 7.

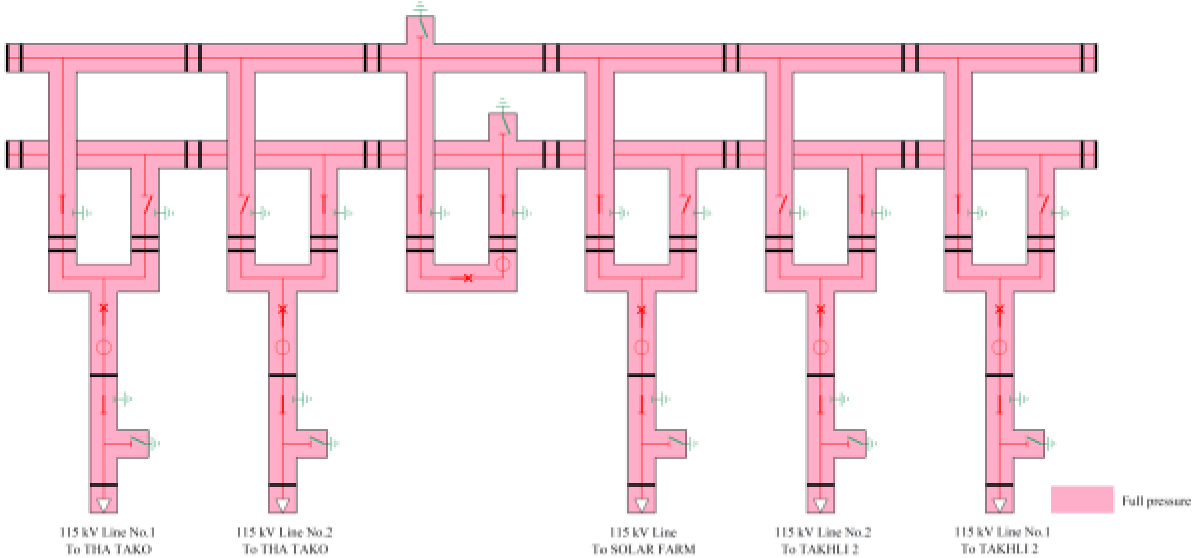

Fig. 12 Hua Wai 115kV GIS single line diagram

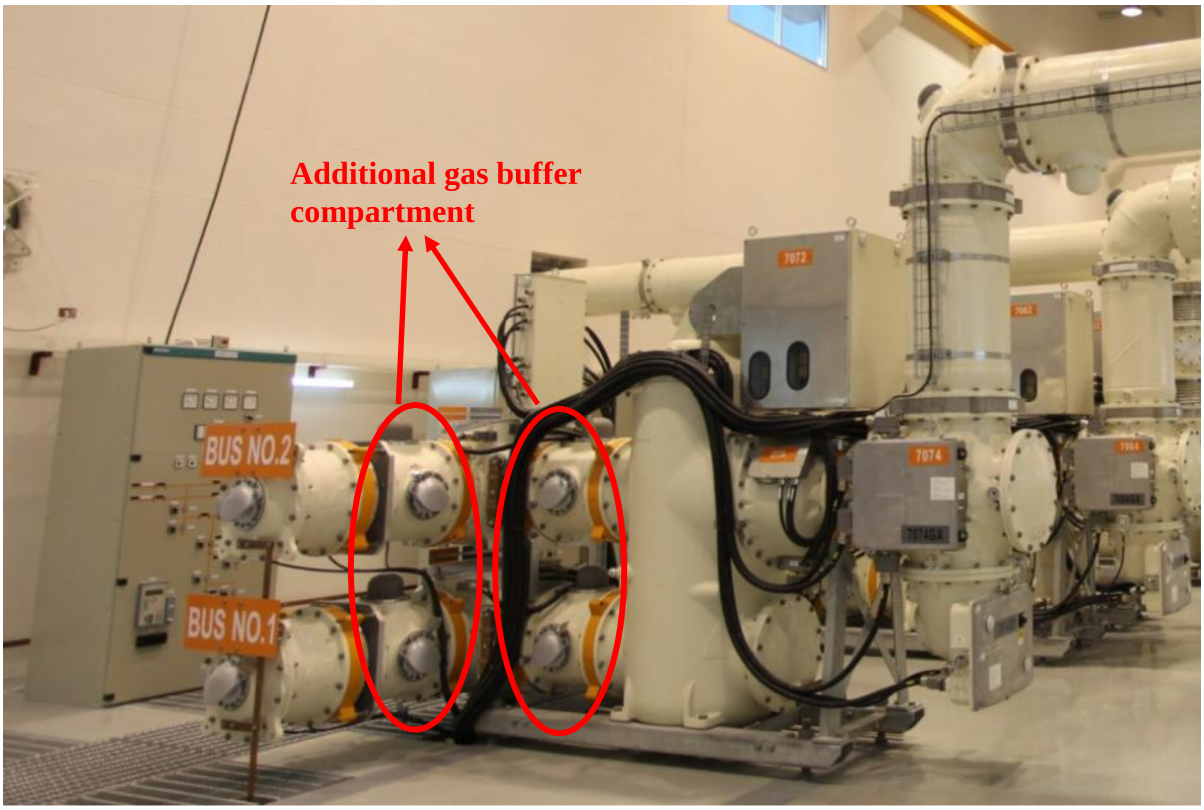

Fig.13 115kV GIS Hua Wai substation

The gas buffer compartments are installed between busbar disconnecting switch and circuit breaker and at the both ends of the main bus, as shown in Fig.13.

5. Conclusions

In summary, to improve the service continuity of GIS, the proposed GIS design requires additional gas buffer compartments and disconnecting switches for bus sectionalization. The addition of gas buffer compartments has two main purposes. First, it serves as a safety barrier during the maintenance so that the bays adjacent to the affected bay do not have to be de-energized. The other is to enable future extension for GIS without interruption of power supply. The additional disconnecting switches installed at the main bus are mainly used to sectionalize the GIS into subsections during the dielectric test prior to re-energization. Only the subsection where the dielectric test is applied has to be de-energized, while the others are unaffected, i.e. they can still be energized at system voltage. Moreover, the service continuity criteria for EGAT were thoroughly specified to communicate with the GIS manufacturers in fair, clear, and flexible manners, allowing them to optimize their designs, and fulfilling the requirements.

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