Improvement of service continuity in GIS while considering health and safety aspects

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Abstract

Résumé:
This paper gives an overview of the constraints that exist with GIS technology during any maintenance, repair or extension activity and their possible consequences on the service continuity. It is detailing the safety rules that GE Grid Solutions has adopted. It also details the optimum technical solution developed by GE Grid Solutions and called maintenance isolating device (MID), consisting of additional insulating gaps inside the GIS arrangement. Benefits that this solution provides during the lifetime of the substation are detailed, together with some examples of projects delivered with this feature.

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Improvement of service continuity in GIS while considering health and safety aspects Arnaud Ficheux, Bertrand Portal GE Grid Solutions SAS High Voltage Switchgear - GIS Aix-les-Bains, France arnaud.ficheux@ge.com Abstract— This paper gives an overview of the constraints that exist with GIS technology during any maintenance, repair or extension activity and their possible consequences on the service continuity. It is detailing the safety rules that GE Grid Solutions has adopted. It also details the optimum technical solution developed by GE Grid Solutions and called maintenance isolating device (MID), consisting of additional insulating gaps inside the GIS arrangement. Benefits that this solution provides during the lifetime of the substation are detailed, together with some examples of projects delivered with this feature. Keywords - Gas-insulated substation; GIS; Service continuity; MRE; safety rules; MID; Maintenance-isolating device I. INTRODUCTION Gas-insulated substations (GIS) have now more than 50 years of operation in the world and their use is getting more and more popular for applications where space or environmental constraints are of importance. Compared to air-insulated substations (AIS), GIS have significant advantages on these aspects. Based on return on experience of GIS during decades, when dealing with maintenance or repair and duration of outages, some users consider that AIS technology has some advantages over GIS technology. The compactness of the solution and the pressurized elements are two main factors limiting the flexibility of the GIS during these operations. In the past, this was less considered as high voltage substation and networks
were designed with some significant redundancy and flexibility. Nowadays, the substations are getting more and more critical and operators expect higher level of service continuity on their equipment. This has a direct impact on the design and installation of the GIS equipment. Manufacturers have been working in the past decades on these topics and they come-up with various solutions. IEC standard on GIS 62271-203 [1] has also integrated this aspect during the revision of 2011 with its annex F of edition 2.0. A new revision of this standard is just starting, and it will revisit and clarify the content of this annex. The content will be based on the work also performed at CIGRE level within the new working group WG B3.51 [2] which will review this topic in more details. This paper is reviewing the constraints and solutions adopted for GIS technologies and gives details of the optimum solution for GIS called maintenance isolating device (MID) with some examples of implementation. II. SERVICE CONTINUITY REQUIREMENTS A. General Drivers Several drivers influence the service continuity of a substation (AIS or GIS type) when an unexpected event arise or during any maintenance or extension activity. They can be categorized as following: • Single line diagram: it has a direct impact on service continuity and its choice can be directly influenced by factors like criticality of the substation, redundancy of the critical feeders, segregation of the busbars, impact on the network of the sudden loss of the substation (or part of the substation). • Components: the reliability of the components (like active switching devices) will impact significantly the service continuity and the overall availability of the substation and must be selected with care. • Spare parts: the availability of spare parts influences the service continuity by improving the quick return to service of the faulty components. • Training: this includes all necessary staff training to cope with quick responsiveness and rectification to reenergize the substation with limited disturbances on the network B. Specific GIS drivers For GIS type of substations, additional drivers must be considered. The main ones are the followings: Accessibility: due to the compactness of the GIS arrangement, the service continuity can be impacted by the design arrangement, the space around the equipment to be maintained or repaired. • Gas partitioning: GIS technology is made of an assembly of pressurized enclosures with different switching devices (like circuit-breakers, disconnectors or earthing switches) or passive devices (like instruments transformers, interfaces, surge arresters, busbars, etc). The service continuity is very dependent on the segregation of the different gas zones. Indeed, due to safety issues when working adjacent to pressurised partitions, impact on sections of GIS to be degassed and deenergized can vary. • Strategic spares: GIS components cannot be interchanged as easily as AIS components. It is essential to anticipate the possible replacement of any single GIS component within the shortest period of time, through the a stock of key spare parts • HV tests: it is essential to ensure correct installation and performance of the GIS equipment before it is energised. Performing HV test after completion is the state-of-the-art answer. This can imply outage of several feeders or even the complete substation depending on the initial design of the substation. These additional drivers can impact the service continuity performance of a GIS substation and the acceptance of the technology by the end users. International standards on GIS are now covering most of these aspects. IEC 62271-203 standard is under revision and is preparing a revised Annex F, considering the outcome of the CIGRE Working Group B3.51 which has been established recently. III. GIS CONTRAINTS When designing GIS solutions, the constraints need to be applied by manufacturers and also by users when doing some site activity. The respect of these safety principles in GIS design and in substation engineering allows the site staff to work with confidence, for safe and quick interventions. These principles have been specifically defined by GE Grid Solutions teams. However, they are specific to GE solutions and can be used as a general guide. Details have been given in the paper presented during the CIGRE Nagoya A3-B3 colloquium in 2015 [3]. A summary of these principles is given hereafter. They are also used as background practices by the teams working on CIGRE WG B3.51 and on the revision of Annex F of IEC 62271-203. A. Mechanical constraints Due to the limited mechanical strength of partitions, it is necessary to limit the constraints that can apply on these partitions during any site activity like dismantling and repair. Two kinds of mechanical constraints can be present on these gas partitions: • Stress applied directly on the pressurized gas-barrier. • Risk of mechanical shock on the pressurized gas-barrier. Depending on the design of the GIS and its specific gas partitioning, some working situations are acceptable or permitted while some others are clearly not acceptable and thus forbidden. So far, international standards and guides give only guidance and it is to the GIS manufacturer to define the rules allowing or not such operation and if they are allowed, under which conditions. B. Electrical constraints The electrical constraints have also an impact on outages, and two kinds of electrical constraints need to be considered: • When working on GIS equipment. • When performing HV dielectric tests once works are completed. IV. SAFETY RULES The next principles are now commonly used by GIS manufacturers and are followed by the personnel working on 1 isolating gap in open position Test voltage O Netw ork voltage Overvoltage risks HV test FORBIDDEN the GIS at site. They describe the basic safety rules applied to gas-compartment arrangements. These arrangements are dependent on GIS architecture, gas partitioning, location of partitions, supporting elements and earthing switches. This leads to different levels of maintenance, repair and extension capabilities. These rules must be considered from the early stage of GIS design to optimize service continuity during maintenance, repair or extension actions. Three categories can be defined: • Operations that are forbidden • Operations that are recommended • Operations that are authorized under conditions A. Forbidden operations Where a direct risk of mechanical stress or mechanical shock exists onto a pressurized partition, it must be forbidden to undertake any work directly behind this partition. Two cases of such condition are given in Fig. 1. Fig. 1: Forbidden activities directly behind pressurised partition When performing HV test after repair or extension work, it is forbidden to have only one dielectric gap and no earth connection between the tested section and the section energized, as shown on Fig. 2. The safety of the personnel and the integrity of the GIS and test equipment cannot be ensured. Fig. 2: Forbidden operation during high voltage dielectric tests of GIS B. Recommended operations In order to reduce the risk of working adjacent to a pressurized partition, the recommended solution consists in adding an intermediate mechanical partition between the
pressurized partition and the locations where connection activity needs to take place, as shown on Fig. 3. Fig. 3: Recommended activity thanks to the intermediate partition C. Authorized operations In some specific GIS configurations, it is not always possible to have an intermediate partition. In such case, the intermediate barrier can be a support insulator or a combination of support insulator and electrode (see Fig. 4). This support insulator will withstand the potential stress applied onto the equipment when making the connection (like a partition). However, risk of direct mechanical shock onto the pressurized partition cannot be eliminated. Therefore, site activity behind this intermediate support insulator could be authorized under specific circumstances and provided additional safety precautions are taken on site (like availability of appropriate tools and working conditions, training of operators, etc.). This must be well documented before executing any work. If these conditions are not met, such operation must be forbidden. Intermediate support insulator Atmospheric air pressure AUTHORIZED Fig. 4: Authorized activity thanks to the intermediate support insulator D. Mandatory operations The section of GIS where work is taking place shall be earthed to protect equipment and personnel in case of unexpected event (overvoltage, failure of dielectric gap, wrong operation, etc.). This earth can be applied through a normal earthing switch or through a temporary earth connection, suitably designed. This requirement of dielectric gap and earth connection is illustrated on Fig. 5. Section of GIS isolating gap in open position whereork is performed O Netw ork voltage C 1 earthing switch in closed position MANDATORY Fig. 5: Safety rule while working close to sections of GIS in service After repair or extension of a GIS section, a high voltage dielectric test is required to validate the correct assembly of the newly installed equipment. The safety rule to perform this dielectric test is to have a double isolating gap and an earth switch in between, as illustrated with Fig. 6. 2 isolating gaps in open position Test voltage O O Netw ork voltage C 1 earthing switch in closed position MANDATORY HV test Fig. 6: Mandatory procedure for high voltage dielectric tests of GIS Pressurised partition SF6 filling pressure FORBIDDEN Intermediate partition SF6 reduced pressure OK RECOMMENDED V. SERVICE CONTINUITY LEVELS IN GIS The service continuity is usually determined through the number of feeders that are out of service during any maintenance (M), repair (R) or extension (E) activity. The following definition is not a specific GE Grid Solutions definition and denomination. It has been widely used for setting the MRE levels by different users, manufacturers and consultants worldwide. • MRE 0: all feeders are in service (no impact on the service continuity) • MRE 1: one feeder is out of service (either the feeder impacted by the default or adjacent feeder (in case of extension)) • MRE 2: two adjacent feeders are out of service etc. These levels of service continuity are under review by above mentioned CIGRE working group and IEC maintenance team and will be the basis for further improvements and clarity. VI. MID SOLUTION TO IMPROVE SERVICE CONTINUITY Different solutions exist for optimizing the service continuity. They depend on the voltage level, the product characteristics and the manufacturer choice. But they do not automatically fulfill the same functionalities. A detailed comparison of the following three solutions was given in the CIGRE paper presented at Nagoya A3-B3 colloquium: • “Basic solution”: this is a GIS arrangement which has no specific features to cover this service continuity aspect. This is typical of GIS substations delivered before the years 2000. • “Buffer solution”: it consists in adding additional gas partitions or support insulators between the section where work is taking place and the sections that remain at normal filling pressure • “MID solution”: it stands for Maintenance Isolating Device and it consists in adding dielectric gaps at right locations within the substation (typically in the common point of a double busbar scheme). This paper is focusing more specifically on this solution with the benefits it can provide. When a MID is opened, it creates an isolating gap replacing the function of an adjacent disconnector that had to be degazed to work safely. It is equivalent to a dismantling link, but the main advantage is that it does not require opening of the GIS as it is manually operated from the outside of the GIS. As additional dielectric gaps are created, this solution brings an undoubtedly advantage when performing dielectric tests after repair or extension, as shown on the following Fig. 7. Compared to a basic GIS solution, the change is within the common point compartment with the addition of the two isolating gaps, one common point earthing switch and also one partition in the busbar disconnector. Fig. 7: Service continuity with MID solution during repair (left) and during HV test (right) The next Fig. 8 give a typical layout of this MID in place of the usual T-cross inside the common point compartment. On the left, the MID is in closed-closed position. On the right, the MID is in closed-opened position. Fig. 8: typical arrangement of a MID in the common point Fig. 9 gives a view of a MID arrangement on a 245 kV B105 GIS. The 3-phase MID is visible in the middle, between the two busbar disconnectors. The operation is manually performed, with a special tool placed on top of the upper phase and the 3 phases are operated once, through the linkage visible on the picture. A position indicator gives a clear view of the position of the device and in addition, real position of O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O O
3-phase GIS (fig 10). The technical solution was reviewed with both clients to make sure about it meets their requirements in terms of safety and operational procedures. More than 200 bays of this type of GIS have been implemented in UK with this generation of equipment for different customers. Fig. 10: First MID implemented at 145 kV level – UK At the end of years 2000, the concept was extended to 245 kV level and then to 420 kV level. With the 252 kV B105 GIS, a focus in the development was made towards accessibility and maintainability. The MID was the perfect device to optimize the service continuity during maintenance, repair and extension. The benefit of the additional gap was also seen as crucial to limit outages even during HV tests. This solution was presented and discussed with various users during the GIS Users Group that GE Grid Solutions established in 2008 for close exchange on future technologies to be implement in GIS. One of the early adopters of the MID solution at this voltage level was ESBI in Ireland with the order of the first GIS with this feature in 2009 (Fig. 11). Fig. 11: Double busbar B105 245 kV with MID – Ireland Other utilities adopted this solution like PSE in Poland (Fig. 12) and RTE in France (Fig 13). Fig. 12: Double busbar B105 245 kV with MID – Poland Fig. 13: Double busbar B105 245 kV with MID – France Early 2010, a CIGRE joint working group B3/C1/C2.14 on circuit configuration optimization decided to integrate this MID solution into the technical brochure TB 0585 [4]. Then, the technical solution was applied onto the 420 kV to meet some customer requirements. Again, the early adopters, National Grid (Fig. 14) and Scottish Power (now SPEN) in UK decided to implement the functionality on their 420 kV GIS. Fig. 8: Double busbar T155 420 kV with MID – UK More than 650 bays of GIS have been deployed on various networks in the world using this MID feature (see Table 1) for the most common voltage levels of 145 kV, 245 kV and 420 kV. This demonstrates market adoption of the solution. Albania 145 kV 245 kV 420 kV Total Albania 9 9 Algeria 5 5 Egypt 26 26 Equatorial Guinea 9 9 Finland 6 6 France 76 76 Ireland 46 46 Israel 64 7 71 Morocco 16 16 New Zealand 12 12 Poland 53 53 Russian Federation 7 7 Saudi Arabia 11 11 Senegal 7 7 Spain 13 4 17 Turkey 49 49 United Kingdom 209 26 235 Total 209 344 102 655 Table 1 – references of MID in the world for different voltage levels II. CONCLUSION Service continuity of the GIS is really dependent on the design and precautions (like safety rules) taken by manufacturer to ensure safe operation of the equipment. The user has also to clearly specify the requirements he is expecting on service continuity. This can highly influence the solution proposed by the GIS manufacturer. CIGRE and IEC are working on this topic to better clarify the requirements and the possible solutions. The paper illustrates the service continuity aspect for the replacement of a busbar disconnector in a double busbar scheme substation. The solutions to be provided by GIS manufacturers can be different depending on voltage level and single line diagram schemes. The paper It shows, through the example of the MID (maintenance isolating device), the benefits of the solution to improve the service continuity. This solution is now implemented for some years on many substations REFERENCES [1] IEC 62271-203, High-voltage switchgear and controlgear - Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV [2] CIGRE WG B3.51 Service continuity guide for the maintenance, repair and extension of HV GIS [3] Nagoya 2015, paper 313, "Service continuity of GIS during maintenance, repair or extension activity", A. Ficheux, O. Chuniaud, C. Laurent. [4] CIGRE Technical Brochure 585: “Circuit Configuration Optimization”

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