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Abstract. Electricity represents the main form of energy, necessitating its transmission through the grid's transmission lines to reach various distribution network nodes. In Kosovo, the transmission lines function at voltage levels of 110 kV, 220 kV, and 400 kV, whereas in Europe, certain transmission lines are equipped to handle higher voltage capacities. Furthermore, medium voltage distribution lines operating at 35 kV and 10 kV are dedicated to serving large-scale consumers, while the low voltage distribution system, up to 0.4 kV, is specifically designed to supply power to commercial and residential customers. To meet consumers' electricity consumption demands, appropriate voltage levels, as mentioned above, are established through the use of ascending or descending substations. This paper offers a concise introduction to the Gas Insulated Substation (GIS) system. A GIS is a high voltage substation wherein the primary conducting structures are enclosed within a sealed environment, employing SF_6 (sulfur hexafluoride) gas as the insulating medium. This paper begins by presenting the general characteristics of substations and subsequently delves into the fundamental concepts of GIS systems. Finally, it extensively explores the implementation of the GIS system in SS 110/10(20) kV - Pristina VI, emphasizing its significance and highlighting the distinctions between the GIS and Air Insulated Substation (AIS) systems.

Keywords: Gas Insulated Substation**,** Air Insulated Substation, Sulfur Hexafluoride Gas, Switchgear, Circuit Breaker, Bushings.

1 Introduction

Electricity flows multiple substations at varying voltage levels on its journey from the generating station to the end consumer. Substations can be categorized based on their voltage rating, their roles within the power distribution network, the predominant insulation techniques applied to interconnections, and the architectural design and construction materials employed.

The development of high and extra-high voltage electrical networks has brought about substantial advancements in the design and construction of substations. Electricity demand tends to concentrate in proximity to industrial and urban centers, necessitating the transmission and distribution of energy within regions characterized by spatial constraints. The increase in demand for electricity and growing energy density in metroplolitan cities have made in necessary to extend the existing high voltage network rght up to the consumer. Stepping down the voltage from transmission to the distribution level at the substations lovated near the actual consumers not only yields economic advantages, but also ensures reliable power supply. For this reasons, a new type of switchgear has been developed which, while occupying minimum space, meets all the present day requirements and is also compatibile with the environment [1].

In addition to the transmission lines, the substation comprises essential components such as transformers, switchgears, disconnectors, circuit breakers, and related elements [2].

The dimensions of Air Insulated Substations (AIS) are constrained by the required air insulation distances, prompting the adoption of a solution for enhanced compactness, achieved by utilizing insulating gas within a pressurized enclosure known as Gas Insulated Substation (GIS). Approximately 80 % of the global production of SF_6 gas finds application in Gas Insulated Substations (GIS) and circuit breakers due to its exceptional dielectric strength, capacity for interrupting current, and superior heat transfer characteristics.

In Kosovo, one of the first substations that used this technology is SS 110/10(20) kV, Prishtina VI, which is supplied by 110 kV cable lines.

The paper is structured as follows: GIS System is presented in section 2; GIS Structure is presented in section 3; The Iımplementatıon of the GIS System ın SS 110/10(20) kV - Prishtina VI is presented in section 4; Differences between the GIS System and the AIS System and the importance of the implementation of GIS System are presented in section 5. Finally Conclusions of this paper are summarized in section 6.

2 GIS Ssystem

A GIS is a high-voltage substation in which the main conducting structures are contained within a sealed medium with a dielectric gas known as sulfur hexafluoride gas or SF_6 as the insulating medium. A GIS consist of a metallic enclosure connected to the earth (earthed vessel), a central conductor, solid insulators and gas. Each element is divided into separate gas modules, which modules are installed in the device and ensure tight module integrity [3].

GIS is totally capsuled, that is impervious to and distinguished from the external ambiance. This is a huge benefit from environment viewpoint such as ocean based oil rigs, particle or mist pollution sources. Nevertheless, because the gas isolated switchgear is totally capsuled, a needed visible disconnecting means cannot be directly accomplished. The grounding and disconnect switches, needed in both air and gas insulated arrangements, will have view ports in gas isolated devices [4].

Under normal conditions, the breaker contacts are closed, but when a failure occurs in the electrical system, these contacts separate and an arc occurs between them. The displacement of the mobile contacts is synchronized with that of a valve that allows the entry of high-pressure SF_6 into the chamber where the arc is occurring.

The properties of SF_6 allow the absorption of free electrons in the path of the arc, forming ions that do not carry electrical charge, because they become too heavy. The dielectric strength of the gas increases notably, so the arc is extinguished.

The reasons why we need GIS are [5]:

- GIS has small ground space requirements;
- GIS have easy maintenance (nearly zero Maintenance);
- Less field erection time & less erection cost;
- For Fast Growing Major Cities where land availability is costlier;
- Non-Flammability & Non-Explosive , Oil-free & Less Pollution.

3 GIS Structure

The figure below shows the cross-section of a GIS module for voltage level 110 [kV], where all the construction elements of this system are shown.

The most important devices of GIS structure are as follows:
1. Busbar and grounding disconnector;
2. Circuit breaker;
3. Current transformer;
4. Voltage transformer;
5. Line and the grounding disconnector;
6. The ground-disconnector tester;
7. Cable unit and Bushings;
8. Control Cabinet (local);

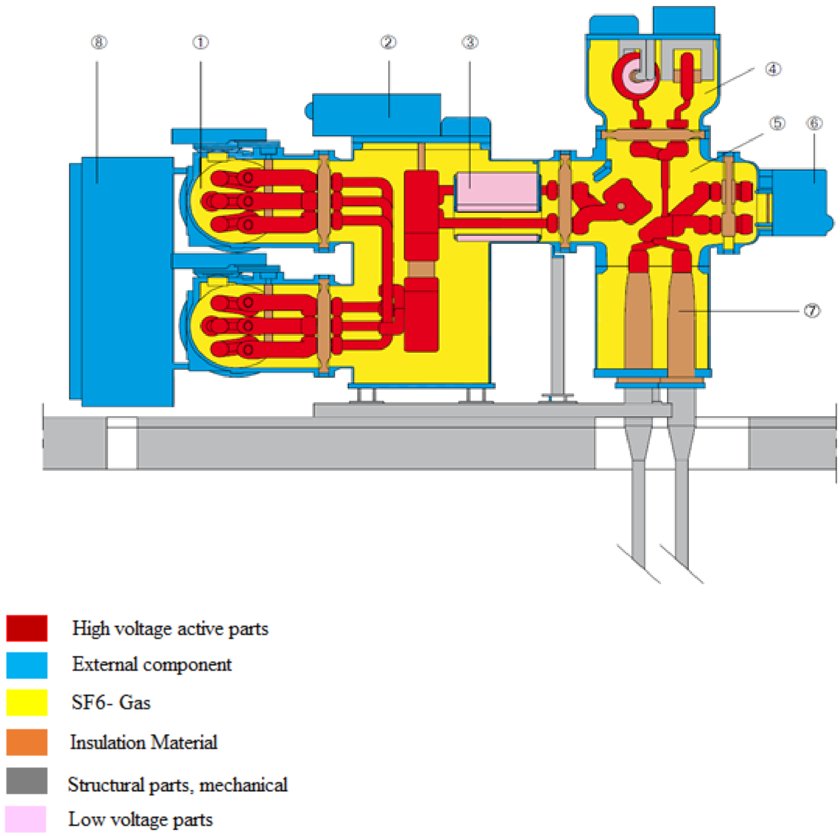

Fig.1. GIS Structure [6]

3.1 Circuit breaker

Circuit breakers are the most important modules of switchgears. Their wide flexibility significantly affects the scope of a design, even to the point of saving the space of complete substations. Basically, ELK-04 circuit breakers are equipped with self-break, with one breaker unit per pole. This unit requires minimal maintenance and also consumes very little energy during the response time of this unit [6].

3.2 The grounding disconnector

Two different types of closed modules are ready to be combined; line and grounding disconnectors in a closed block system. On the part of the busbar disconnector, the module is composed of 3 porcelain or ceramic materials, while on the side of the feeder disconnector, this is composed of 4 porcelain insulators. So these two types of disconnectors are composed of a dielectric, which resists high voltages. However, for maximum safety, these two are equipped with separate control units. So this form ensures safe disconnection and safe grounding [6].

3.3 The ground-disconnector tester

The ground-disconnector tester can effectively and safely pass the short-circuit current. This module can be located in the part of the line disconnector, but also in the part of the busbar disconnector. This module makes it impossible to make errors in the operation of the ground-disconnector. The ground-disconnector tester is equipped with a spring-loaded operating mechanism to ensure very quick switching. The operating mechanism consists of a small electric motor, which contains all the necessary elements competent for a safe mechanical movement as well as electrical interlocking. This tester can also work manually, where its manual operation is possible between the handle which is located near this tester [6].

3.4 Cable unit and Bushings

Any type of cables can be connected to the GIS via the cable connection (termination) unit for XLPE and liquid-filled cables. All cable end units comply with IEC 62271-209 standards. The main elements of cable connections are connecting plugs made of epoxy resins, and pre-manufactured connecting rings made of silicone rubber. An advantage of the GIS block installation is that there is a permanent separation of the part of the switchgears from the cable installation.

Gas-Air bushings allow the transition from the GIS System to the overhead lines or to the transformer. These are characterized by a fiber-reinforced busbar with vulcanized shields, which are made of silicone rubber. These bushings are fail safe, burst resistant and easy to handle.

Fig.2. Cabble terminators qnd Air-Gas Bushings

3.5 Current Transformers and Voltage Transformers

For the purpose of measurement and protection, single-phase current and voltage transformers are used, Sometimes modern three-phase current and voltage sensors are also used. In general, the voltage transformers are located in a single model (or space), separated or part of the line disconnector by an isolated barrier. While the current transformers are integrated or located in the part of the circuit breker. The primary insulation is provided with SF_6 gas for both transformers, i.e. both for the current transformer and for the voltage transformer. While the terminals of the secondary winding are connected to the gap between a box consisting of a multiple disk with bushings [6].

3.6 Control and Monitoring

- **Conventional local control cabinet** - All auxiliary electrical components for control, signal, interconnection etc, are located in separate control cabinet. The main parts of the local control cabinet are:
  - Local operation and visualization of switching status (on and off) by control buttons and position indicators;
  - Protection of the operators and the establishment with the realization of the interconnection functions;
  - Acquisition and visualization of operational measurement values (voltage and current);
  - Visualization and handling of alarms, warnings and operation counters.

- **Digital control and protection** - There are several digital control and protection devices that can be configured according to the desired control and protection philosophy. In the case of digital control technology, the single line diagram with position indicators and control buttons is replaced by a digital interface. Digital control devices provide the same functions as conventional control technology. In addition, many versatile, additional control and protection functions can be implemented, as:
  - Synchronous control;
  - Automatic reclosing;
  - Monitoring of operating frequency;
  - Defect recorder;
  - Backup protection.

Fig.3. Control and monitoring

4 Iımplementatıon of the GIS System ın SS 110/10(20) kV - Prishtina VI

The main reason for the realization of this implementation was the need to improve the quality and reliability of the electricity supply for the commercial center of Pristina, to enable future development and to ensure greater flexibility in the distribution network and to reduce losses in transmission. In general, this program has a number of important benefits, such as:

- Improvement of reliability and quality of supply for the city center;
- The discharging process of transformers within Substations Prishtina I, II, and III.
- Reduction of technical losses in the distribution network;
- Creation of conditions for the advancement of the 10 kV network to the 20 kV voltage level, leading to a significant reduction of additional distribution losses;
- Optimization of power flow in the 110 kV lines, as a result of the discharge of the transformer in the Prishtina I, II and III substations;
- Reduction of large amounts of energy not sent to consumers, as a result of eliminating bottlenecks in the distribution network and reducing the frequency of faults in cables and transformers.

This project follows the M2 road south from the substation location, before heading east through a mixed area of open terrain and residential buildings to the SS 220/110 kV - Prishtina IV. This project aimed to install 110 kV energy cable lines to connect SS 220/110 kV - Prishtina IV with NS 110/10(20) kV – Pristina VI. The cables are XLPE insulated and are suitable for operation at the specified guaranteed continuous rate during all seasons of the year. The nominal system voltage is 110 kV with a maximum system voltage of 123 kV [7].

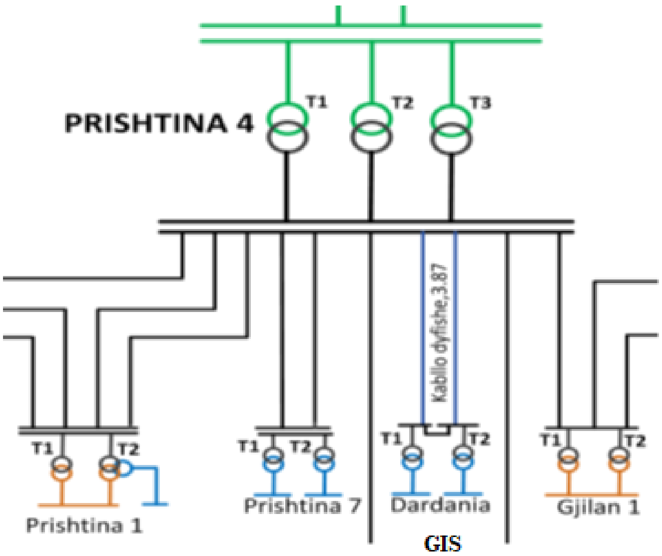

Fig.4. Connection of the transmission network of SS 110/10(20) kV - Prishtina VI, 2x40 MVA

The figure 5 show the distribution of cables in the part of the transformers

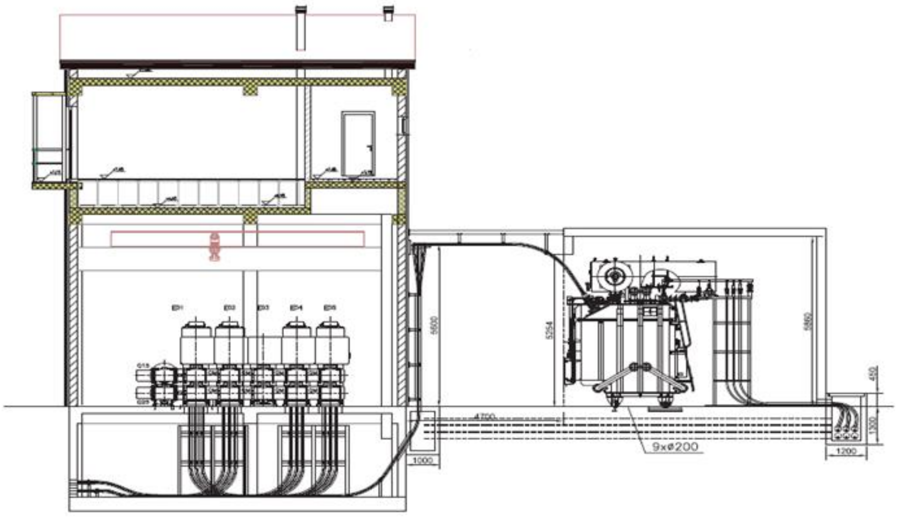

Fig.5. Cable distribution to transformer

4.1 The construction part of the GIS system

GIS as it was emphasized earlier, will be supplied by SS 220/110 kV – Prsihtina IV through the double XLPE Al 1000 mm^2 cable line with a length of about 3.87 km. While the secondary side of the two transformers are connected to the existing equipment of SS 35/10 kV – Prishtina III, eliminating the 35 kV voltage. The existing MV equipment had to meet the technical safety criteria which will be adapted to the nominal parameters and fault currents raised as a result of the installation of 2x40 MVA, 110/10(20) kV transformers in the GIS. In the figure 6, a single line diagram of the part of the GIS system is shown.

Where are:
E01- Transformer and measuring field;
E02- Line field (output);
E03- Connecting Field;
E04- Line field (output);
E05- Transformer and measuring field.

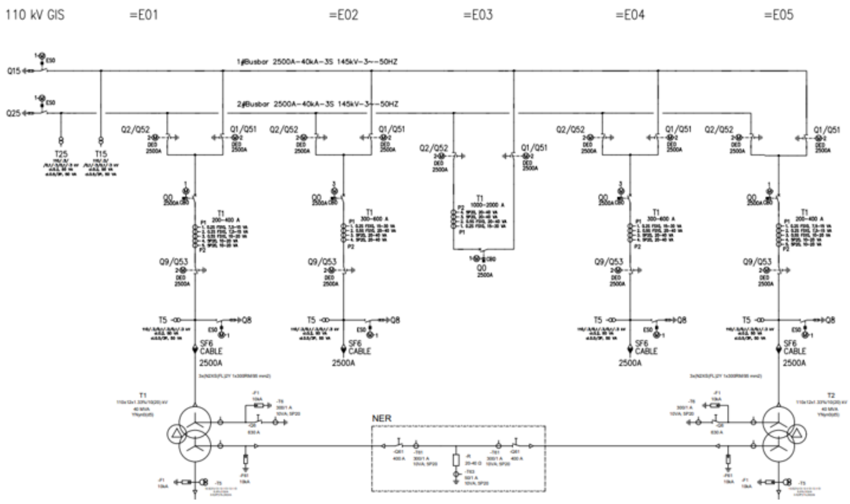

Fig.6. Single line diagram of the GIS

4.1.1 Current transformers

Current transformers for 110 kV transformer bases have the following accuracies:

- Class 0.2 s for commercial measurement;
- Class 0.2 or 0.5 s for monitoring (SCADA, etc.);
- 5P20 for protection.

For GIS planned to use 6x3=18 CT and 2x3=6 CT for SS 220/110 kV – Prishtina IV.

All current transformers are pole type with ring core (toroidal design) and are located inside the metal enclosure of the switchgear - GIS. Current transformers are designed to continuously maintain a current of 120 % of the nominal current.

4.1.2 Voltage transformers

All voltage transformers comply with IEC 60186. They are inductive type, insulated with SF_6 gas and located in a separate SF_6 compartment.

For GIS planned to use 6x3=18 VT, 2x1=2 VT in busbar of SS 110/10(20) kV – Prishtina VI and 2x3=6 VT for SS 220/110 kV – Prishtina IV.

4.1.3 Disconnector and earthing

HV disconnectors and earthing switches conform to IEC 60129. Electrical ratings and characteristics are as follows:

Table 1. Characteristics of the 110kV dsconnector used in GIS

110 kV Disconnector	
Nominal voltage	110 kV
Short-circited nominal current	40 kA
Rated nominal current	2500 A

Table 2. Characteristics of the Characteristics of earthing switches used in GIS

Earthing switches	
Nominal voltage	110 kV
Short-circited nominal current	40 kA
Rated nominal current	2500 A

5 GIS vs AIS

The dimensions of Air Insulated Substations (AIS) are imposed by the air insulation distances, so the solution to make them more compact is to use a better insulating gas inside a pressurized enclosure (GIS). A gas-insulated substation (GIS) can easily be installed inside an industrial building, as they are usually installed in a monolithic concrete layer or directly on the floor of the building. In the GIS system, the active components of the system, since they are isolated, are protected from exposure to atmospheric air, moisture, pollution, etc. This results in a more reliable system that requires less maintenance and has a longer lifespan than the AIS System [8].

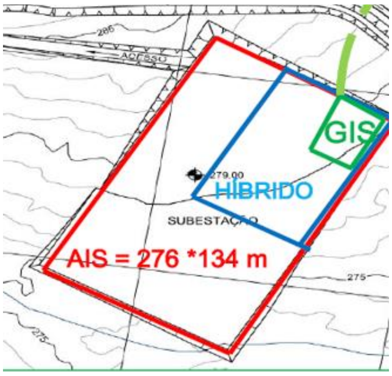

Fig.7. Space covered by a GIS System vs AIS System

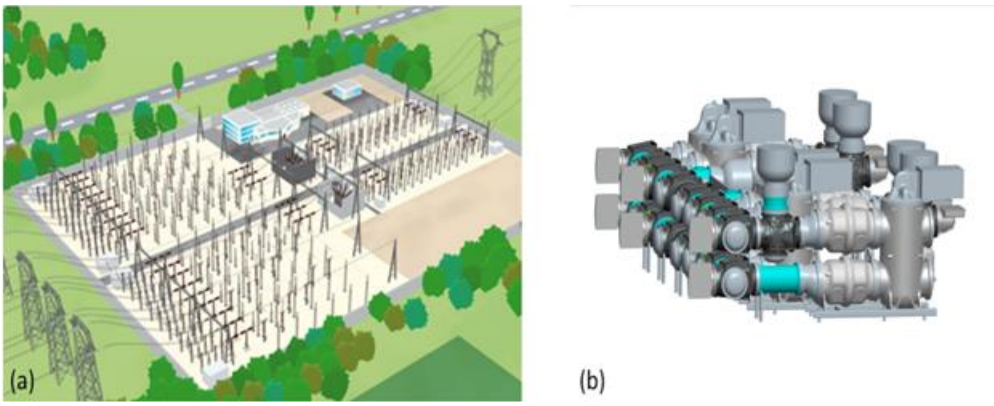

Fig 8. Systemi AIS vs GIS [9]

6 Conclusions

In this paper, we have presented the implementation of the GIS System in the SS 110/10(20) kV - Prishtina VI. At the very beginning of this paper, we have shown the characteristics of Substations in general to continue with the basic concepts of GIS Systems. In the following chapters we have focused in detail on the implementation of the GIS system in the SS 110/10(20) kV - Prishtina VI, elaborating the structure, the basic components, the method of installation of this system. In the end we have presented differences between the GIS system and the AIS system and the importance of the implementation of this system in the SS 110/10(20) kV - Prishtina VI.

It is imperative to recognize that the most suitable substation configuration may not exclusively entail either Air Insulated Substations (AIS) or Gas Insulated Substations (GIS). On occasion, a hybrid or mixed-technology approach could be the most advantageous arrangement. Generally, numerous factors may favor the adoption of GIS technology; however, the decision ultimately hinges on the significance attributed to these considerations and whether the return on investment justifies opting for GIS technology over AIS.

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