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A Study on Gas Insulated Substation with Reference to 220/33kV GIS, Khanapara

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ABSTRACT: Due to rapid industrialization and increasing population all over the world, the need of efficient and reliable power source has become the prime demand. But since geographic area has reduced due to increasing population, creation of a compact but efficient power supplying medium is required. Gas Insulated Substation is the solution to such problems. Gas Insulated Substation uses Sulfur hexafluoride (SF_6) gas which has a superior dielectric properties used at moderate pressure for phase to phase and phase to ground insulation. In Gas Insulated Substationthe high-voltage conductors, circuit breaker interrupters, switches, current transformers, voltage transformers and lightning arresters are encapsulated in SF_6 gas inside grounded metal enclosures. Because of its compact nature, the size of the plant is reduced and hence the space consumed is decreased. This paper presents a study of Gas Insulated Substation (GIS) with reference to the 220/33kV GIS, Khanapara in Guwahati.

KEYWORDS: Gas Insulated Substation, GIS, Air Insulated Substation, 220/33kV GIS Khanapara

I. INTRODUCTION

Globally economy and population continues to grow which results in rise of electrical power requirements. For this purpose, substation equipment has to be made more efficient and reliable to cope up with increase in demand, especially adapting current power distribution and transmission system [1]. Although in last few years an important development has been made by integration of Smart Metering (AMI) and Smart Grid technology, but this technology limits itself only in distribution phase as it directly related to communication between consumer and demand. We all know that power is produced, then transmitted and then distributed through Grid Stations or Sub-stations. For more efficiency the transmission and distribution sector has to be improved and it is found that construction of Gas Insulated Substation [GIS] is a further step for better efficiency. [1, 2]

GIS uses Sulfur hexafluoride (SF_6) gas which has a superior dielectric properties used at moderate pressure for phase to phase and phase to ground insulation. In this type of substation,the high-voltage conductors, circuit breaker interrupters, switches, current transformers, voltage transformers and lightning arresters are encapsulated in SF_6 gas inside grounded metal enclosures. GIS is used when space is to be provide a high position in the big cities.in case of Air Insulated Substations (AIS) clearance between phase to phase and phase to ground need to be very large. For this reason, a large space is required in AIS. But as the dielectric strength of SF_6 gas is much higher relative to the air, necessary for phase to phase and ground clearance for all equipment are much lower in GIS which results in significant reduction of sub-station size.

GIS is preferable in following places.

- Smart cities, metros, cities and towns
- Under ground stations
- Substations and power plants located off shore
- Hilly areas and valley regions

In this paper, a theoretical study of Gas Insulated Substation (GIS) is presented with special reference to the 220/33kV GIS, Khanapara, located in Guwahati, India.

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II. CONSTRUCTIONAL FEATURES

Gas Insulated Substation contains the same compartments found in AIS. Only live parts are enclosed in metal body filled with a dielectric gas such as SF_6. The active parts are supported on insulators molten resin. Some of these bushes are designed as barriers between adjacent modules such that the gas does not pass through them. The entire system is divided into compartments which are relative to the other gas-tight. Thus, the gas detection system in each compartment can be independent and simpler. The housings are of nonmagnetic materials such as aluminium or stainless steel and are connected to ground [1]. The Main components of GIS are shown in Fig.1.

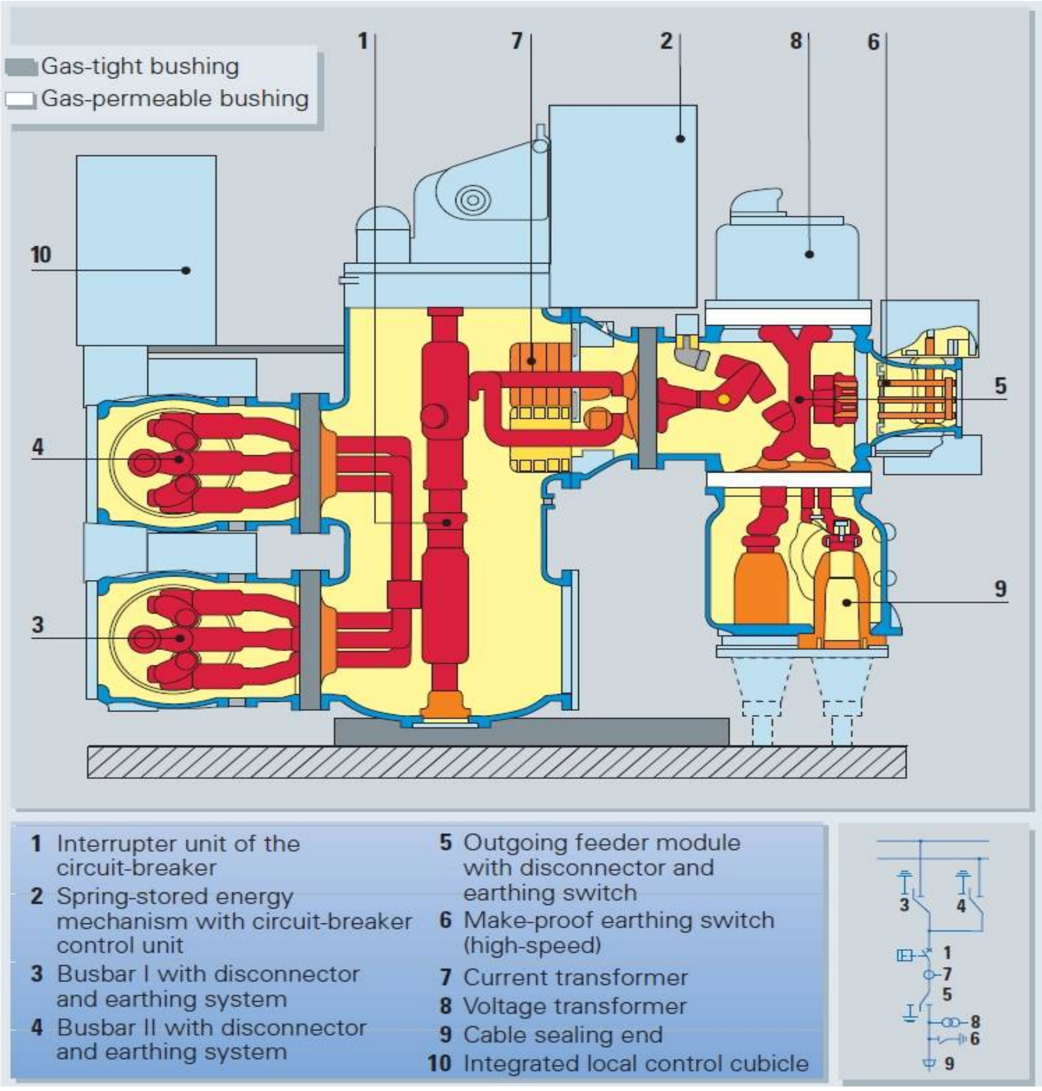

Fig.1: Components of GIS

III. ARRANGEMENT AND MODULES

- **Arrangement:**The arrangement of GIS is single-phase or three-phase enclosed. The assembly consists of completely separate pressurized sections designed to minimize the risk of damage to personnel or adjacent sections in the event of a failure occurring within the equipment. Rupture diaphragms is provided to prevent the enclosures from uncontrolled bursting and suitable deflectors provide protection for the operating

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personnel. In order to achieve maximum operating reliability, no internal relief devices may be installed so that adjacent compartments would not be affected. Modular design, complete segregation, arc-proof bushings and "plug-in" connection pieces allow ready removal of any section and replacement with minimum disturbance of the remaining pressurized switchgear.

- **Bus-bars:**All bus-bars are three-phase or single phase enclosed and plug-connected from bay to bay.
- **Circuit-breakers:** The circuit-breaker is usually of the single pressure type with one interrupter per phase. The arc chambers and contacts of the circuit-breaker are freely accessible. The circuit-breaker is designed to minimize switching over voltages and also to be suitable for out-of-phase switching. The specified arc interruption performance must be consistent over the entire operating range, from line-charging currents to full short-circuit currents.The circuit breaker is designed to withstand at least 18–20 operations (depending on the voltage level) at full short-circuit rating without the necessity to open the circuit-breaker for service or maintenance. The maximum tolerance for phase disagreement is 3 ms, i.e. until the last pole has been closed or opened respectively after the first. A standard station battery required for control and tripping may also be used for recharging the operating mechanism. The energy storage system (hydraulic or spring operating system) will hold sufficient energy for all standard IEC close open duty cycles. The control system provides alarm signals and internal interlocks, but inhibit tripping or closing of the circuit-breaker when there is insufficient energy capacity in the energy storage system, or the SF6 density within the circuit-breaker has dropped below a minimum permissible level.
- **Disconnectors:** All isolating switches are of the single break type. DC motor operation (110, 125, 220 or 250 V), completely suitable for remote operation, and a manual emergency drive mechanism is required. Each motor-drive should be self-contained and equipped with auxiliary switches in addition to the mechanical indicators.
- **Grounding switches:** Work-in-progress grounding switches are generally provided on either side of the circuit-breaker. Additional grounding switches may be used for the grounding of bus sections or other groups of the assembly. DC motor operation (110, 125, 220 or 250 V), completely suitable for remote operation, and a manual emergency drive mechanism is required. Each motor drive should be self-contained and equipped with auxiliary position switches in addition to the mechanical indicators.
- **Instrument transformers**: Current transformers (CTs) are of the dry-type design not using epoxy resin as insulation material. Voltage transformers are of the inductive type, with ratings up to 200 VA. They are foil-gas-insulated.
- **Cable terminations**: The cable end housing should be suitable for oil-type, gas-pressure-type and plastic insulated (PE, PVC, etc.) cables. Facilities to safely isolate a feeder cable and to connect a high-voltage test cable to the switchgear or the cable are provided.
- **Control:** An electromechanical or solid-state interlockingcontrol board are supplied as astandard for each switchgear bay. This failsafeinterlock system will positively preventmaloperations.

IV. ABOUT KHANAPARA GAS INSULATED SUBSTATION

The 220/33 kV GIS substation located at Jawaharnagar in Khanapara, was build at a cost of Rs.49.56crore and is operated by the Assam Electricity Grid Corporation, to cover the areas such as Dispur, Beltola, Bashishtha, Narengi, Khanapara and Panjabari. Assam is the 8th state in the country to have such facility. The GIS at Khanapara has been set up on a 6 Bigha plot. The equipment has been imported from Hungary. The GIS Khanapara has two feeders one of which is incoming and other is outgoing. The incoming feeder carries 220KV from the nearby substation and step down it to 33KV. Later it is transmitted to other substation. The incoming transmission line is Samuguri and the outgoing transmission line is Sarusajai. Fig.2 shows the single line diagram of GIS, Khanapara.

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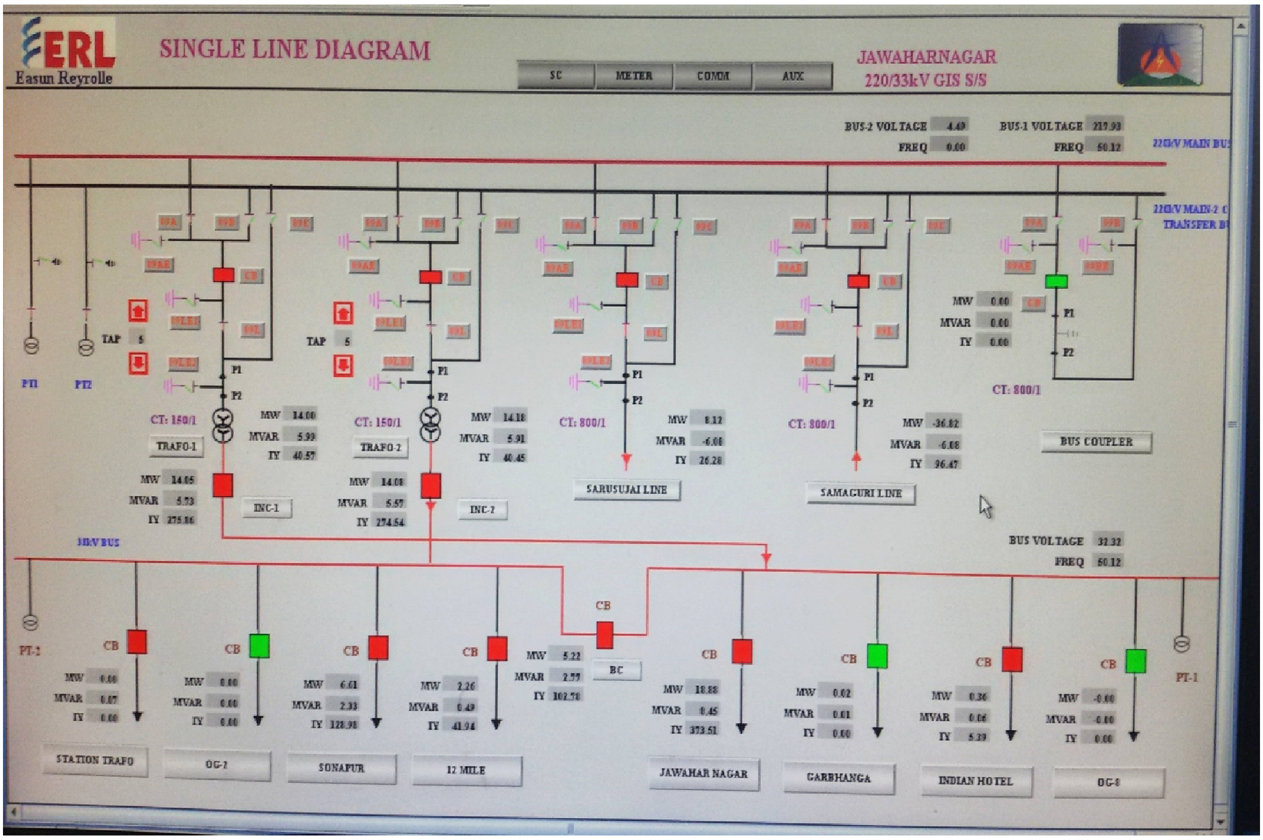

Fig.2: Single line diagram of GIS, Khanapara

The components in GIS Khanapara are circuit breaker, instrument transformers, isolator, earth switch, relays etc. Khanapara GIS uses SF_6 gas as arc quenching medium for circuit breaker. Due to increase of power demand in Assam, power substation number needs to be increased; but the geographical criterion which is hilly and compact land supply, the AIS construction dealing with a high space requirement is less possible. Hence GIS which can be constructed in a very less space come into picture. It also provides minimum hazards since the components of GIS substation are sealed within SF_6 filled pipes whereas in AIS the same components are exposed to changing atmospheric conditions that may lead corrosion between the pipes and the atmosphere. This may lead to damage of different parts of the circuits. The changing of equipment also causes huge amount of expenditures.

V. TYPES OF PROBLEMS FACED IN KHANAPARA GIS

1. **Circuit Breaker**: Inside every circuit breaker there is micro switch, this micro switch contains spring attached, which may get damaged due to various reasons. To overcome these problems, the spring needs to be replaced timely.
2. **Effect of Temperature:** Between two contacting chambers, there is grease and windings present. Due to temperature effect the grease may melt down which forms black pots and also lead to pressurizing of the chamber. This problem may cause a great deal of trouble. Hence the temperature should be kept in a moderate value.
3. **Disadvantage of SF_6:** SF_6 is known to be a greenhouse gas which leads to release of CFC. Hence it is dangerous to health when inhaled directly. Hence care must be taken to stop leakage of SF_6 from the chamber. SF_6 gas is very costly and periodic replacement is required. Thus to overcome the disadvantage of SF_6 we can replace the gas by some other suitable gases which must be economical and it should have very high breakdown voltage and high dielectric strength.

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VI. FUNDAMENTAL RESEARCH ON SF_6-FREE GAS INSULATED SWITCHGEAR ADOPTING CO_2 GAS AND ITS MIXTURES

SF_6 has been recognized as one of the global warming gases. So SF_6 gas can be replaced with CO_2 gas which has very low global warming potential compared to SF_6 gas (1/23,900).

The CO_2 gases that are applicable to an environmentally-banning electric power equipment are required to have no or minimal toxicity, global warming effect and should remain gaseous at low temperature, for e.g. - around -30^{0}c. when selecting the alternating gases such as N_2, O_2, H_2, CO_2, rare gases (He, Aretc) and their mixtures also require to have adequate and arc quenching capability, chemical stability and have no flammability and explosiveness. Table 1 shows the fundamental gas properties of SF_6, CO_2 and N_2. CO_2 has a lower boiling temperature than SF_6 and it is known that CO_2 remain gaseous at low temperature ranges down to -40^{o}c. even at a high gas pressure.

Table 1: Fundamental gas properties of SF_6, CO_2 and N_2.

GAS	**SF_6**	**CO_2**	**N_2**
Molecular mass	146.06	44.01	28.01
Density (kg/m^2)	5.9	1.8	1.1
Chemical stability	Stable	Stable	Stable
Boiling temperature(^{o}C)	-51	-78	-198
Dielectric strength (%)	100(-)	34(-)	25(+)
Arching time strength(microsecond)	0.8	15	220

As for insulating capability, as also shown in the Table1, CO_2 is naturally lower than SF_6, but its 50% breakdown voltage is about 35% higher than that of N_2 at a high gas pressure of 0.9MPA. The table also shows that the arcing time constant of CO_2 is higher than that of SF_6. But is below $(1/10)^{th}$of that of N_2. Qualitatively smaller arcing time constant suggest better thermal interrupting capability. Although CO_2 is inferior to SF_6 in insulation and arc quenching capabilities, it suppresses N_2gas which is regarded as an alternative gas in arc quenching capability. These suggested CO_2 gas is a promising alternative gas.

VII.CONCLUSION

Substation forms an important link between two transmission networks or between a transmission and a distribution network. It has a vital influence on reliability of service. Apart from ensuring efficient transmission and distribution of power, the substation configuration should be such that it enables easy maintenance of equipment and minimum interruption in power supply.Gas insulated substation has several advantages over the conventional substation. This paper presents a brief study on GIS with reference to the 220/33kV GIS, Khanapara. Due to the properties like less space requirement, almost maintenance free, safer operation, cost effective, versatile and reliable in operation, GIS will replace most of the conventional substation in near future.

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