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REVIEW PAPER ON GAS INSULATED SWITCHGEAR (GIS)

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ABSTRACT: A rapid improvement has been seen in the field of power distribution sector, yet the processes of distribution of electrical power supply and transmission use the same set of conventional equipments which were used before. The significant and detailed information about the design of gas insulated metal clad switchgear has been widely covered in this paper in a descriptive way. With the help of real practical examples, quality insurance, the best and state of the art production, various stages of technical design and the progressive steps of development are explained in this paper. Research done by the experts say that, the GIS is free in terms of maintenance as it requires comparatively less space, its reliability is more and it is multi-component. The system uses SF_6 gas as the primary insulation medium, so its properties, maintenance, monitoring, gas handling, secondary system, disconnecting, grounding and switching, etc. are also described here. This paper indicates numerous advantages of Gas insulated metal clad switchgear and, GIS is not only used for indoor substations but also can be used for outdoor Substations. The highly reliable has many advantages and it is urged to be used at high voltage levels of 12KV, 36KV, 72.5KV, 145KV, 245KV, 420KV and above yet the system may consist few drawbacks. The GIS must be used from the economic point of view, low maintenance cost, easy installation, long life and it require very little space as compare to other Conventional sub- station of same rating.

KEYWORDS: Transmission, Distribution, Electrical power supply, Gas Insulated metal clad switchgear (GIS), Air Insulated Substation (AIS), Sulphur hexafluoride (SF_6), Gas handling unit, High voltage level, Kilovolt (KV).

I. INTRODUCTION

We know the world economy population continues to grow exponentially which obviously results into the substantial rise in electricity demands. In order to meet the never ending

increase in the demand of electrical energy or electricity, the equipment in the substation has to be made more reliable and flexible compared to conventional systems. As we all have studied the basics of power generation and transmission process viz. the generation of power in generating stations, transmission of power at high voltages and finally the distribution of electricity by stepping it down into suitable voltages for respective consumers through various substations. The sector of transmission and distribution of electrical energy has to be uplifted and improved to increase and maintain the efficiency at required values. The system of GIS should also be able to adapt to the existing system of power distribution and transmission. The substations which are used for converting the voltages into suitable values should be able to serve the assigned local areas of distribution as the sources of energy supply in which these GIS systems are located. The main functions of the substation includes receiving of electrical energy which was transmitted at very high voltages from the power generating stations and reduce the value of voltage suitable for the local consumer distribution and to provide facility of switching. There are some types of substation like some are simply operated for making connections between various transmission line while some are operated for converting the type of supply which convert AC to DC or vice versa or to convert the frequency from megahertz to hertz or vice versa. In the event of fault, the electrical equipment or circuit has to be disconnected where points are provided to install safety devices. The substation also regulates the voltage on the outgoing distribution feeders. These substations have types like air or gas for the insulation of high voltage substations where high voltage switchgears and devices are installed.

II. CHARACTERISTICS OF GIS

Insulation Medium:- For connections like phase to phase and phase and ground, a superior dielectric sulphur hexafluoride (SF_6) gas is used at moderate pressure. The various switchgear equipment like instrument transformers (current and potential transformers), switching devices like circuit breakers and interrupters, high voltage conductors are immersed in the SF_6 gas inside grounded metal enclosures. The SF_6 gas insulation is only required for a few centimeters of layers while the conventional insulation systems require meters of insulations.

Dielectric Strength :- The Dielectric strength of the gas SF_6 increases with pressure and is more than that of dielectric of oil at a pressure of 3kgf/cm^2 (or kg/cm^2). The density of gas is 5 times that of air at 20^{o}C at atmospheric pressure.

Compactness and Space:- The GIS uses very less space. If we compare the GIS system with other insulating system, in terms of space requirement, it uses only about 10% of the space of the conventional outdoor systems of insulation. Hence by a factor of 10, the GIS becomes smaller than the conventional systems e.g. AIS. In the ares or localities where space is substantially expensive, not available or very less space is available, GIS can be used efficiently. 522.45m^2 (12.15m*43m) would be the space or the building area required if we use the GIS systems. In the process of undertaking the structural size of the system, the height

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of the substation also plays a quite vital role. 11 meters for 400KV is the height of the structure or the building required for the successful use of GIS, while 28 meters of height is required for conventional systems. This is a great difference between the GIS and the conventional systems. 10,672m^2 is the overall compound size required for the operation of GIS.

Protection from pollution:- Moisture , pollution , dust, etc.have little influence on SF_6 insulated substation. Yet, such substations are housed inside a small building or closed space for the purpose of facilitating and maintenance. Like conventional power houses, the physical construction of the building or the space need not to be very strong. The gas insulated substation (GIS), are not affected by the natural or environmental factors. In fact, these modified substations are even more suitable for extreme climatic conditions and severe environments like humidity, saline, polluted atmosphere comprises of industrial exhaust.

Reduced switching over voltage:- The over voltage while closing and opening line, cables motors capacitors etc. are low in GIS as compared to conventional systems of power transmission.

Reduced installation time:- In the process of installing the GIS substation, it uses the principle of building block principle. As a result, it helps to reduce the installation time to a few weeks. The conventional substation takes more time like a few months or years.

Life of substation :- To preserve the substations for a longer amount of time and for trouble free operations, the SF_6 gas envelopes the current carrying conductors and insulators by the chemical composition of the SF_6 gas. While in the conventional systems of insulation like AIS, where in steel infrastructure are used, it gets rusty because of moisture. Due to all these factors, the life of GIS increases by a great number (40 to 50) years unlike conventional systems having the life of 20 to 25 years.

Safety:- By the use of SF_6 gas, operating environment are nicely protected by metal casings which are earthed. Thus, insulated gas stations are very safe and reliable.

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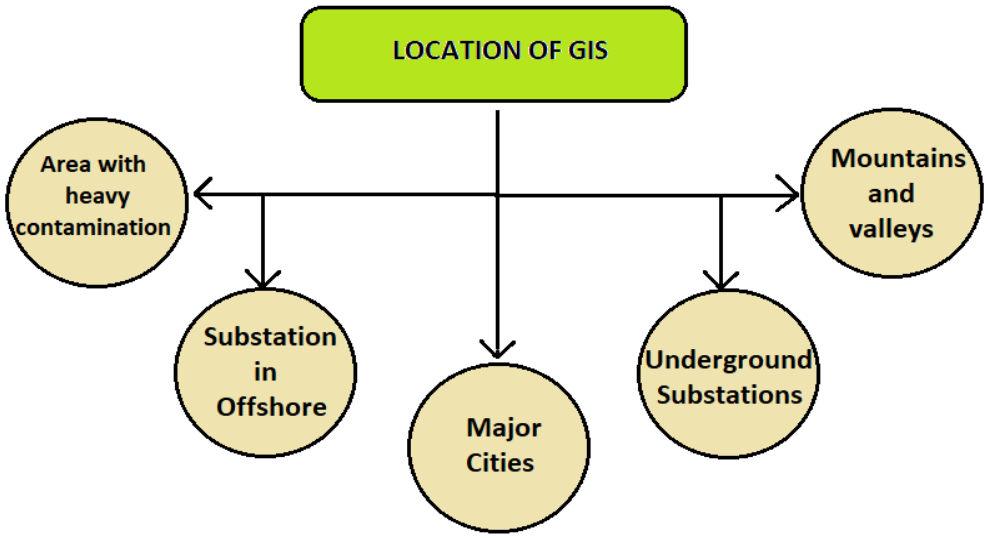
Economic:- Initial investment required for installation of GIS is little bit high, but the cost can be comparable to lower maintenance of GIS, reliable, and secure against conventional substation (AIS).

Location of GIS:- Following locations are preferred by GIS system:



Environmental effect : There are various strong greenhouse gasses that contribute to global warming on a large basis. Sulphur Hexafluoride (SF_6) is one of them. Compared to other gasses, SF_6 is one of the best greenhouse gasses. This was discussed at the international conference held at Kyoto in 1997. Due to very less human activity, SF_6 gas is an extremely minor contributor to the total greenhouse gasses. Still, the gas has a very long life in the atmospheric belt of the Earth, i.e. it can stay in atmosphere upto 3200 years approximately. As a result, the SF_6 gas released into the atmosphere is effective and quite permanent. If we take a span of 100 years, the contribution or effect of the SF_6 gas is less than 0.1%. A medium that is capable of providing effective insulation at the effect of less space is our core requirement for the insulation media required for the substations. Other than this, it should be capable of providing utmost safety to the equipment, even at high or over voltages its atomic or molecular properties should remain intact. Apart from this, iot should also be non toxic. As found, the SF_6 gas completely satisfies all the above mentioned requirements. More than 10,000 tons of SF_6 gas is produced per year and roughly about 8000 tons of the gas is used as the insulating medium for the electrical equipment which is 80% of the total production of the gas. The gas provides best arc quenching properties and has the best cooling effects, because of which life of components increases in which it is used. The SF_6 gas is chemically stable and is non toxic. It can remain stable upto temperature of 500^oC. The density of the gas is 6.12g/l which is five times higher compared to air. I possess the rapid recombination after the sparks and also has a very good dielectric strength. As a result, the SF_6 gas becomes more

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effective than the air for arc quenching. Currently, according to a survey, emissions of SF_6 gas contributes less than 0.005% of the potential global warming.

III. NEED OF GIS

1. Availability of sufficient space. It is very much essential to establish a substation which is near to load centres. It becomes economical and feasible in following ways:
    a. Feeder lengths are reduced.
    b. Due to short length feeders, the quality of voltage regulation is improved.
    c. The GIS needs only 10% os space as that of the conventional substations.
2. Suitable for difficult or extreme climatic conditions like high altitude or atmospheric conditions.
3. The GIS substations are superior to air insulated substations.
4. The gas insulated technology becomes more favorable with the increase in voltages. The GIS technology allows a significant size reduction for the substations of 765KV, 800KV.
5. It can overcome all the drawbacks of conventional systems.

IV. LAYOUT / SINGLE LINE DIAGRAM OF GIS

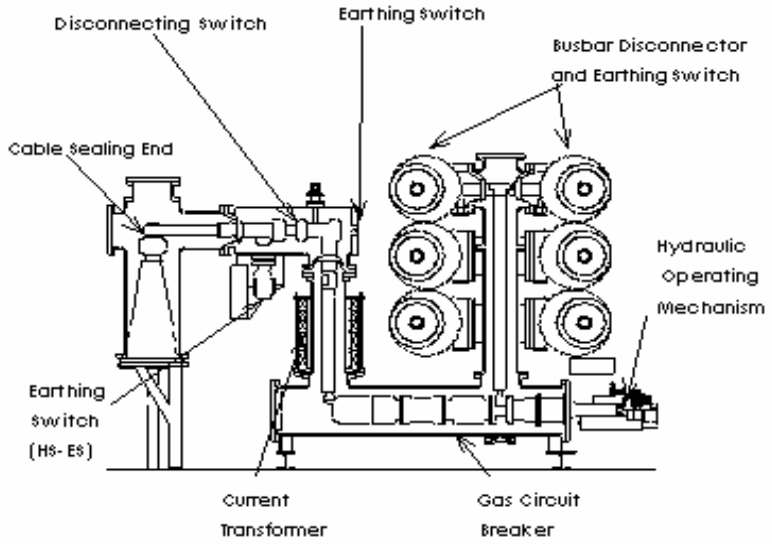

Fig.1: Layout of GIS

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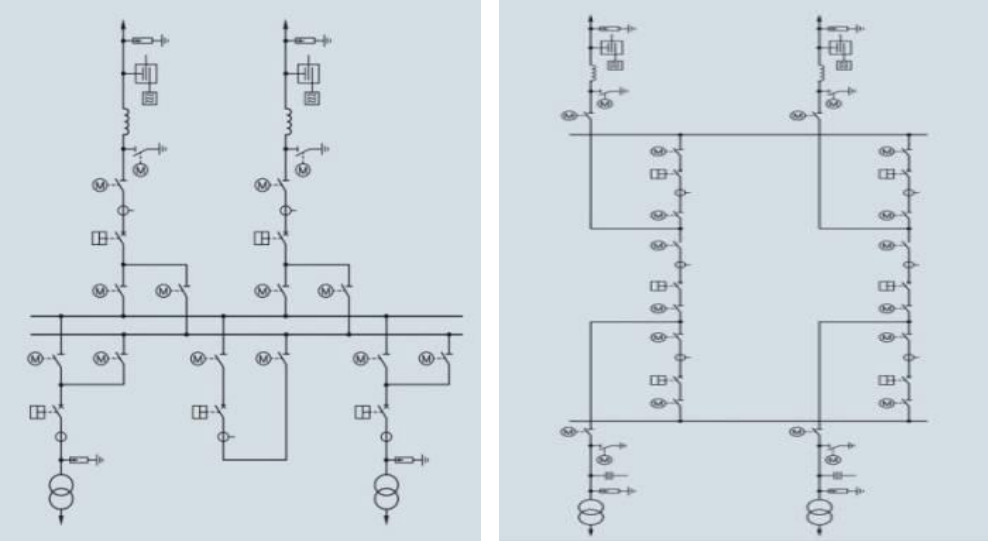

Fig : a - SLD of GIS with double Bus Bar (2BB).

b - SLD of GIS with one half Bus Bar (1.5 BB)

V. MAIN COMPONENT OF GIS

Following are the main components of GIS:

1. Gas bushings consisting of insulator discs.
2. Bus Bar
3. Insulation medium is the SF_6 gas.
4. Circuit Breakers of SF_6.
5. Isolators or disconnectors
6. Earthing Switches
7. Current and potential transformers.
8. Lightning arrestors
9. Gas handling systems.

1. **Gas bushings consisting of insulator discs:** The SF_6 switchgear cable connection assembly are connected by various types of high voltage cables and it enables the cables and GIS to be tested by separated transformer connections consisting of oil bushings, enclosures, main circuit end terminal and removable connections of the system.

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2. **Bus Bar:** The conductors of bus bar are made up of aluminium tubular section which are joined between different section by using plug in tulip contacts which fit automatically during field connections. Enclosures are made from non- magnetic aluminium stainless steel material. As the resistance of stainless steel is higher than that of aluminium the losses in stainless enclosures in therefore higher.
3. **Sulphur hexafluoride gas (SF_6 gas) :** One sulphur and six fluorine atoms is the chemical composition of the SF_6 gas. In the year 1900, in the laboratories of Faculte de Pharmacie de Paris, the SF_6 gas was first realized. SF_6 gas can be used as insulating material was first realized in the year 1937 by the General Electrical Company. In the middle of the 20^{th} century, after the second world war, the popularity of using sulphur hexafluoride gas as insulating material in electrical system was rising very rapidly. At the beginning of sulphur hexafluoride gas was only used for insulating purposes in the electrical system. But immediately it was realized that this gas has tremendous arc quenching property. Hence, this gas was started to be used in circuit breaker as arc quenching medium. Sulphur hexafluoride medium voltage circuit breakers were launched into market from 1971.
    a. **Manufacturing:** SF_6 or sulphur hexafluoride gas is commercially manufactured by reaction of fluorine (obtained by electrolysis) with sulphur.

S + 3F2 = SF6 + 262KCal + bi product

b. Gas Properties:

Density at 20^oC	$6.14Kg/m^3$
Colour of Gas	Colourless
Molecular Weight	146.06
Thermal Conductivity	0.0136w/mk
Critical Temperature	45.55^oC

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Critical Density	730 kg/m^3
Critical Pressure	3.78MPa
Sound Velocity in SF6 gas	136m/s . It is less than 3 times that of air
Specific Heat	-1221.66kg/mol

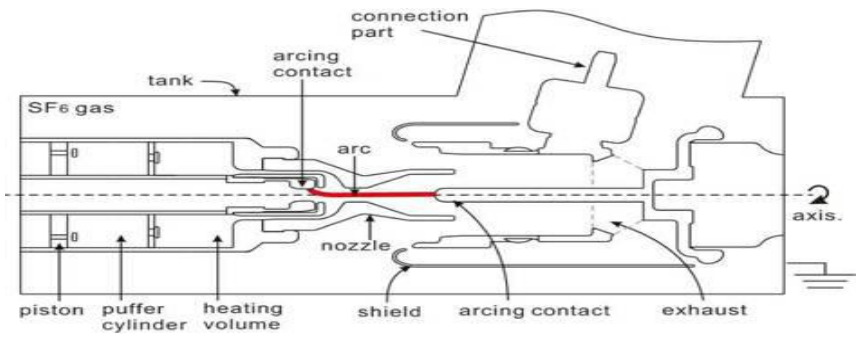
c. **Electrical properties :-** Sulphur Hexafluoride gas is extremely electromagnetic. Due to arcing between contacts of circuit breaker, it absorbs free electrons. All this happens because of high electro-negativity. Heavy and big ions, which have very low mobility are produced due to the combination of free electrons. Sulphur hexafluoride has very excellent dielectric property, due to absorption of free electrons and low mobility of ions. Dielectric strength of sulphur hexafluoride gas is about 2.5 times more than that of air.

4. **Circuit Breaker or SF6 circuit breaker :-** A SF_6 circuit breaker is a circuit breaker in which current carrying contacts operate in SF_6 gas. The gas molecule of SF_6 gas is absorbed by another SF_6 molecule which in turn forms a negative ion with the collidation of free electrons. There are two different ways in which the attachment of electrons with SF_6 gas molecules can happen.

$$SF_6 + e^- = SF_6$$

$$SF_6 + e^- = SF_5 + F$$

Under the influence of an electric field, the ions do not get sufficient energy to have cumulative ionization in the gas due to the negative ions formed which are much heavier than the free electrons. Avalanche breakdown is avoided by removing an electron from the contact space. The gas possesses the characteristics of very low time constant due to electro-negativity of SF_6 gas. **"Puffer Principle"** is used in SF_6 circuit breakers.



5. **Disconnector / Isolator Switches or Earthing Switches :-** For protection of the system an earthing switch and it has the slowest operation. With main isolator moving

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contact an earthing arm is interlocked. It operates only when the high voltage is system is not energised.

Circuit breaker module GCB

6. **Instrumental Transformer (C.T & P.T) :-** A housing is formed to encapsulates which forms a separate gas tight module. With the insulating film, pressurized gas is inside the enclosure. To provide protection against over voltage, an insulation is provided. To switchgear connection of high voltage is directly connected. From gas tight bushing plate to terminal, primary and secondary connections are done. The primary of the current transformer is connected to the power line in the series. So the primary is nothing but the current coil which flows through the power line as it does not depend on the load.
7. **Surge / Lightning Arrester :-** Surge arrester can be connected directly if it is needed.The function of its limit to over voltages. Their active part consists of metal oxide resistors with a strongly nonlinear voltage current characteristic. Surge arresters are brim joint to the switchgear through a gas tight bushing. In a tank of arrester module, it has an inspection hole in which a conductor inspected and at the bottom there are the connection for monitoring, arrester testing and operation counter.
8. **Gas Handling System :-** The close circuit gas system is engaged in SF_6. Since the gas is not feasible, it is reconditioned and rehabilitated after each operation of the circuit breaker. Necessary auxiliary system is provided for such purpose. The low and high pressure system are provided with Low pressure alarms which monitor the gas pressure drops, falling which Dielectric strength will be reduced and arc quenching ability of the circuit breaker will be endangered. The gas is stored in the high pressure chamber at 16 atmospheres while the gas pressure on the low pressure side is 3 atmospheres. Lot of care is required to prevent gas leakages at joints by providing sealing. The temp. is kept 20^oC. A heater backed with a thermostat at 16^oC is provided in the high pressure chamber to prevent thawing of the gas in the high pressure chamber at low temperature.

VI. SUBSTATION USING GIS

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Tata Power Plant, Dharavi, Mumbai (2018).

VII. SUGGESTION AND FUTURE SCOPE OF DEVELOPMENT

a. Improve the Circuit-breaker technology, which reduces the number of interrupter units despite the increasing braking capability.

b. Improvement of machining technology of parts used for the minimized shapes and volumes. Use of computerized production of high quality standards and testing equipment.

c. Integrated components Design which has several functions such as grounding switch, dis-connectors within one gas compartment.

d. To avoid the unnecessary tasks and maintaining the activities for use of intelligent monitoring and diagnostic tools.

e. Reducing the temperature which will result in proper lubrication between parts from grease.

f. Use of CO_2 is the replacement to dangerous gas SF_6.

VIII. CONCLUSION

GIS or gas insulated switchgear system available for the high voltage, only SF_6 (sulphur hexafluoride) is used for insulation due to excellent strength of SF_6. After studying locality, it can be concluded that they have more conservative design,better decomposition product management techniques. Additionally they have improved gas handling and better particle control techniques. Achieving availability and maintaining it requires serious approach to quality control from both ends manufacturer as well as the users.In the future we can see the gas insulated current transformer work in the substations, leads to its compact size which is more feasible.

After evaluating the presented cycle shows the advantages of SF_6 insulation (GIS) to a level distribution. Equipment is, however, only to a very small for a global warming potential

contribution. Use of capacity of electricity distribution networks and its design have a sway. Therefore, prohibitions and restrictions on the application of the use of insulated medium voltage SF_6 cannot be justified from an ecological point of view.

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