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A Review on Sulphur hexafluoride (SF_6) Gas as Best Insulating Medium

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ABSTRACT

As the power system is huge and complex network. It involves transmission, distribution and generation. So the number of faults occurs in power system. On the occurrence of fault heavy fault current starts flowing through the power system which will damage the power system equipment. For reliable operation of power system proper protection and isolation is required. To interrupt heavy fault current proper dielectric medium is required. This dielectric medium will be air, oil, vacuum, and various types of gases. The ratings of Circuit breakers are also classified on the basis of dielectric medium such as HT circuit breakers & LT Circuit breakers. Firstly the oil circuit breakers are developed in Europe and air circuit breakers as well as the vacuum circuit breakers were developed. Now-a-days Sulphur hexafluoride (SF_6) circuit breakers are widely used. The SF_6 gas is used as an Arc quenching medium in circuit breakers because it has good arc quenching property and their high dielectric strength. The Sulphur hexafluoride circuit breakers have high breaking capacity. This Sulphur hexafluoride gas is also used for switchgear and transmission line, for gas insulated substation which will helps to increasing demand of electric power with high efficiency and reliability.

Keyword: Sulphur Hexafluoride (SF_6), GIS (Gas insulated Substation), MV (Medium Voltage) switchgear, HV (High Voltage) switchgear, Air insulated Substation (AIS), Current Transformer (CT), Voltage Transformer (VT).

1. INTRODUCTION

Hexafluoride (SF_6) was first synthesized in the laboratories of fluorine obtained by electrolysis was permitted to react with Sulphur and powerfully exothermic reaction giving rise to an extremely stable. Sulphur Hexafluoride (SF_6) gas is considered as one of the best insulating medium. In most of HV power equipment Sulphur Hexafluoride (SF_6) gas is used as an insulating medium. In switchgears, circuit breakers, and transmission line and in gas insulated switchgears Sulphur Hexafluoride (SF_6) gas is most useful medium for insulation. Sulphur Hexafluoride (SF_6) gas provides higher efficiency and reliability for power equipment in electric power system. With the help of Sulphur Hexafluoride (SF_6) gas electric power supplies demand will increase with higher efficiency and reliability. So Sulphur Hexafluoride (SF_6) gas plays an important role in electrical power system. Sulphur Hexafluoride (SF_6) switchgear is able to fulfill the customer requirements in terms of compactness, reliability, reduce maintenance, personal safety, life duration, etc. More recently Sulphur Hexafluoride (SF_6) has been adopted for use in MV switches, ring main units, contactors, and circuit breakers, gas insulated substation, covering all the needs of the electrical distribution industry. Sulphur Hexafluoride (SF_6) gas has lower operating noise. Sulphur Hexafluoride (SF_6) gas doesn't emit any hot gases as well as it has relatively low maintenance over the other medium.

2. BRIEF HISTORY OF SULPHUR

1. In 1937, general electrical companies recognize that gas could be used for insulation in electrical power system.
2. In 1939, Thomson-Houston patented the principle of using Sulphur Hexafluoride (SF6) for insulating cables and capacitors. 3. Commercially, Sulphur Hexafluoride (SF6) gas is used in electrical plant construction. Since, 1960 in USA and in Europe. 4. In 1964, the first Sulphur Hexafluoride (SF6) insulated substation ordered by EDF and put into service in Paris region in 1966. [3]

3. PROPERTIES OF SULPHUR HEXAFLUORIDE (SF_6) GAS

3.1 Physical Properties SulphurHexafluoride (SF_6) gas

- The Sulphur Hexafluoride (SF_6) gas is colorless and odorless gas.
- It is Non-toxic when it is in pure form.
- It is Non-flammable.

- Sulphur Hexafluoride (SF_6) is in gaseous state at normal pressure.
- The density of Sulphur Hexafluoride (SF_6) gas is 5 time that of air at 20^0C atmospheric pressure.
- The gas starts liquefying at firm low temperature. This Process of liquefaction is depends on pressure at 15 kef /cm^2.The gas starts liquefying at 10^0C.
- The heat transferability in Sulphur Hexafluoride (SF_6) gas is 2 to 2.5 times that of air at the same pressure.
- Its heat contented property at temperature below 6000 ^{0}K is much Higher than nitrogen. [4]

Table No. 1. Physical Properties of Sulphur Hexafluoride (SF_6)

Density	6.14 kg m^3
Thermal Conductivity	0.0136 W m^{-1} k^{-1}
Critical point • Temperature • Density • Pressure	 44.55^{0}C 730 kg m^3 3.78 MPa
Sound velocity	136 m g^{-1}
Refractive index	1.000783
Formation heat	-1221.66 kJ mol^{-1}
Specific heat	96.6 J mol^{-1} K^{-1}

3.2 Chemical Properties

- It is steady up to 500^0C.
- The chemical inertness of this gas is beneficial in switchgear. The life of metallic part, a contact is longer in Sulphur Hexafluoride (SF_6) gas.
- It is an electronegative gas.[4]

3.3 Dielectric Properties

- Dielectric strength of SF_6 at atmospheric pressure is 2.35 times that of air.
- At higher pressure the dielectric strength of the gas increases. At pressure which is about 3 kgf/cm^2 the dielectric strength of Sulphur Hexafluoride (SF_6) gas is more than that of dielectric oil.[4]

4. MOISTURE

The SF6 in the equipment Should be enough dry so it can avoid condensation of moisture. However, if the moisture condenses as ice, the breakdown voltage is not affected. So dew points in the gas in the equipment need to be below about –10°C. For additional margin, levels of less than 1000 ppmv of moisture are usually specified and easy to obtain with careful gas handling. Absorbants inside the GIS enclosure help keep the moisture level in the gas low, even though over time, moisture will evolve from the internal surfaces and out of the solid dielectric materials (IEEE Std. 1125-1993).

Small conducting particles of about mm size are reduce the dielectric strength of SF6 gas. This effect becomes greater as pressure is raised past about 600 kPa absolute . The conducting particles are moved due to the electric field, it gives result in leading to dielectric breakdown at operating voltage. Therefore Cleanliness is very important for GIS.

5. SULPHUR HEXAFLUORIDE (SF_6) CIRCUIT BREAKERS

A Sulphur Hexafluoride (SF_6) circuit breaker is that in which Sulphur Hexafluoride (SF_6) gas is used for quenching the arc, the gas is compressed.

5.1 Construction of Sulphur Hexafluoride (SF_6) circuit breaker:

Sulphur Hexafluoride (SF_6) circuit breaker consist of two parts,

- The Interrupter unit: The interrupter unit involves moving and fixed contact which is used for compressed a set of current carrying parts and an arcing probe, which is connected to Sulphur Hexafluoride (SF_6) gas reservoir. The slides vanes in the moving contact are fundamentally used to allow the high pressure gas into the main tank.
- The Gas system: The Sulphur Hexafluoride (SF_6) circuit breaker has a closed circuit gas system. Sulphur Hexafluoride (SF_6) gas is very costly so it is reprocessing after every operation. Low and High pressure chambers are present in this unit which has a low pressure alarm with a warning switches. When the pressure of the gas is very low then dielectric strength of gases decreases and arc quenching ability of the breaker is in danger of extinction, then this system gives a warning alarm.

5.2 **Working of Sulphur Hexafluoride (SF_6) circuit breaker:**

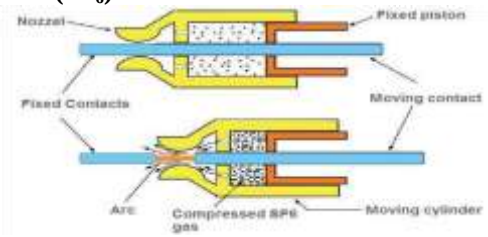

Figure 1. Construction and working of SF_6 circuit breaker

When at a normal condition, there is a normal current flowing through the contact which is not separated and Sulphur Hexafluoride (SF_6) gas will remain at the normal pressure. When fault occur an excessive amount of current will flow through the circuit breaker then circuit breaker contacts will get separated then arc will form across the circuit breakers contacts. During separation process a moving contact will get separated from a fixed contact. As moving cylinder is connected to a moving contact a moving cylinder will also get move backward. As there is a fixed piston inside the moving cylinder and when the moving cylinder moves backward, the pressure of SF_6 gas will get increases and this gas will release through a nozzle. When this gas passes through an arc path an arc will get quenched.

6. GAS INSULATED SUBSTATION (GIS)

A gas-insulated substation (GIS) gas is used as dielectric medium & that gas is SF6, at normal pressure for insulation such as phase to phase & phase to ground. The HV conductors, circuit breaker, switches, CT's, & VT's are in SF6 gas inside grounded enclosures.

As compare to SF_6 the atmospheric air insulation requires more space for insulation Therefore GIS can reduce this space by the factor of 10. It Can be used where space is expensive or lack of space. In a GIS the parts of various Power system elements are protected from the deterioration from exposure to atmospheric air, moisture, contamination.

GIS is more reliable & also required less Maintenance as compare to AIS. GIS was first developed in 1968 and 1972. After experience of 5years, the rate of use of GIS is increased upto 20%.

7. APPLICATION OF SF_6

1. High voltage switchgears and switching application: The excellent insulating properties of sulphur hexafluoride have permitted the construction of high voltage circuit breaker and switching stations.
2. SF6 gas is used in hydroelectric substation: SF_6 is supplied for one of the world's largest hydroelectric power stations between Paraguay and Brazil.
3. It is used in gas insulated transmission line: Gas Insulated Transmission line are well suited for high power transmission. Pure SF_6 gas is filled in conventional design and is being operating safely.
4. It is used in MV switchgears and HV switchgears: The advantage of SF_6 is excellent for its arc quenching ability that's why it is used in it.
5. High voltage cable and tubular transmission line: These are used for high power distribution in heavily concentrated industrial areas, high voltage cables.
6. It is used in transformer: SF_6 gas is used in the transformer because of its excellent heat transfer capacity, non-flammability and non-toxicity.

8. CONCLUSIONS

The use of Sulphur Hexafluoride (SF_6) gas in power system will advantageous for better performance, for reducing size, for reducing weight, for reliability and for reducing global cost. Sulphur Hexafluoride (SF_6) switchgear has lower maintenance cost than older types of switchgears. It is also advantageous in the case of operation of switchgears such as in circuit breakers it will reduce the time of operation. It is useful for LT and HT switchgears as well as MV Switchgears. Still the elementary practices are employed, the use of Sulphur Hexafluoride (SF_6) gas does not constitute any threat to the personnel or environment. One condition for this is that gas insulated switchgear guaranteeing the corresponding low SF_6 emission is used. The reuse process of SF_6 for a closed SF_6 cycle applying consistently is important.

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