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# $SF_6$ $N_2$ Mixtures for Application in EHV Gas Insulated Systems

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**ABSTRACT:** $SF_6$ gas insulated equipment forms a major component of growing electrical power networks all over the world. Due to an exceptional combination of physical and chemical properties, $SF_6$ has become an indispensable insulation medium for electric power equipments. The global warming potential of $SF_6$ has prompted experiments on alternate to pure $SF_6$.Efforts have been made to study the performance of the $SF_6$ mixtures. At this point of time, 100% replacement for $SF_6$ looks unfeasible but the mixtures of $SF_6$ with different gases can offer a realistic solution. This paper attempts to present the design and evaluation of $SF_6$ and $SF_6N_2$ mixtures for EHV rating GIS.

**KEYWORDS**: Gas mixtures, dielectric strength, Breakdown, GIS, $SF_6$,$N_2$

## I.INTRODUCTION

Pure SF6 exhibit excellent insulating and arc quenching properties. It remains the preferred choice for the insulation medium in circuit breakers and the Gas insulated equipments. SF6 filled equipments have increased in the power networks due to increase and expansion of power demand. The rise in number of installations has also increased the release of SF6 into atmosphere due to equipment leakage and maintenance problems. Serious concerns are raised by the environmentalists about the global warming potential of SF6 which is 23900 CO2 equivalents .All the developing countries have agreed to take collective efforts to reduce carbon emissions across globe. SF6 has been included in the list of green house gases. Alternate for pure SF6 looks impossible today. However, efforts are made to investigate the insulation properties of Air and Nitrogen which are natural gases. The studies revealed that pure Nitrogen or Air could result in uneconomical designs. However, the studies on the mixtures like N2- SF6, CF4- SF6 and CO2- SF6 have shown promising results. With small amount of SF6, the mixture can offer dielectric strength and the insulation properties at par with the pure SF6.The mixtures are undergoing extensive investigations for the dielectric performance under clean and ideal conditions as well as with defects. Typical properties of these insulating gases are compared in Table I.

**Table I: Typical properties of insulating gases**

| Characteristics | $N_2$ | $CO_2$ | $CF_4$ | $SF_6$ |
|---|---|---|---|---|
| Molecular weight (g/mol) | 28.01 | 44.01 | 88.00 | 146.06 |
| Critical dielectric strength [kV(cm.bar$^{-1}$)] | 32.9 | 30.1 | - | 89 |
| Boiling point (° C) | -196 | -79 | -127.8 | -64 |
| Global warming Potential (GWP) | 0 | 1 | 5700 | 23900 |

The selection of a gaseous dielectric depends upon the design and the application of the equipment. It is the dielectric or the insulation medium which maintains the electrical isolation between the two electrodes namely HV electrode and

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the earth electrode. When external energy is not available, the gas does not carry any charge as there are no free electrons. The presence of free electron can result in an avalanche thus producing the breakdown in a dielectric. Depending upon the number of free electrons in the gas, the electric conductivity will suddenly change after a certain voltage. This drastic change of dielectrics results in drop of applied voltage which is called electrical breakdown in a gas [1].

## II. SELECTION OF THE GASEOUS DIELECTRICS

The suitability of a dielectric in equipment depends upon its performance in Uniform fields and non uniform fields. The maximum dielectric strength of a gaseous dielectric is achieved when the stressed electrode configuration produces uniform field distribution in the electrode gap. However, in most cases formation of uniform field may not be possible due to the components geometry or specific requirements. The gas mixtures are evaluated on the basis of following parameters:

- Dielectric strength under product configuration
- Performance during lightning and switching Impulses
- Behavior of the gaseous under metallic particle impurity

To derive the characteristics, the mixtures are compared for the sparking potentials of pure $SF_6$ [2].The sparking potential of $SF_6$ in uniform field can be computed as:

VSF6 = 1321(pd)0.915 (1)

Where VSF6 is in volts when the product pd is in kPa.cm
P –Pressure in kPa
d- Spacing between the electrodes in cm
Based on the information, the sparking potential for mixtures of air or $N_2$ with $SF_6$ can be put as :

M = 38.03N0.21 (2)

Where M - sparking potential of the mixture as a percentage of sparking potential of pure $SF_6$
N- Percentage of $SF_6$ in the mixture by volume.
From the experiments carried out, it can be concluded that the sparking potential of $SF_6$ mixtures can be predicted for uniform and non uniform fields with the expression:

V=K(pd)aN bU c (3)

Where a,b and c-0.915,0.21 and 0.85 respectively for $SF_6$-$N_2$, $SF_6$-air and $SF_6$-$N_2O$ mixtures[2].

The studies on uniform field breakdown characteristics on $SF_6$-$N_2$, $SF_6$-air and $SF_6$ $N_2O$ mixtures revealed that on addition of small amount of $SF_6$ to the mixtures can improve the breakdown voltage significantly. The breakdown characteristics under non uniform field showed that breakdown strength changes with gas pressure in a non linear manner. The trend is due to the corona stabilized breakdown phenomenon. The phenomenon is a function of gas mixture ratio, radius of the sharp electrode and the voltage polarity [3].

## III. DESIGN AND THE EXPERIMENT

Insulation breakdown is a statistical phenomenon. A detailed consideration is required for design, planning and execution of experiments. Experiment setup and model should simulate the exact working (application) environment. The failure mode should also have fair agreement between experiment and real life application. With this consideration a full scale model replicating the actual product environment and scale has been replicated for experiments. The aim of the experimental evaluation is based on the requirements of Gas insulated switchgear and Gas insulated Lines.

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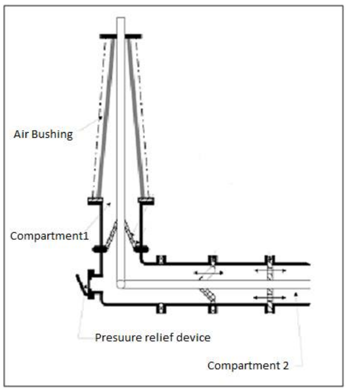


Fig 1: Schematic of GIS as coaxial geometry

Most of the component in Gas insulated switchgears and Gas insulated lines represents concentric cylinder geometry. An experimental EHV GIS model is designed to evaluate and validate the performance of the $SF_6$ $N_2$ mixture.
The basic intent of the experiment is to establish the allowable stress levels for different ratios of $SF_6$-$N_2$ gas mixture. The evaluation of the model will be based on two variables:

- Ratios of $SF_6$ and $N_2$ mixtures
- Absolute pressure of mixtures

The component's construction is designed to achieve the near-uniform field (quasi uniform field) by concentric cylinder geometry. For insulation purpose $SF_6$ is deployed between the concentric cylinder geometry (active part and enclosure). The filed factor is a function of diameters of concentric cylinders. The proposed model for experiment replicate the realistic geometry for 245 kV and 420 kV GIS and GIL products. The protection to the enclosure against the rise in Pressure is provided by Pressure relief device[4] . This device will operate in case the pressure increases beyond the threshold value. Support insulators are provided wherever necessary to prevent the undesired flashovers. The enclosure is provided with Gas Pressure Monitoring devices to check the uniformity of pressure in the enclosure. The gas is filled in the enclosure through the gas filling port. The thickness of the outer sheet for the enclosure is chosen as 20mm.
For evaluation purpose, an Air to $SF_6$ bushing is connected to the enclosure. The bushing will maintain the air clearance and the insulation during the application of power frequency voltage and the Impulse voltage.The cut section of the model is shown in fig 2

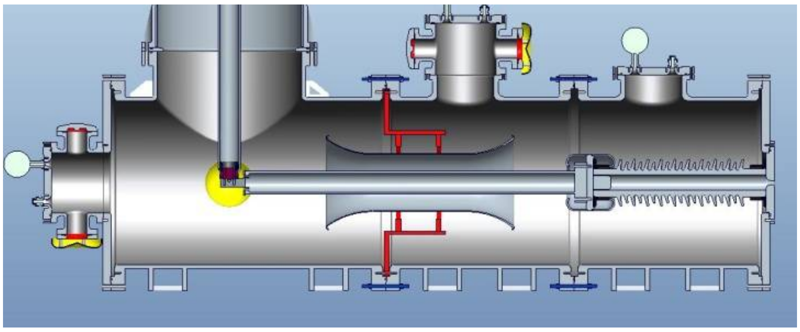

Fig 2: Cut Section of the EHV GIS model

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## IV. EVALUATION AND RESULTS

The evaluation of the any product is carried out as per relevant National or International standards. Similarly ,the evaluation of GIS model is also carried out as per IEC 60060-1 [5],IEC 62271 [6] and IEC 60270[7].To evaluate the performance under AC power frequency voltage ,a Double shielded laboratory is used. The laboratory has High voltage source and a Partial discharge detector in the circuit. The schematic of AC test set up is shown in fig 3.

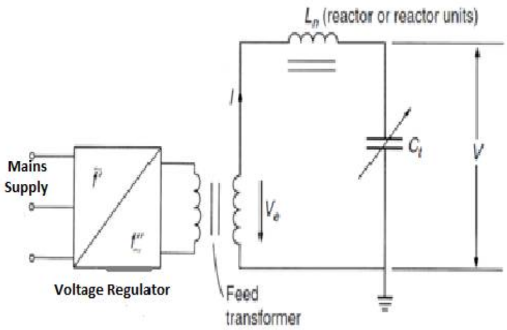


Fig 3 : Schematic of Test set up for AC test

The GIS model is subjected to AC power frequency voltage test. The evaluation was carried out for following configurations:

- 10/90 SF6/N2 mixture
- 20/80 SF6/N2 mixture
- Gas pressure varied between 4-6 bar

The withstand and the breakdown value for the mixture was found after repeated breakdowns in a group of 10 voltage applications. The breakdown stress (kV/mm) is plotted Vs. Pressure. Fig 4 shows characteristics of breakdown stress for Pure $SF_6$ as well as $SF_6N_2$ mixture.

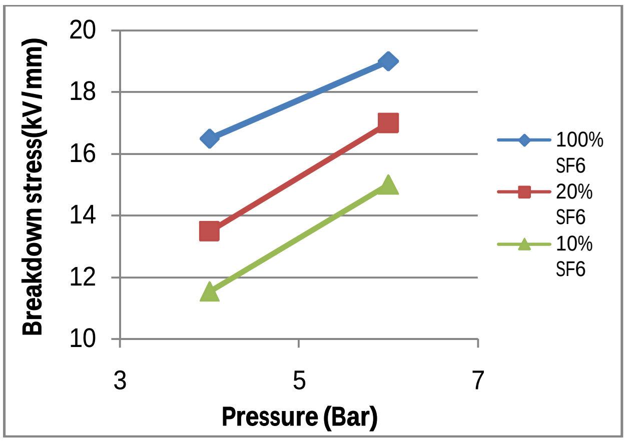


Fig 4: Characteristics of breakdown stress for Pure $SF_6$ as well as $SF_6N_2$ mixture.

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The partial discharge(PD) measurement in the model is carried out as per IEC 60270.The precaution and the measurement is same as adopted for GIS with Pure $SF_6$.The voltage was slowly increase till the measurement voltage and partial discharge value was noted. The process was repeated for the artificial contamination inside the GIS.The characteristics of the PD was found to be in line with the conventional GIS with Pure $SF_6$. The pattern for the PD with impurities on electrode is shown in fig 5.

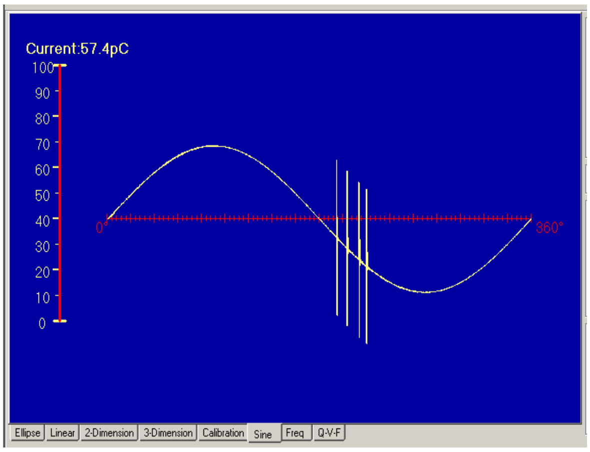
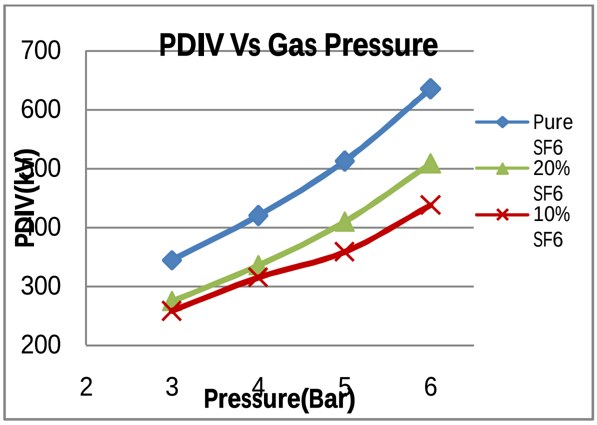



Fig 5: PD pattern with impurities on the electrode

The partial discharge inception voltage with respect to Varied pressure was measured for the two gas mixtures .The characteristics of partial discharge value with increase in pressure is plotted as given in fig 6.




## V. CONCLUSION

From the above experiment and the results, it can be concluded that $SF_6N_2$ mixture can offer viable solution for application in EHV GIS. The withstand and breakdown voltages are found to be near the desirable value as pr relevant standards. The GIS with $SF_6$ mixture can be evaluated in the same way as that of pure $SF_6$. The characteristic of the PD value is also same as that of pure $SF_6$.The $SF_6N_2$ mixture can replace pure $SF_6$ by operating at higher pressure to get the same dielectric properties. The reduction in $SF_6$ content will also help to address the environmental concerns.

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## BIOGRAPHY

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