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Metallic Particle Contamination in Three Phase Gas Insulated Busduct with Various Gas Mixtures

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ABSTRACT
Sulphur Hexafluoride (SF_6) is generally found to be very sensitive to field perturbations such as those caused by conductor surface imperfections and by conducting particle contaminants. A study of CIGRE group suggests that nearly 20% of failures in Gas Insulated Substations (GIS) are due to the existence of various metallic contaminations in the form of loose metallic particles. The breakdown strength of SF_6 is susceptible to metallic particle contamination, the presence of contamination is therefore a problem with gas-insulated substations operating at high fields. Thus, it is needed to develop the alternative dielectric gas or gas mixtures having better insulating characteristics and no greenhouse effect. The purpose of this paper is to develop techniques, which will formulate the basic equations that will govern the movement of metallic particles like Aluminium and Copper in a three phase gas insulated bus duct containing SF_6 and other gas mixtures like air, Argon, Carbon dioxide, Krypton, Nitrogen and Xenon. Simulation is carried out on wire like particles with three phase power frequency voltages of 400 kV and 600 kV applied to inner conductors in a three phase gas insulated busduct and the results have been presented and analyzed.
Keywords **-** Breakdown strength, Gas insulated busduct, Gas Insulated Substations, Metallic particle contamination, Sulphur Hexafluoride.

I. INTRODUCTION

Demand for electrical power has become one of the major challenges faced by the developing countries. Considering the relatively low per capita power consumption, there is a constant need for power capacity addition and technological up gradation whereas non-conventional energy systems have proved to be good alternative sources for energy. In developing countries like India most of the additional power has been met by conventional electric sources. Hence, the emphasis has shifted towards improving the reliability of transmission and distribution systems and ensuring that the innovations are not harmful to the environment. Several authors conducted experiments on insulating particles. Insulating particles are found to have little effect on the dielectric behavior of the gases [1-5]. However the presence of atmospheric dust containing conducting particles, especially on the cathode, reduces the breakdown voltage. Conducting particles placed in a uniform ac field lift-off at a certain voltage. As the voltage is raised, the particles assume a bouncing state reaching a height determined by the applied voltage. With a further increase in voltage, the bounce height and the corona current increase until break down occurs [5]. The lift off voltage is independent of the pressure of gas. After the onset of bouncing, the offset voltage is approximately 30% lower than the lift-off voltage. Several methods of conducting particle control and de-activation are given. Some of them are:

a. Electrostatic trapping
b. Use of adhesive coatings to immobilize the particles
c. Discharging of conducting particles through radiation, and
d. Coating conducting particles with insulating films.

The work reported in this paper deals with the movement of metallic particles in 3-phase common enclosure Gas Insulated Busduct with SF_6 gas and other mixtures. In order to determine the axial movement in an uncoated enclosure system, the Monte-Carlo technique has been adopted in conjunction with motion equation. The present paper deals with the computer simulation of particle movement in three phase common enclosure GIB with coated as well as uncoated system. The specific work reported deals with the charge acquired by the particle due to macroscopic field at the tip of the particle, the force exerted by the field on the particle and drag due to viscosity of the gas. Wire like particles of aluminium and copper of a fixed geometry in a 3-phase Busduct have been considered. The results have been compared with the particle movement in uncoated and coated Busduct. The movement pattern for higher voltages class has been also obtained. Monte-Carlo technique has been adopted for determining the axial movement of the particle. It has been assumed that at every time step the particle can have a maximum movement 1^0 to 4^0 from vertical.

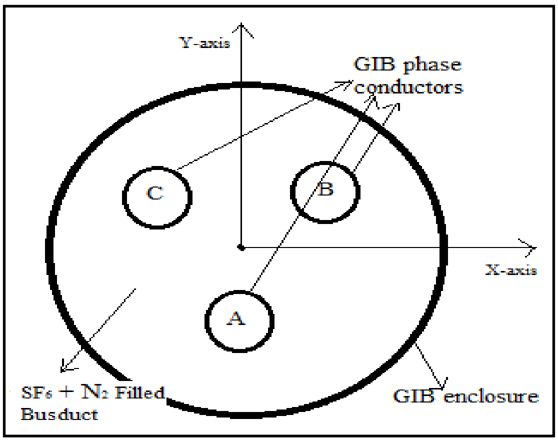

Fig.1. Typical three phase common enclosure Gas Insulated Busduct.

II. MATHEMATICAL MODELING

The movement pattern of the particle is simulated by using the following motion equation:

$$m\frac{d^2y}{dt^2} = F_e - mg - F_d \qquad (1)$$

Where
m = mass of the particle,
y = displacement in vertical direction,
g = gravitational constant.

The motion equation using all forces can therefore be expressed as:

$$m\,\ddot{y}(t) = \left[\frac{\Pi\varepsilon_0 l^2 E(t_0)}{\ln\left(\frac{2l}{r}\right)-1} \times \frac{V\sin\omega t}{[r_0 - y(t)]\ln\left(\frac{r_0}{r_i}\right)}\right] - mg - \dot{y}(t)\Pi r\left[6\mu K_d\left(\dot{y}\right) + 2.656\left[\mu P_g l\,\dot{y}\right]^{0.5}\right] \qquad (2)$$

The above equation is a second order non-linear differential equation and it is solved by using Runge-Kutta 4th order method.

The viscosity of a mixture of two gasses can be approximately calculated from the equation.

$$\mu = \frac{\mu_1}{1 + \dfrac{\frac{x_2}{x_1}\left[1 + \sqrt{\frac{\mu_1}{\mu_2}}\left(\frac{m_2}{m_1}\right)^{\frac{1}{2}}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{m_1}{m_2}\right)^{\frac{1}{2}}}} + \frac{\mu_2}{1 + \dfrac{\frac{x_1}{x_2}\left[1 + \sqrt{\frac{\mu_2}{\mu_1}}\left(\frac{m_1}{m_2}\right)^{\frac{1}{2}}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{m_2}{m_1}\right)^{\frac{1}{2}}}} \qquad (3)$$

Where, x_1 and x_2 are proportions, μ_1 and μ_2 viscosities and m_1 and m_2 are molecular weights of N_2 and SF_6 gasses respectively. m_1=28 g/mole, m_2=146 g/mole

III. SIMULATION

The Gas Insulated Busduct phase conductors and Enclosure radii are 32mm and 250mm respectively. Al/Cu metallic Particle length=12mm, radius=0.25mm and GIB pressure is 0.4MPa.

Software was developed in C language considering the above equations and was used for all simulation studies.

IV. RESULTS AND DISCUSSION

Figures 1.a to 1.f shows the maximum radial movement of Aluminium particles with SF_6 and other gas mixtures for power frequency voltage of 400 kV. It is observed that Aluminium particles have movement of 11.49mm to 11.65mm in SF_6 gas with other gas mixtures for the mentioned voltage.

Figure 2.a to 2.f shows the maximum radial movement of Copper particles with SF_6 and other gas mixtures for power frequency voltage of 600 kV. It is observed that Copper particles have movement of 7.10 mm to 8.6 mm in SF_6 gas with other gas mixtures. Table.1 shows the maximum radial movement of Aluminium particle with SF_6 and Xenon gas mixture for 400 kV. It is observed that for 100% SF_6 and 0% Xe the maximum radial movement of Aluminium particle is 11.56 mm.

And for 60% SF_6 and 40% Xe the corresponding movement is 11.49 mm. Table.2 shows the maximum radial movement of Copper particle with SF_6 and Xenon gas mixture for 600 kV. It is observed that for 100% SF_6 and 0% Xe the maximum radial movement of Copper particle is 7.84 mm. And for 80% SF_6 and 20% Xe the corresponding movement is 7.10 mm.

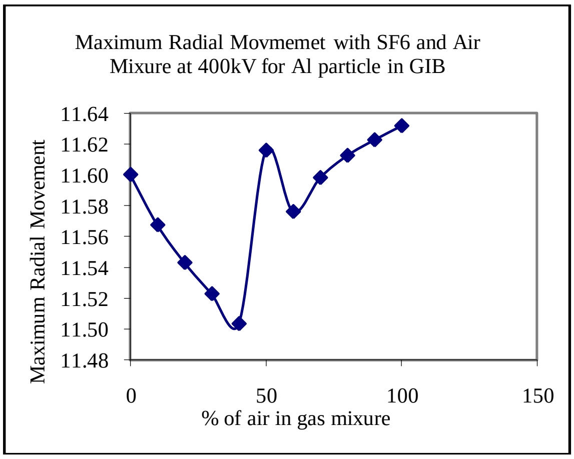

Fig.1.a

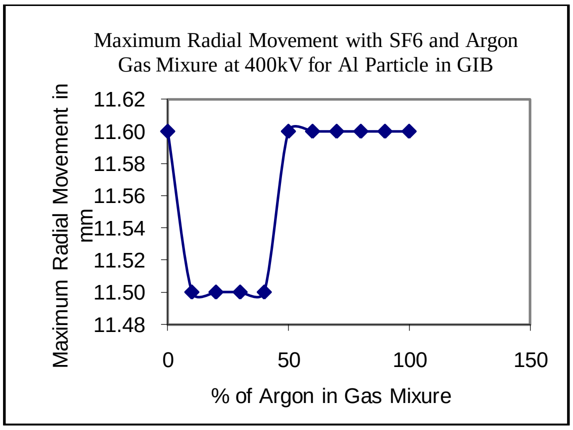

Fig.1.b

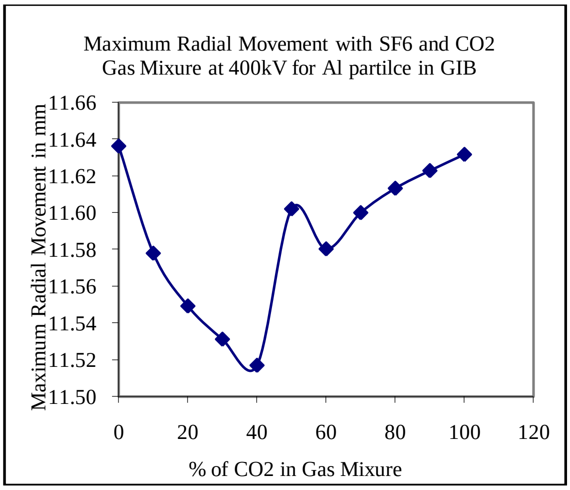

Fig.1.c

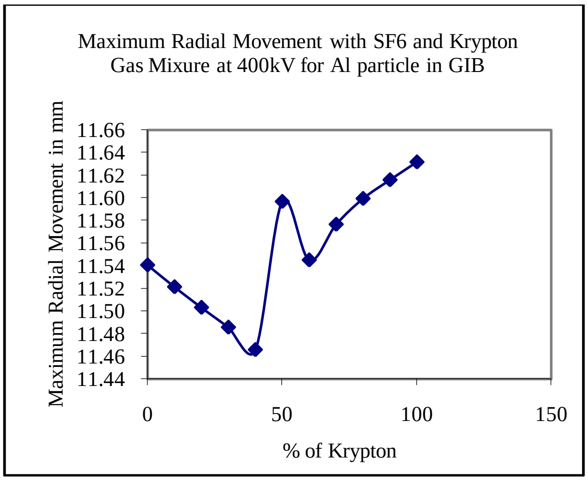

Fig.1.d

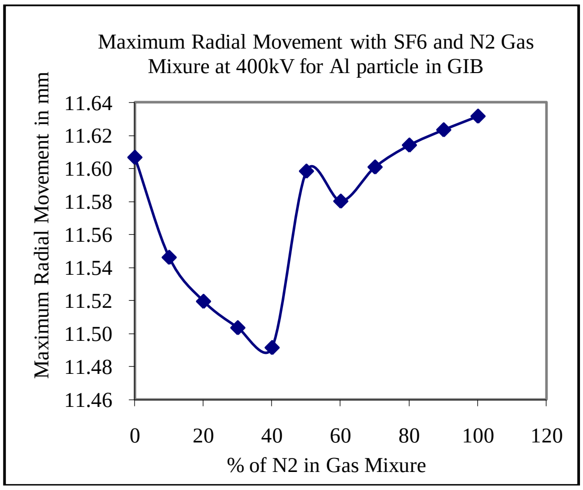

Fig.1.e

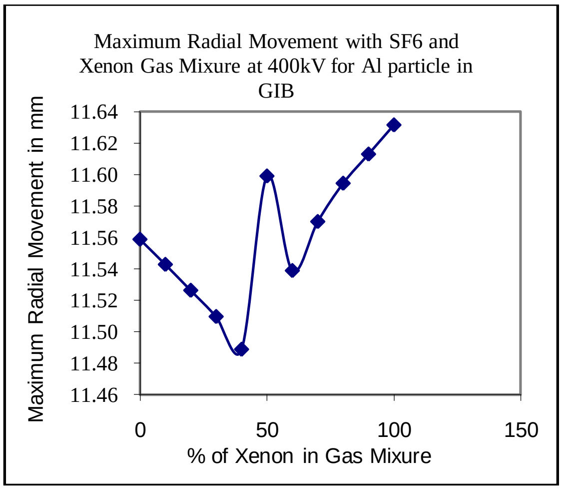

Fig.1.f

Figure 1.a-1.f: Maximum radial movement of Aluminium particles in GIB filled with mixture of SF_6 gas and other gases respectively.

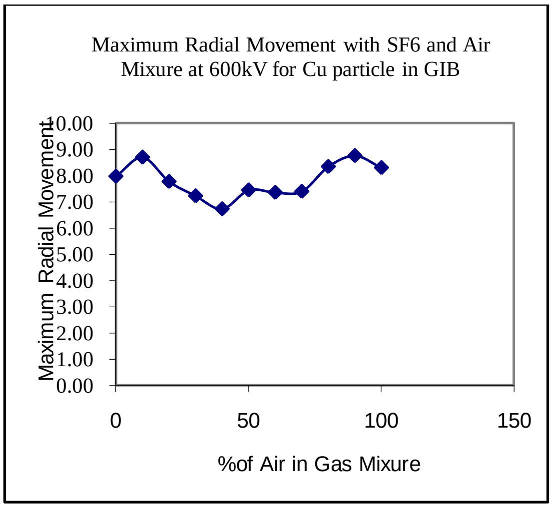

Fig.2.a

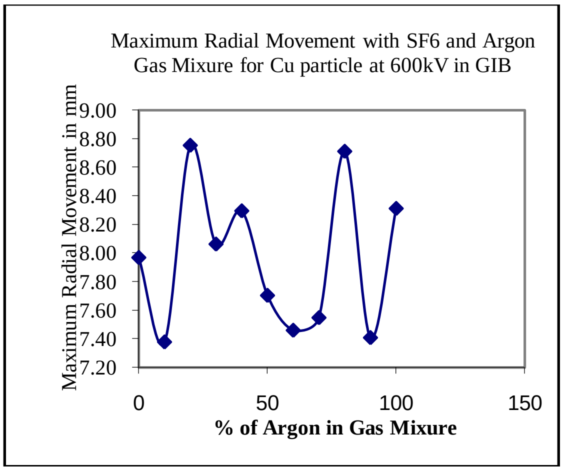

Fig.2.b

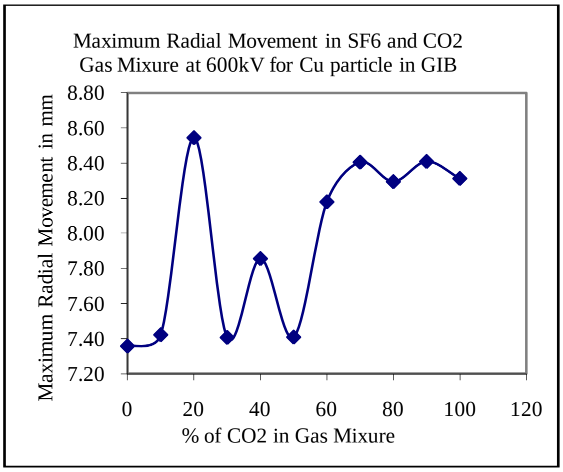

Fig.2.c

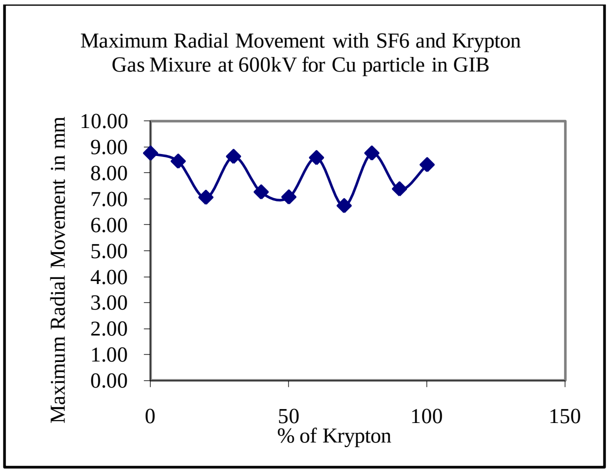

Fig.2.d

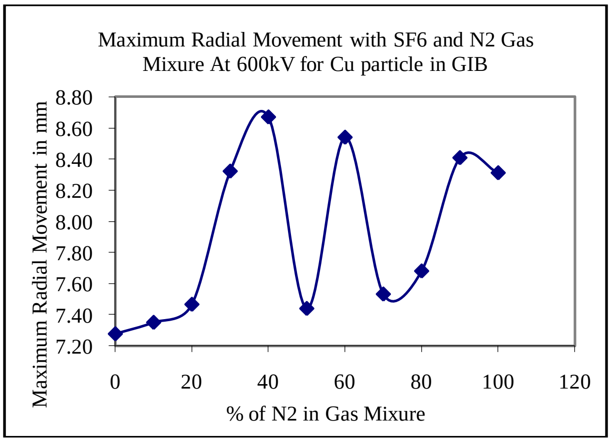

Fig.2.e

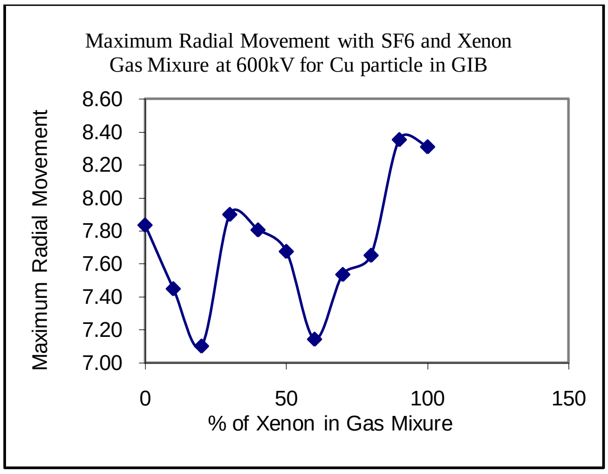

Fig.2.f

Fig.2.a-2.f: Maximum radial movement of copper particles in GIB filled with mixture of SF_6 gas and other gases respectively.

%SF6	%Xe	Ymax(Al)
100	0	11.56
90	10	11.54
80	20	11.53
70	30	11.51
60	40	11.49
50	50	11.60
40	60	11.54
30	70	11.57
20	80	11.59
10	90	11.61
0	100	11.63

Table.1: Variation of maximum movement (mm) of aluminum particle (l=12mm, r=0.25mm) in three phase GIB (32 mm /250 mm) with SF_6 and Xe mixture for 400 kV.

%SF6	%Xe	Ymax(Cu)
100	0	7.84
90	10	7.45
80	20	7.10
70	30	7.90
60	40	7.81
50	50	7.68
40	60	7.14
30	70	7.54
20	80	7.65
10	90	8.35
0	100	8.31

Table.2: Variation of maximum movement (mm) of Copper particle (l=12mm, r=0.25mm) in three phase GIB (32 mm /250 mm) with SF_6 and Xe mixure for 600 kV.

V. CONCLUSION

A model has been formulated to simulate the movement of wire like particles in 3-phase common enclosure Gas Insulated Busduct with SF_6 gas and other gas mixtures. The results have been presented and analyzed in this paper. Distance traveled in the radial direction is found to be decreasing with SF_6 with other gas mixtures. From the above results it is observed that in three phase common enclosure Gas Insulated Busduct with 40% to 50% gas mixture the radial movement is minimum compared with pure SF_6. Hence 40% to 50% of gas mixture is highly reliable for the operation of GIS.

VI. ACKNOWLEDGEMENTS

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