Performance of Three Phase Gas Insulated Substation Using SF$_6$/KR, SF$_6$/N$_2$, SF$_6$/AIR Gas Mixtures under Particle Contamination

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Abstract

In threephase encapsulated Gas Insulated substation SF$_6$ gas is encapsulated in inside grounded enclosures. Since insulation strength of SF$_6$ gas is quite good, but its Global Warming Potential is several hundred times more than CO$_2$ gas which is the main root of global warming. Considering the environmental effects, it is highly recommended to reduce the green house gas effects due to sf6. One possible solution is diluting the SF$_6$ gas using various gas mixtures such as SF$_6$/Kr, SF$_6$/N$_2$, SF$_6$/Air at high pressure. From the past studies it is mentioned that twenty percent of faults in three phase gas insulated substation are due particles present in the insulating gas. These particles may be conducting in nature or insulating in nature. In this paper conducting particle movement in three phase GIS is analysed using above mentioned gas mixture and results were presented, copper particles were considered for the study.

Keywords: gas insulated substation, green house gas, conducting particles, copper particles

Introduction

One of the prime threaten in front of utilities are, they try to inflate and progress their infrastructure such as substation, transmission lines is land acquisition and ROW is complicated and needs much time to do the project. In that motive, researchers are encouraged to find alternative solution and make use of space available to upgrade grid. The three phase encapsulated Gas Insulated Substation (GIS) offers a way out to space crisis in impenetrable urban vicinity where limited land is available at too expensive cost. The uniqueness of this kind of substations employ SF$_6$ gas as insulation medium, such that distance between live and non active parts in a substation are reduced considerably resulting in drop of overall space of substation[1-

3].

But many anti SF_6 voices where heard over the influence of the gas on the atmosphere. From the reports it is mentioned that SF_6 is kept in the basket of green house gasses Kyoto Summit on Climate Change held in December 1997. So there is a need to find possible solution to SF6 gas, according to report [2-5] one such alternative is to go for mixture gas such as SF6/Kr, SF_6/N_2, SF_6/Air. The mixture gas is most optimistic dielectric gas for the rationale of SF_6 gas amount. From the earlier studies the major faults in GIS are due to particle contamination. Even though insulation strength of SF_6 is lofty, the withstand voltage hugely reduced due to presence of metallic particles [6-7]. In this investigation. In this investigation paper conducting metallic particle movement in encapsulated GIS with and with out coating the electrodes is analysed using above mentioned gas mixture and results were presented, copper particles were considered for the investigation.

Modelling Technique
The Fig. 1 and Fig. 2 shows a typical encapsulated three phase busduct with and without dielectric insulating epoxy coating. The enclosures are filled with SF_6 gas at high pressure. A metallic particle initially at resting position gets lifted up after acquiring sufficient charge and move in the direction of applied field having conquering the forces such as drag and own weight.
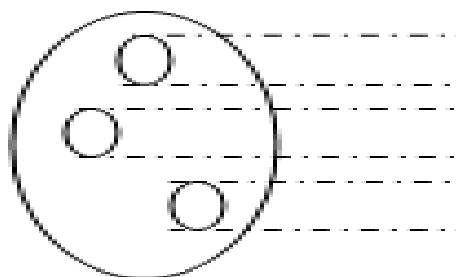
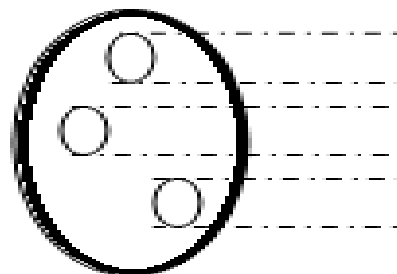**Figure 1**   **Figure 2**

The simulation contemplates several parameters such as Reynolds number, coefficient of restitution, skin friction, shock friction, macroscopic field.

MATHEMATICAL ANALYSIS
Many authors [3-6] have recommended possible solutions for the motion of particles of various shapes like sphere, wire and so on. since we are concentrating on wire like particles, the moton equation is dependent on the direction of the particle (y), electrostatic force, gravity force and drag force, The drag force is dependent on shock friction and skin friction. The equation 1 and 2 given below gives the shock friction and skin friction

$$F_{d1} = 6\pi\mu r y K_d \, (\dot{y}) \qquad\qquad 1$$

Where μ the viscosity of the fluid or gas, r isis the copper particle radius, y is copper particle velocity, k coefficient of drag.

$$F_{d2} = 1.328(2\pi r)\left[\mu\rho_g l\right]^{0.5} \dot{y}^{\,1.5} \qquad\qquad 2$$

Where ρ_g the gas mixture density, l is the particle length.

CALUCLATION AND SIMULATION OF ELECTRIC FIELD IN 3-PHASE BUSDUCT WITH AND WITHOUT COATING

The charge attained by the wire particles in contact with a bare enclosure and coated enclosure can be expressed in [2]. The electric field in encapsulated 3-phase GIB at the conducting particle can be written as

$$E(t) = \sum_{i=0}^{3} E(i) \; --- 3$$

Where, E(t) is the electric field in direction due to the field of three conductors on the surface of the particle at the enclosure. E(i) where i=1, 2, 3. are the components of the electrical field in direction. The gravitational force and drag forces are measured as described by authors [3-6].

SIMULATION STUDY:

Computer simulations of the wire particles motion were conceded out on GIB of 32mm inner diameter of enclosure and 250mm outer diameter with 345KV applied to inner conductors with equal phase shift. A conducting metallic particle motion, in an external electric field will be subjected to a united impact of some forces discussed above. Software was developed in developer C language to calculate and to analyse the motion of conducting particle.

RESULTS AND DISCUSSIONS

From Table I it is observed that for an applied voltage of 345kV for 100% SF6 maximum movement was recorded as 7. 167006mm for Copper particles. In case of 20%, 40%, 60% and 80% of kr in SF6/Kr gas mixture the corresponding values of particle movement are 7. 162761mm, 7. 107876mm, 7. 109143mm, 7. 069825mm, respectively. Similarly In case of 20%, 40%, 60% and 80% of N_2 in SF6/N_2 gas mixture the corresponding values of particle movement are 7. 150159mm, 6. 976185mm, 7. 001143and 7. 132594mm respectively. Similarly In case of 20%, 40%, 60% and 80% of Air in SF6/Air gas mixture the corresponding values of particle movement are 7. 118617mm, 7. 06955mm, 6. 912118mm and 7. 022599mm respectively. The figure 3-5 shows the particle movement for different proportions of SF6/Kr, SF6/N_2, SF6/Air. And the figure 6-8 shows the particle movement for 40% SF6 and 60 % kr, N2 and Air respectively. From the above table and figure it is observed that it is ideal to use SF6 gas mixture of 20% to 40% for minimum particle

movement. It is also recommended that, it is better to go for 20% SF_6 in encapsulated GIB considering global warming in mind

Table 1. 1

S. no	SF$_6$ (%)	PARTICLE MOVEMENT (MM)		
		Kr	N$_2$	Air
1.	100	7. 167006	7. 167006	7. 167006
2.	80	7. 162761	7. 150159	7. 118617
4.	60	7. 107876	6. 976185	7. 06955
5.	40	7. 109143	7. 001143	6. 912118
6.	20	7. 069825	7. 132594	7. 022599
7.	0	7. 129605	7. 151536	7. 16409
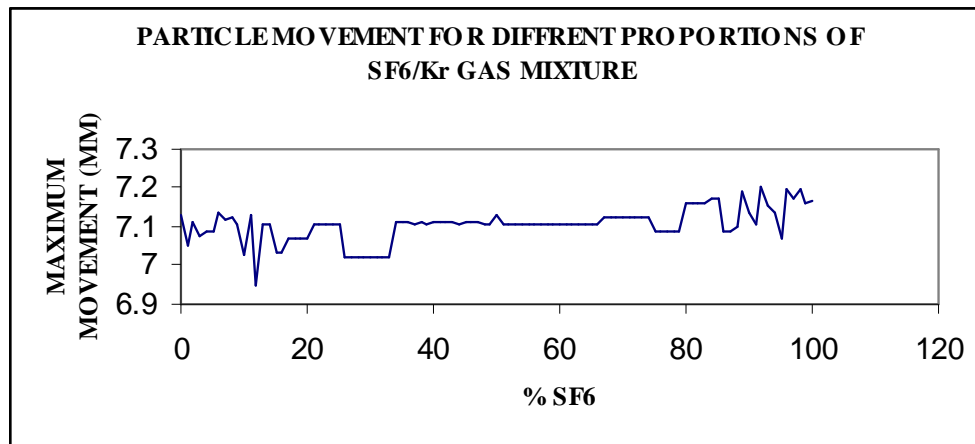
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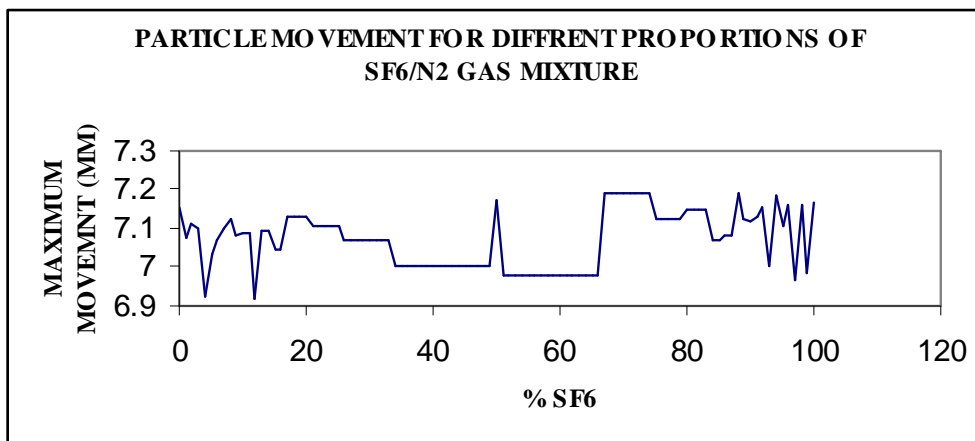
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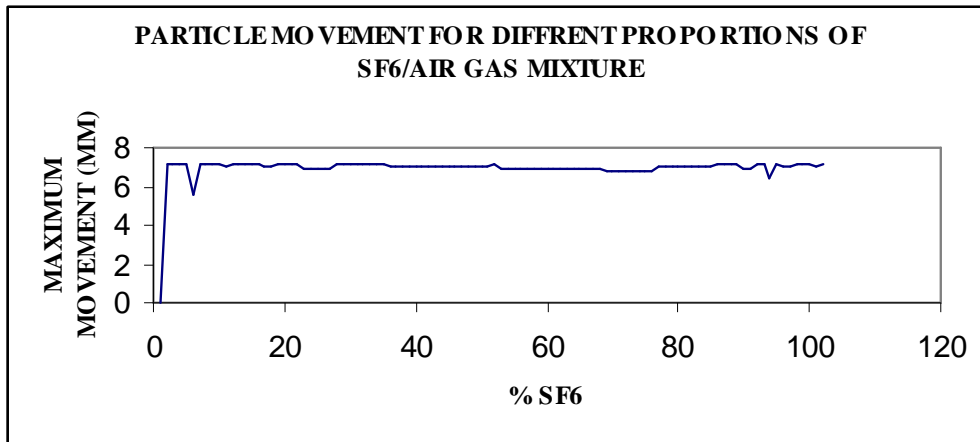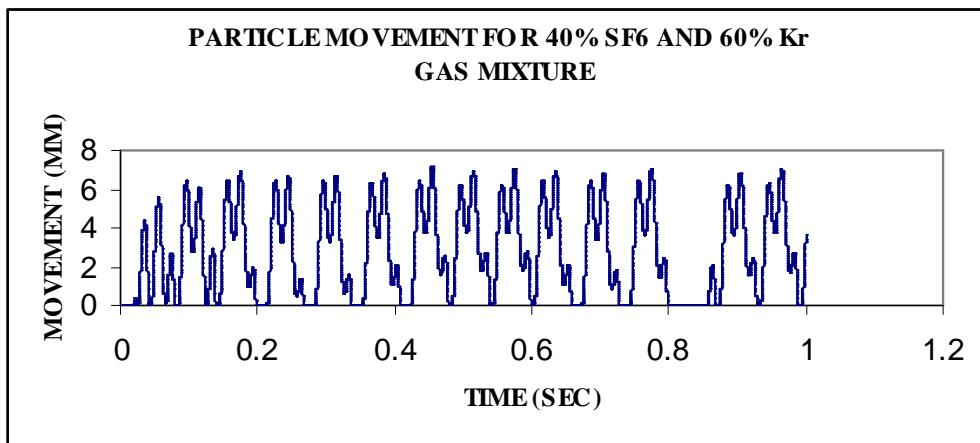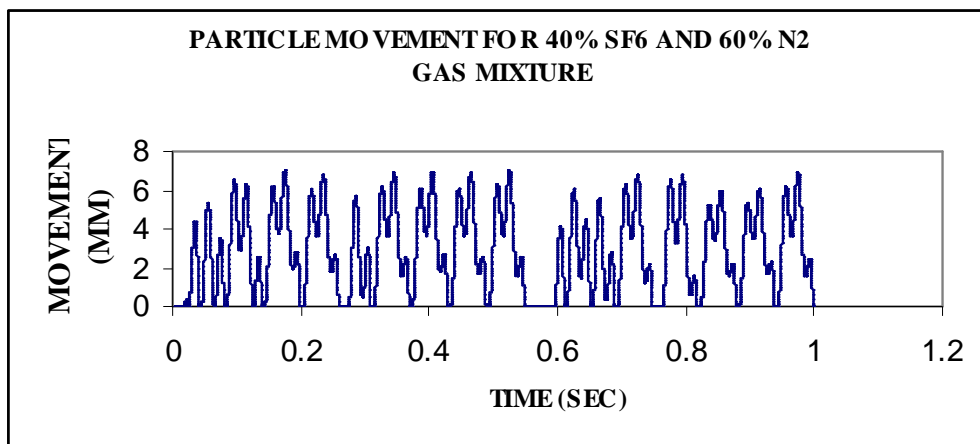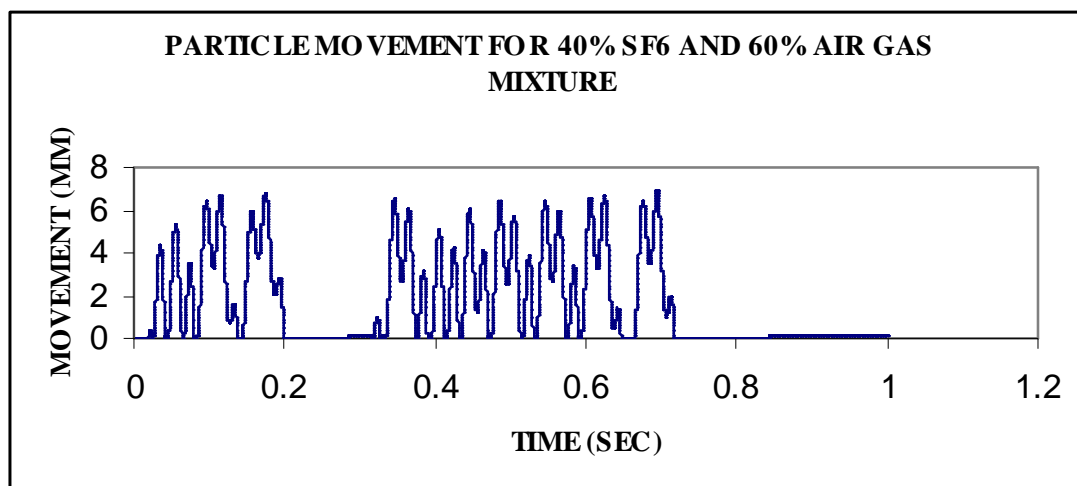
Figure 5

Figure 6

Figure 7

Figure 8

CONCLUSION:

In this paper the motion pattern for various metallic particles of copper wire type in a three phase common enclosure gas insulated busduct has been investigated the calculations are made for power frequency level. The results have been presented and analyzed for various gas mixtures mentioned. From the above results it is found that for gas proportion of 20 % SF_6 and 80% of any one of remaining gas such as Kr, N2 and Air is highly recommended keeping the reliability and global warming in mind.

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