Various Effects of Particle Movement in a Single Phase Uncoated Encapsulated GIS with Various Gas Mixtures

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ABSTRACT

SF_6 gas compressed in metal encapsulation has lessened the size of transmission and distributed substation as well as reliability is enhanced considerably over conventional substations. Metal encapsulated gas insulated substation (GIS).Basically consists of enclosure, insulators to support conductor which is crammed with SF_6 gas. Since SF_6 is a green house gas leads to global warming, one alternate arrangement to SF_6 is to use gas mixture .This gas mixture gives matching chemical and physical properties as SF_6. In a GIS the withstand capability of voltage level depends on field perturbations which occurs due to imperfections on the surface and by contaminated particles which are conducting. The conducting particles lifts up and migrate to various portions in between inner conductor and outer enclosure which leads to breakdown at voltage levels below SF_6 gas insulation characteristics. In this paper, using the equation of particle motion in an electric field, simulation of particle movement is carried out for various gas mixtures such as SF_6/Air, SF_6/Ar, SF_6/Kr, SF_6/CO_2 and $SF6/N_2$ of various proportions. Cu and Al are considered as metallic particles for the study to examined and presented.

Keywords

Encapsulated GIS, global warming, particle contamination, gas mixtures, particle movement.

1. INTRODUCTION

The most commonly used insulating gas in electrical system is SF6 gas till date [1]. Encapsulated Gas insulated substations are most widely used in the modern electrical power systems for distribution and transmission of electrical power. The entire substation equipments such as disconnectors,busbars,current transformer, potential transformers, circuit breakers, power transformers,etc are insulated with sf6[2]. The power industry uses approximately 80% of the SF6 produced worldwide and rest of the sf6 production is used in various industries related to magnesium,aluminium,semiconductors ect,demand for sf6 is raising day by day . Accumulation of sf6 is serious concern since sf6 is a 'greenhouse' gas and it leads to global warming [3] and it is estimated that global warming potential of SF6 is 25,000 times greater than that of CO2. The possible solution to this problem is to use gas mixtures such as Air/Ar/Kr/ CO2/N2 in sf6.

The dielectric strength of this gas mixtures are very high , but voltage with stand voltage reduces drastically within the Gas Insulated substation due to metallic particles present in the system creates localized electrical stress . These particles are originated during the manufacturing process, assembling process or from mechanical vibrations or from circuit breakers moving parts. The shape of these particles may be of spherical, wire like (filamentary) or fine dust. When these particles are subjected to uniform field of alternating current at certain voltage. As the voltage enhances above certain level, the particle undergo bouncing state due to alternating current reaches a height depends on the applied voltage. As the voltage increases further, the bouncing height increases which leads to break down .so, metallic free wire particles are more dangerous and harmful and more pronounced effects takes place at higher voltages [4].

The reliability of compressed Gas Insulated Substation can be improved by eliminating the effects of these metal particles and one of the methods suggested is using adhesive coatings on GIB electrodes. The movement of particle in GIS is a serious concern

In this paper ,work related with the particle movement of wire like conducting particle in single phase encapsulated Gas Insulated Substation using various gas mixtures is been carried out with different proportions. The particle movement in enclosure is determined using analytical method in conjunction with motion equation. The simulation work specifically reports the acquired charge of the particle, the force exerted by the electrical field on the charged particle, force due to drag and particle movement random behavior.

2. MATHEMATICAL MODELING

The typical arrangement of single phase encapsulated gas insulated substation is shown in the figure 1.The enclosure is filled with sf6 gas mixture at high pressure. In the enclosure the metallic particle is said to be at rest, under the bus bar, the particle tends to lift up and travel if sufficiently large enough voltage is applied. The particle travels in the direction of field after getting sufficient charge overcoming drag force and own weight force.

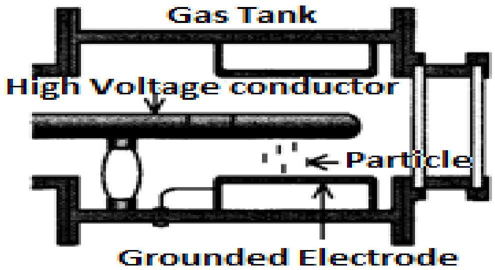


Fig. 1 Typical 1-phase encapsulated GIS

The particle macroscopic field, Reynolds's number, viscosity of Sf6 gas mixture and restitution coefficient is considered for simulation. A new charge is acquired by the particle during return flight which is dependent on instantaneous electric field. Many Authors [3-5] suggested solutions for the motion equation of various particle of spherical and wire type in nature in a encapsulated Gas Insulated Substation is depent on the drag force, electrostatic force and gravitational force. The motion equation can written as

$$Fe - mg - Fd = \frac{d^2y}{dt^2} \quad \text{---1}$$

This equation results in second order non-linear differential equation, using Runge-Kutta 4th order method is used to solve this equation.

3. SIMULATION OF ELECTRIC FIELD IN GAS INSULATED BUSDUCT WITH GAS MIXTURES

The viscosity of the gas mixture is very important in GIS to the drag force and the viscosity of two gasses can be calculated from the equation

$$\mu = \frac{\mu 1}{1 + \frac{\frac{x2}{x1}\left[1+\sqrt{\frac{\mu 1}{\mu 2}\left(\frac{m2}{m1}\right)}\right]^2}{\frac{4}{\sqrt{2}}\sqrt{\left(1+\frac{m1}{m2}\right)}}} + \frac{\mu 2}{1 + \frac{\frac{x1}{x2}\left[1+\sqrt{\frac{\mu 2}{\mu 1}\left(\frac{m1}{m2}\right)}\right]^2}{\frac{4}{\sqrt{2}}\sqrt{\left(1+\frac{m2}{m1}\right)}}} \quad \text{---2}$$

Where x_1, x_2, m_1, m_2 and μ_1, μ_2 are gas proportions, molecular weights and gas viscosities in that order correspondingly. Subsequent to this equation value of Reynolds number is calculated to substitute in motion equation. The Gas Insulated Busduct conductors and Enclosure radii are 27.5mm and 76mm respectively. Al/Cu metallic Particle length=12mm, radius=0.25mm and GIS pressure is 0.4MPa, Restitution Coefficient is 0.9. Considering the above equations c program was developed and used for all simulation studies.

4. RESULTS AND DISCUSSIONS

From Table I it is observed that for voltage of 75 KV for pure SF6 i.e. 0% concentration of Gas Mixtures (Ar/Kr/Air/ CO2 /N2) maximum movement of 1.771632 mm recorded for Copper particle and in case of 30% gas mixture(Ar/Kr/Air/ CO2 /N2) and 70% SF6 mixture the corresponding values are 1.702797 mm, 1.765492mm, 1.762953 mm, 1.750118mm, 1.763348 mm respectively . It is observed that as the percentage of gas mixture changes the maximum radial movement also changes. From Table I it is observed that, radial movement is less for 60% of Ar in SF6 and Ar gas mixture, less for 60% of Kr in SF6 and Kr gas mixture, radial movement is less for 60% of Air in SF6 and Air gas mixture, radial movement is less for 100% of CO2 in SF6 and Co2 gas mixture, radial movement is less for 30% of N2 in SF6 and N2 gas mixture. Figures 1-5 shows the particle movement of Aluminum particle of wire type with SF6 Gas Mixtures for 75 KV in a Single phase encapsulated GIS for a proportion of 70% SF6 and 30% Gas Mixture.Similarly From Table II it is observed that for voltage of 75 KV for pure SF6 i.e. 0% concentration of Gas Mixtures (Ar/Kr/Air/ CO2 /N2) maximum movement of 9.327675mm recorded for Aluminum particle and in case of 30% gas mixture (Ar/Kr/Air/ CO2 /N2) and 70% SF6 mixture the corresponding values are 9.027155mm, 9.119467mm, 9.128488mm, 9.132974, 9.043084mm respectively. From Table II it is observed that, radial movement is less for 60% of Ar in SF6 and Ar gas mixture, less for 60% of Kr in SF6 and Kr gas mixture, radial movement is less for 60% of Air in SF6 and Air gas mixture, radial movement is less for 100% of CO2 in SF6 and Co2 gas mixture, radial movement is less for 30% of N2 in SF6 and N2 gas mixture. Figures 1-5 shows the particle movement of Copper particle of wire type with SF6 Gas Mixtures for 75 KV in a Single phase encapsulated GIS for a proportion of 70% SF6 and 30% Gas Mixture.

Table I: Variation in particle movement of Aluminum particle of wire type with SF_6 and Gas Mixtures of various proportions for 75 KV in a Single phase encapsulated GIS

Gas Mixture	Maximum Movement (mm) for 75 KV			
	% concentration of Gas Mixtures (Ar/Kr/Air/ CO2 /N2)			
	0	30	60	100
Ar	9.327675	9.027155	8.988458	9.397079
Kr	9.327675	9.119467	9.097766	9.134595
Air	9.327675	9.128488	9.035624	9.134826
Co2	9.327675	9.132974	9.094575	8.890908
N2	9.327675	9.043084	9.440674	9.012948

Table II: Variation in particle movement of Copper particle of wire type with SF_6 and Gas Mixtures of various proportions for 75 KV in a Single phase encapsulated GIS

Gas Mixture	Maximum Movement (mm) for 75 KV			
	% concentration of Gas Mixtures (Ar/Kr/Air/ CO_2 /N_2)			
	0	30	60	100
Ar	1.771632	1.702797	1.768217	1.716991
Kr	1.771632	1.765492	1.762893	1.75722
Air	1.771632	1.762953	1.771599	1.76201
Co_2	1.771632	1.750118	1.764246	1.762482
N_2	1.771632	1.763348	1.745147	1.771889

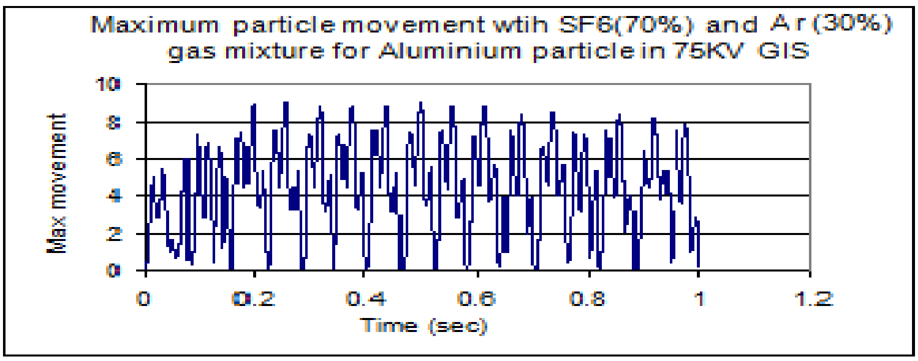


Figure 1

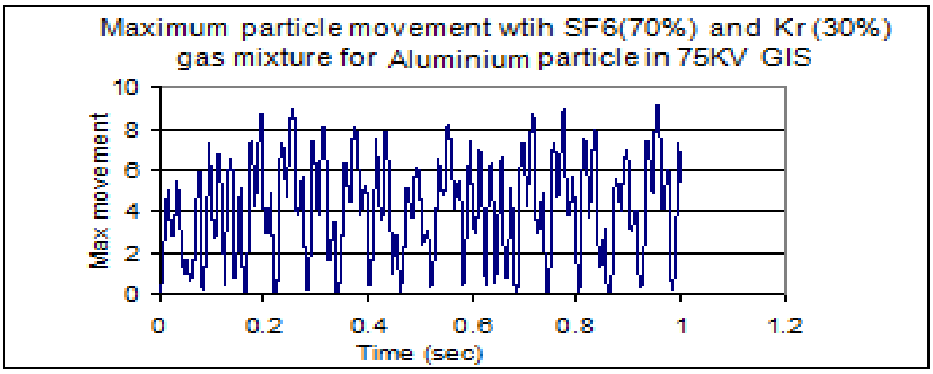


Figure 2

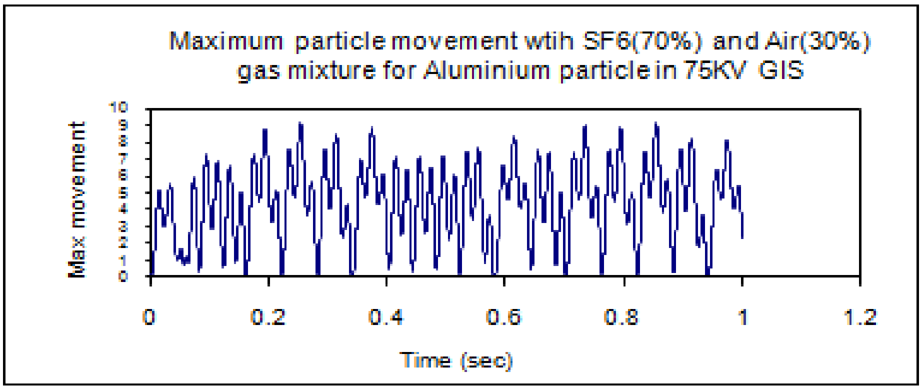


Figure 3

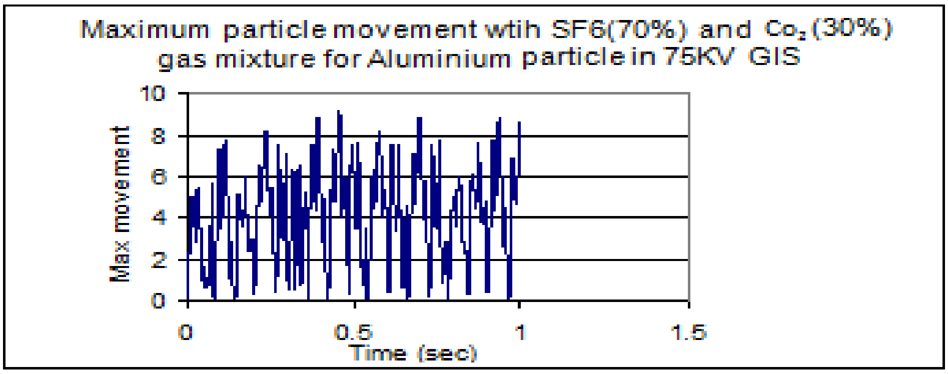
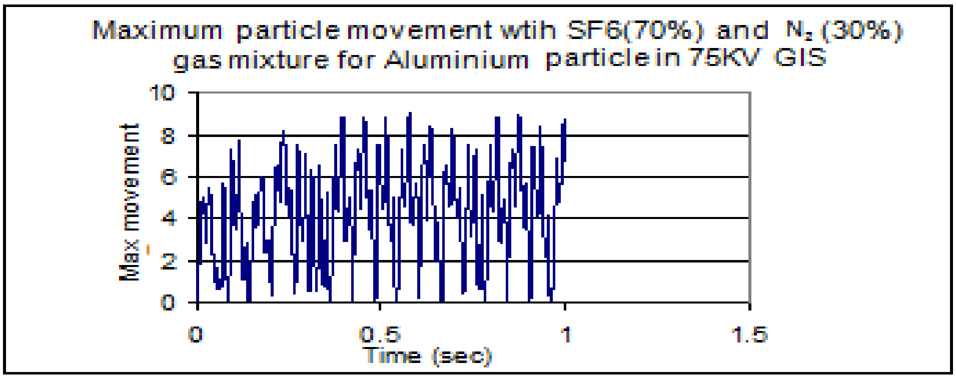


Figure 4



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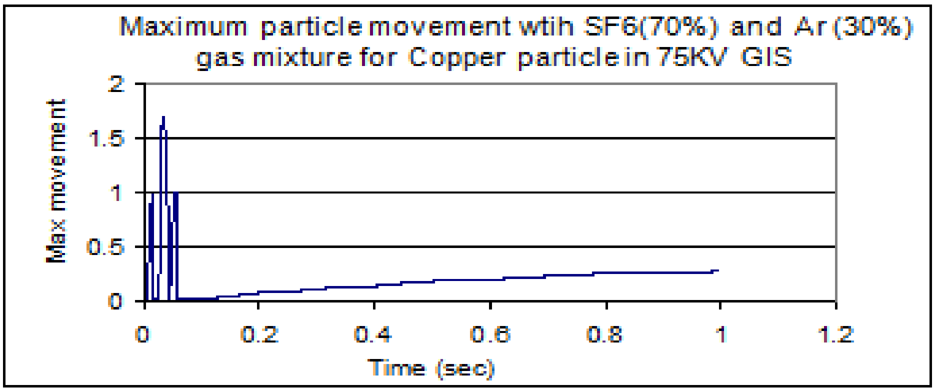

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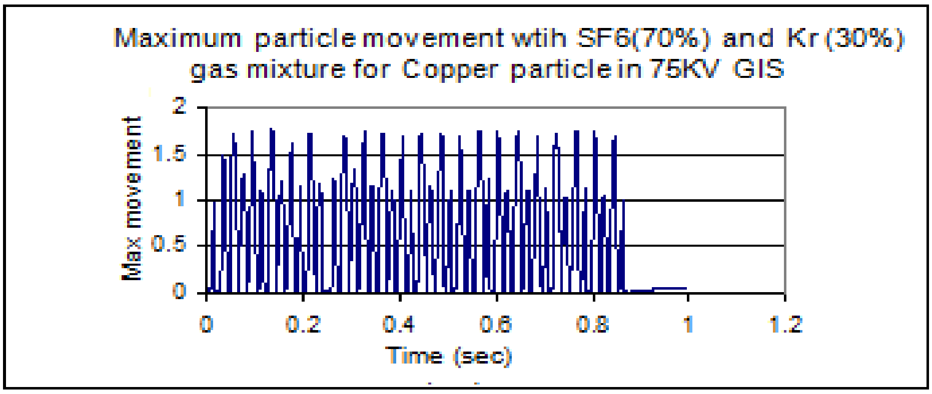

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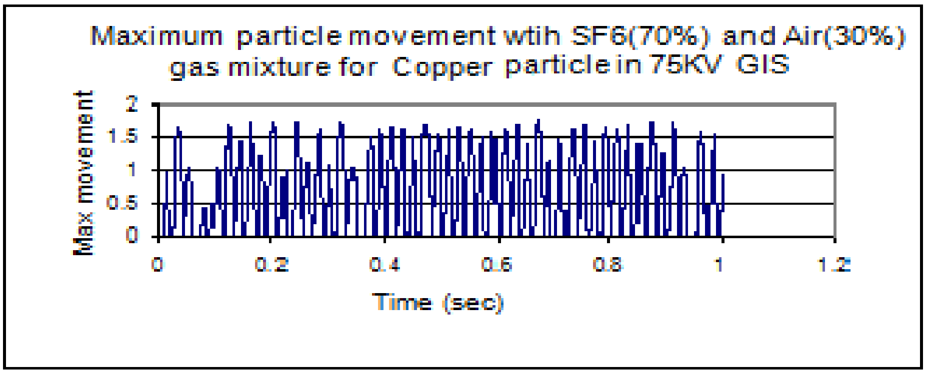

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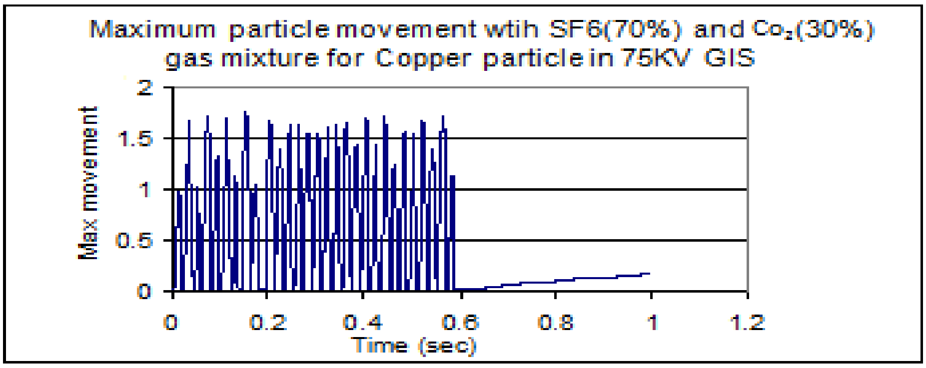

Figure 9

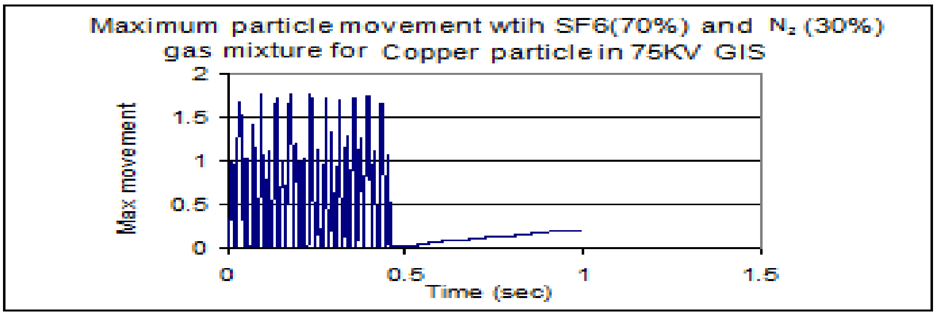

Figure 10

5. CONCLUSION

In this paper with SF_6 gas and other gas mixtures the movements of wire like particles are modeled and simulated. The simulated results are examined and presented. From the findings it is observed that the radial movement of the particle is least for majority of gas mixtures when 40% SF_6 and 60% Gas mixture is used in single phase uncoated encapsulated GIS. Consequently encapsulated GIS have better reliability at this proportion. Since Accumulation of sf6 is serious concern since sf6 is a 'greenhouse' gas and it leads to global warming this kind of encapsulated GIS using various gas mixtures reduces the usage if SF_6 to higher extent. Further this study can be carried out on the particle behavior of various gas mixtures with coating the inner surface with dielectric material of enclosure

6. ACKNOWLEDGMENTS

The authors are gratified to authorities of JNTUH, Hyderabad, and Adams Engineering College, Paloncha, India.

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