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# Performance of $SF_6$ GIB under the influence of power frequency voltages

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**Abstract**

A method based on particle motion is proposed to determine the particle trajectory in Gas Insulated Substation (GIS) or Gas Insulated Busduct (GIB). In order to determine the movement of a particle in a GIB, an inner electrode diameter of 40mm and outer enclosure diameter of 137mm was considered. Aluminium and copper wires of 0.25mm/10mm and 0.25mm/12mm were considered to be present on the enclosure surface. The motion of the wire (particle) was simulated using the charge acquired by the particles, the macroscopic field that the particle site, the drag coefficient, Reynold's number and coefficient of restitution. In order to determine the random behaviour of moving particles, the calculation of movement in axial and radial directions was done at every time step using rectangular random numbers. Typically for Aluminium wire for a bus duct voltage of 100 kV RMS, the movement of the particle (0.5mm / 8mm) for 2 Sec was computed to be 18.0337mm in radial and 424.4979mm in axial directions and the movement of the particle (0.25mm / 12mm) for 2 Sec was computed to be 22.4249mm in radial and 503.618mm in axial directions. Similar calculation is extended for a typical 200 kV (RMS) Gas Insulated Busduct.

**Keywords:** Monte-Carlo, Particle Contamination, Particle Movement, Horizontal Movement, Vertical Movement.

## 1. Introduction

The excellent dielectric properties of Sulphur Hexa floride ($SF_6$) have long been recognized of various high voltage applications. Compressed SF6 gases have been used as an insulating medium as well as are quenching medium in electrical apparatus over a wide range of voltages. Due to high reliability of equipment, Gas Insulated Busduct (GIB) or Gas Insulated Substations (GIS) can be used for longer duration without any periodical inspections. Conducting contaminations could however, seriously reduce the dielectric strength of Gas Insulated system.

The present paper deals with the computer simulation of particle movement in GIB. The specific work reported deals with the charge acquired by the particle due to microscopic field at the location of the particle, the force exerted by the field on particle, the drag due to viscosity of the gas and random behavior during movement.

## 2. Modeling Technique

A typical horizontal bus duct comprising of inner conductor and outer enclosure, filled with $SF_6$ gas is considered for study. A particle (wire) is assumed to be at rest at the enclosure surface, until a voltage sufficient enough to lift the particle and move in the field is applied. After acquiring an appropriate charge in the filed, the particle lifts and begins to move in the direction of the field overcoming the forces due to its own weight and drag. The simulation considers several parameters e.g. the macroscopic field at the location of the particle, its weight, viscosity of the gas, Reynold's number, drag coefficient of restitution on its impact to enclosure. During return flight, a new charge on the particle is assigned based on the instantaneous electric field.

## 3. Theoritical Study

The primary goal of the simulations was to create an appropriate mathematical model of the particle motion in a GIS which will enable further simulations of the motion particles with arbitrary shapes. Several authors [1-7] have suggested solutions for the motion of sphere or a wire like metallic particle in a coaxial system with bare electrodes under AC voltage. The motion equation of a particle can be expressed

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

Where y is the direction of motion m is the mass of particle, $F_e$ is the electric force and $F_d$ is drag force, the direction of the drag force is always opposed to the direction of motion. For laminar flow the drag force component around the hemispherical ends of the particle is due to shock and skin friction [2-3].

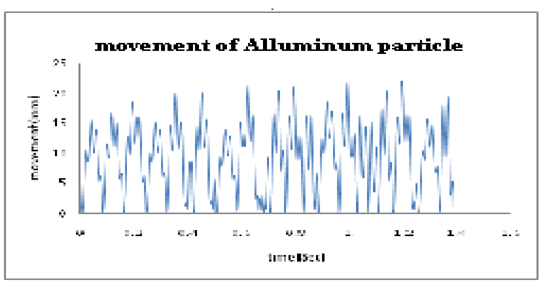
## 4. Simulation of Particle motion

Computer simulations of the motion of metallic wire particles were carried out on GIB of 40mm inner diameter and 137mm outer diameter with 100KV RMS applied to inner conductor. A Software was developed in C language considering the above equations and was used for all simulation studies.

## 5. Simulation Results and Discussions

Fig.1.(a) shows the movement of aluminum particle in radial direction for an applied voltage of 100kV rms and length of the particle to be 12mm/8mm. The highest displacement in radial direction during its upward journey is simulated to be 22.4249mm/18.0337mm. As the applied voltage is increased the maximum radial movement also increases as given in table1. Fig.1.(b) shows the movement of copper particle was determined for 100 kV with similar parameters as above and was found to have a maximum movement of 4.8588mm/3.5191mm in radial direction. The movement of Cu particle for various voltages is also given in Table 1.

(a) Aluminum




(b) Copper

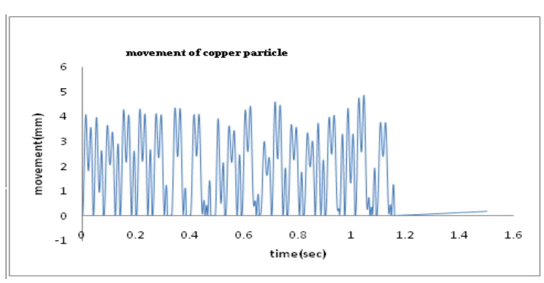


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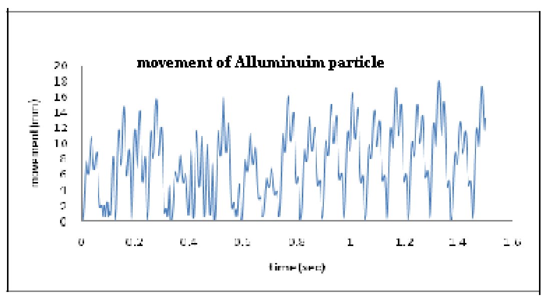
Fig.1 Movement of particle with 0.25 mm diameter and length 12 mm, voltage 100 kV

It is noticed that the movement of copper particle is far less than aluminum particle of identical size. This is expected due to higher weight of particle. The axial and radial movements of aluminum and copper particles are calculated using Monte-Carlo technique for three voltages viz 100kV, 145kV and 200 kV with solid angle of $1^0$. It is significant to note that for all the cases considered, there is no change in maximum radial movement, even when Monte-Carlo method is applied.

(a) Aluminum




(b) Copper

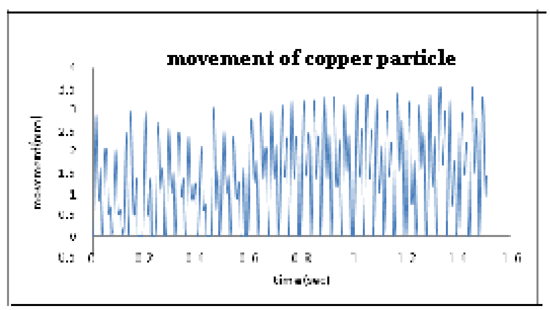



Fig.2 Movement of particle with 0.25 mm diameter and length 8 mm, voltage 100 kV

Table1: Axial and Radial Movement of Aluminum and Copper particles: simulation time: 2 Sec, length: 12mm

| | | | Montecarlo(ø=1°) | |
|---|---|---|---|---|
| Voltage(kv) | type | Max radial movement(mm) | Axial(mm) | Radial(mm) |
| 75 | Cu<br>Al | 0<br>12.6434724 | 0<br>321.9089 | 0<br>12.6434 |
| 100 | Cu<br>Al | 4.8588465<br>22.4252277 | 90.0969<br>503.618 | 4.8588<br>22.4249 |
| 145 | Cu<br>Al | 13.5588784<br>36.0058479 | 169.0688<br>925.8408 | 13.5588<br>36.0057 |
| 200 | Cu<br>Al | 17.9470618<br>57.7206982 | 16.5564<br>506.7857 | 17.9463<br>57.7204 |

Table2: Axial and Radial Movement of Aluminum and Copper particles: simulation time: 2 Sec, length: 8mm

| | | | Montecarlo(ø=1°) | |
|---|---|---|---|---|
| Voltage(kv) | type | Max radial movement(mm) | Axial(mm) | Radial(mm) |
| 75 | cu<br>Al | 0<br>9.6583535 | 0<br>270.3076 | 0<br>9.658 |
| 100 | Cu<br>Al | 3.5190949<br>18.0337695 | 91.1911<br>424.4979 | 3.5191<br>18.0337 |
| 145 | Cu<br>Al | 10.718734<br>28.3301506 | 252.9008<br>763.4532 | 10.7187<br>28.3289 |
| 200 | Cu<br>Al | 16.9603977<br>50.1567259 | 75.2338<br>942.0275 | 16.9603<br>50.155 |

## 6. Conclusions

A model has been formulated to simulate the movement of wire like particle in Gas Insulated Busduct (GIB). Monte- Carlo simulation in adopted to determine the axial as well as radial movements of particle in the bus duct. Distance traveled in the radial direction is found to be same with or without Monte- Carlo simulation**.**

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