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Field Effects on Multiple Particle Contamination And Breakdown Voltage Inside Gas Insulated Bus Duct.

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ABSTRACT:
The metallic particle contamination in the Gas-Insulated Systems (GIS), plays a key role for the occurrence of Partial Discharge (PD), which causes the failure of insulation in the GIS. This paper presents the study of field effects on multiple particle contamination and breakdown voltage initiated by metallic particles inside a gas insulated bus duct filled with SF6 gas. In this paper, A single Phase Gas Insulated Bus duct with inner diameter conductor of 55mm and diameter of enclosure 150 mm is considered. Three metallic Particles of size of 10 mm in length and 0.25 mm radius, 10 mm length and 0.15 mm radius and 7 mm and 0.25 radii are considered to be present in the GIB. the Finite Elements Method is used to evaluate the electric field distributions on and around the metallic particles at different positions of the particles like when resting on the enclosure and particles floating inside the gap. Electric field intensity in the GIS are studied for both single particle and multiple particles at a time. The breakdown voltages for both single and multiple particle contamination are determined. The effect of gas pressure on the breakdown voltages also studied.

Keywords: Multiple particles , Gas Insulated Substations, Particles Contamination, breakdown voltage.

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I. INTRODUCTION

Compressed Gas Insulated Substations (GIS) consists of basically a conductor supported by insulator inside an enclosure, and is filled with SF6 gas. Free conducting particles are most hazardous to GIS. These free conducting particles may have any shape or size, may be spherical or filamentary (wire like) or in the form of fine dust. Wire like particles made of conducting material are more harmful and their effects are more pronounced at higher gas pressures. SF6 gas has been extensively used as insulation media for gas insulated substations (GIS) and Gas insulated transmission lines (GIL), owing to its excellent insulation and arc quenching properties.

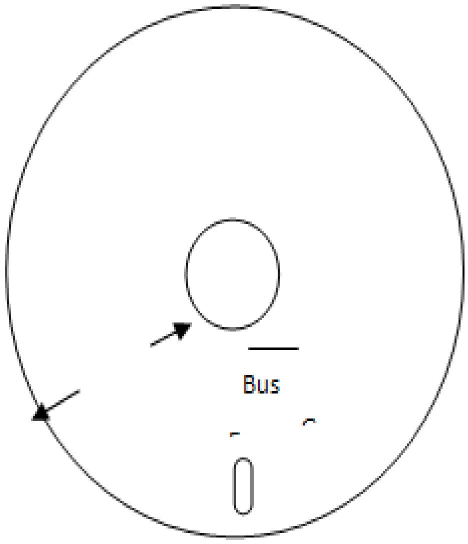
The contaminating particles lower the dielectric strength of the gas sharply. Some theoretical and experimental studies were carried out [1-3] to determine the effect of single contaminating particle in initiating breakdown in gaseous insulation with SF6 gas. The calculation of the breakdown voltage in the SF_6 gas requires the knowledge of the potential and field distribution on and around the particle surface. So in this paper, the potential and electric field distribution are studied in a gas insulated co-axial conductor system with a wire-shaped particles when rested on the enclosure and floating in the co gap.

II. ELECTRIC FIELD CALCULATIONS

The electric field intensity is calculated by using the Finite Element Method (FEM) in this work. The Finite Element Method Magnetics (FEMM) Package is used to simulate the modal and to calculate the electric field inside and around the contaminating particles in side GIS[4]. The electric field distributions on and around wire contaminating particle lies on the earthed enclosure is presented. Also, the electric field distributions around floating contaminating particles between the gap were computed. The applied voltage on the bus conductor taken as 100 kV, For any applied voltage the values of the electric fields can be proportioned.

2.1 Modeling of single Vertical wire Particle Located inside the Gap

Figure 1 shows the coaxial conductors with wire contaminating particles resting on the enclosure. A metallic particles P of length L and radius r is located inside the gap between the bus and enclosure is assumed to be rest on the enclosure. The gap (G) between the bus and enclosure is taken as 48.5 mm. E1 is the electric field at upper tip of particle P .



1. Gas insulated bus duct with wire contaminating particle on the enclosure.

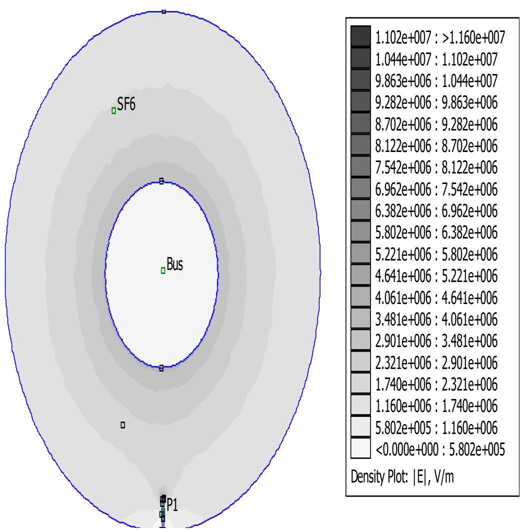


Figure 2. Electric field distribution along gap inside GIB with wire contaminating particle in contact with enclosure.

Figure 2 shows the electric field distribution inside gas insulated bus duct along gap with contaminating particle in contact with enclosure. It is observed that the field intensity is minimum at lower tip of particle and maximum at upper tip of particle. The electric field decreases from upper tip of wire particle, the electric field decreases until it reaches a certain value but after that electric field returns to increase until reaches to a certain value 36.1kV/cm at inner conductor of gas insulated bus duct. Figure 3 shows magnitude of electric field distribution along the surface of metallic particle-1.

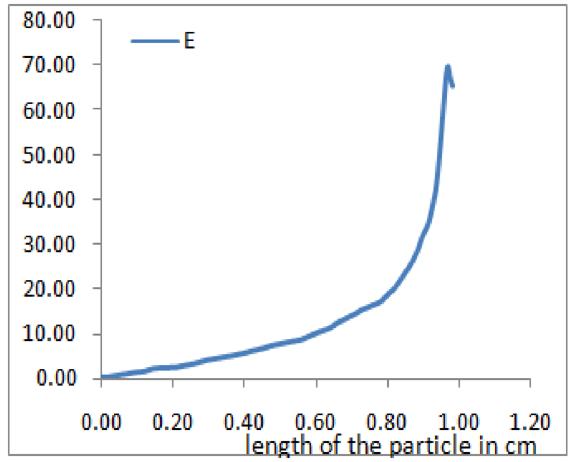


Figure 3. Electric field distribution along surface of wire particle

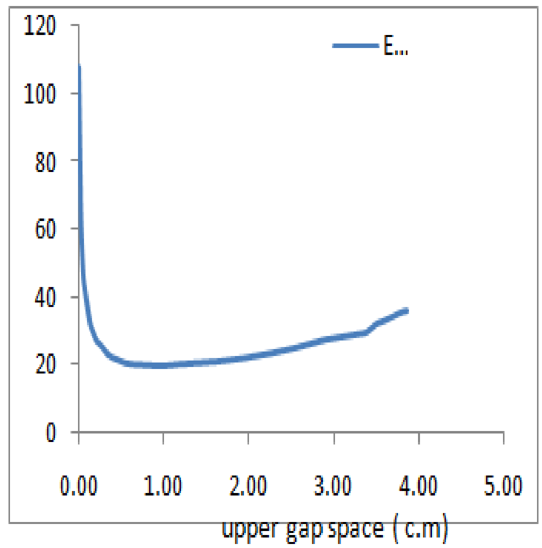


Figure 4. Electric field distribution along gap from upper tip of wire particle up to inner conductor of GIBD

The electric field distribution along the surface of metallic particle-1 increases from zero until it reaches the peak value at upper tip, the magnitude of electric field increases from zero to 101 kV/cm at upper tip of wire particle. Figure 4 shows magnitude of electric field distribution along gap from upper tip of metallic particle up to inner conductor of gas insulated bus duct.

It is observed that for particle-1, magnitude of electric field is maximum (107kV/cm) at upper tip of the particle and decreases gradually to 19.6 kV/cm in the length of gap until it reaches a definite distance (0.96cm) from tip but after that value increases gradually up to the inner conductor(36.1 kV).

2.2 Modeling of Two Vertical wire Particles Located inside the Gap

Two metallic particles p1 and p2 of length, L1=10mm , radius r1=0.25 , length, L2=10mm , radius r2=0.15 are located inside the gap between the bus and enclosure . One of them is rested on the enclosure and other is floating in the gap as shown in Fig.1. It is assumed that the floating particle p2, has floating potential (i.e the total charge on the particle surface is zero) where the floating particle p2 charge is lost by partial discharge effect. The gap (G) between the bus and enclosure is taken as 48.5 mm. E1 is the electric field at upper tip of particle p2 which is earthed and E2;E3 are the electric fields at lower and upper tip of floating particle p2, respectively.

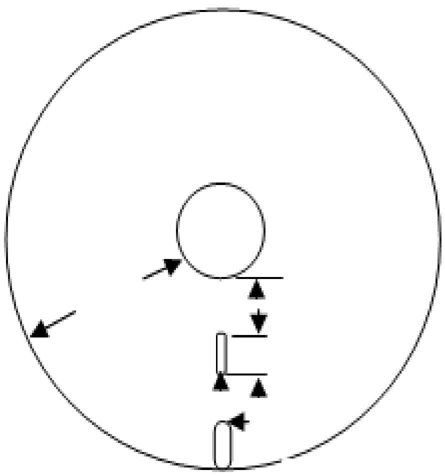


Fig. 5 Two parallel plates configuration with two wire particles located inside the gap.

2.3 Modeling of Three Vertical wire Particles Located inside the Gap

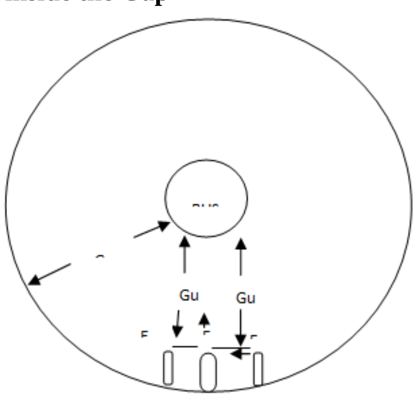


Figure 6.. Gas insulated bus duct with three vertical wire contaminating particles in contact with enclosure.

Three metallic particles p1, p2and p3 of length, L1=10mm , radius r1=0.25 , length, L2=10mm , radius r2=0.15 and length, L3=7mm , radius r3=0.15are located inside the gap between the bus and enclosure . The three particles are rested on the enclosure as shown in Fig.2. The gap (G) between the bus and enclosure is taken as 48.5 mm. E1 is the electric field at upper tip of particle p1 and E2;E3 are the electric fields at upper tips of particles p2;p3 respectively.

III. METHODOLOGY FOR CALCULATION OF BREAKDOWN VOLTAGE

In order to determine the breakdown voltages for the multiple-particle contamination, the particles are represented by a length (L) and radius (r) w inside GIB. On the application of electric field, ionization discharges in the gas results which lead to breakdown of the gas. The breakdown voltage of the sf6 gas is predicted by knowing its net (effective) ionization coefficients (ϖ) .[5-7]

In a non uniform fields, corona discharges will occur when the conditions for a streamer formation in the gas are satisfied. The condition for streamer formation is given by

$$\int_0^{xc} \varpi(x)\, dx \geq K \qquad (3.1)$$

Where, $\varpi(x)=\alpha(x)-\eta(x)$,

$\alpha(x)$ is the first ionization coefficient and $\eta(x)$ is the coefficient of attachment. Both are the functions of field and geometry. xc is the distance from the particle's tip where the net ionization is zero, normally known as the ionization boundary. In case of uniform fields, with large values of pd the criterion for self-sustaining discharge is

$$\alpha-\eta = 0 \qquad (3.2)$$

and is satisfied at threshold value of the electric field intensity. This value of the electric field intensity is usually referred to as the critical field intensity Ecrit. Its value at normal atmospheric pressure for SF6 is about 87 kV/cm.

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or uniform field gaps, breakdown gradients should have a limiting value given by

$$Ecrit = 877.5\, p\, V\ \ cm^{-1} \qquad (3.3)$$

where p is pressure in kPa.

According to Howard discharge inception takes place at points having maximium stress in the gap. Using this approach the discharge voltage can be expressed as[6]

$$Vd = \xi . d . Ecrit \qquad (3.4)$$

Here $\xi = Eave/Emax$ is the field utilization factor.

IV. BREAKDOWN VOLTAGE RESULTS WITH PARTICLE CONTAMINATION

Electric field intensity at bus, top of the particle and bottom of the particles are calculated as the particle moving in side the GIS. Electric field intensities are calculated for each particle i.e P1,P2and P3 individually considered. Variation of electric field intensity with the displacement of particle from the enclosure surface is studied. Field utilization factor Eave/Emax is calculated for every position of the particle.

From the Table-1, when the gas pressure is 300 kPa, it is seen that due to particle-1, breakdown voltage of 226.49 kV occurs when it is on the surface of the enclosure. Similarly for particle-2, the breakdown voltage is 191.51 kV this is because the particle-2 has lesser diameter than particle-1 with same length.

For particle -3 as its length is smaller than other 2 particles, the breakdown voltage is 255.35 kV. The breakdown voltage when three particles considered simultaneously is 153.211 for the spacing between bus and enclosure of 4.8 cm.

Table-1Breakdown voltage in a single phase GIB for single and multiple particles.

VI. COMPARISON BETWEEN BREAKDOWN VOLTAGE FOR GAP WITH PARTICLE CONTAMINATION AND CLEAN GAP

The effect of SF6 gas under different gas pressure with particle contamination is shown in Figures. From these figures we can see the breakdown voltage in side the GIB is increased as the pressure of gas increases.

Figure7shows the difference between breakdown voltage in case of presence of particle contamination compared with breakdown voltage in case of clean gap with particle-3 (L=7mm and r=0.25mm) and At P=300KPa and G=48.5mm, the breakdown voltage in case of clean gap 638.5 kV but in case of gap with particle contamination(particle-3), the breakdown voltage is 255kV, i.e breakdown voltage with particle contamination decreases approximately 40% from it's value in case of clean gap.

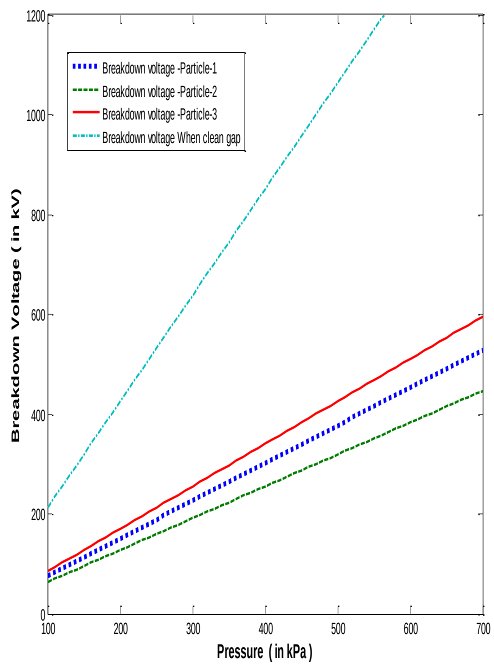

Figure 7: Comparison between Breakdown Voltage for Gap with particle contamination and clean gap

Break down voltage in the case of each particle individually considered and in case of three particles simultaneously considered is also shown in the figure. It can be observed that, the breakdown voltage is increased as the pressure increases. It is also seen that the breakdown voltage due to three particles contamination on the enclosure is least compared to when each particle individually considered.

VII. CONCLUSIONS

Electric field intensity for each of the particles when individually considered in the GIS are calculated at different positions of the particles. From this work, it can be concluded that the electric field is minimum value at lower tip of earthed wire particle and maximum value at upper tip of it.

s.No.	Breakdown voltage (kV)			BV (kV) for Three particles
	P -1	P-2	P-3	
Aluminum particle	226.49	191.51	255.35	153.21

Magnitude of electric field is maximum at upper tip of the particle and decreases gradually until it reaches a definite distance from tip but after that value increases gradually up to the inner conductor. Electric field intensity at upper tip of the particle increases with decrease in radius of the particle. Similarly Electric field intensity at upper tip of the particle increases with increase in length of the particle.

In case of multiple particles in the gap, rested on the earthed enclosure, the electric field decreases as the spacing between the particles increases. For three contaminating wire particles rested on the earthed enclosure with constant spacing between each , the electric field is maximum at the upper tip of the middle particle (particle-2:10mm/0.15particle-1 ,10 mm/0.25mm) and minimum electric field on the upper tip of the right side particle(particle-3;7mm/0.25). The Field intensity is slightly decreased by increasing the distance between the particles for a certain gap spacing and after that it becomes approximately constant. The breakdown voltage increases as the pressure of gas increases. And also The breakdown voltage increases as the spacing between the particles increases.

For the given fixed spacing (0.48 cm) of Bus to enclosure, the breakdown voltage changes with the dimensions of the particles. It is seen that for particle-1 (L1=10mm r1=0.25 mm) breakdown voltage of 226.49 kV volts occurs when particle is on the surface of the enclosure . Similarly for particle-2 (L2=10mm and r2=0.15 mm.) breakdown voltage is 191.51 kV volts. This is because the particle-2 has lesser diameter than particle-1 with same length. For particle-3 (L3=7mm and r3=0.25 mm) as its length is smaller than other 2 particles, the breakdown voltage is 255.35 kV. The breakdown voltage in case of gap with particle contamination decreased to about 40% from its value in case of clean gap without any particle contamination. When three particles at a time on the enclosure surface is considered, it is seen that the breakdown voltage is 153.211 which is minimum. So it also seen that as the gas pressure increases, the breakdown voltage also increase. It is concluded that the when multiple particle contamination is considered, the breakdown voltages are low which increases the flash over chances

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