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Effect of Metallic Particle Movement at Different Positions of Particle on Spacer in a 1-Ø GIB

[1]Giri Prasad. A, [2]Dr.PoonamUpadhyay, [3]Dr M Suryakalavathi, [4]Meghana.P
[1]VNR VJIET (EEE), [2]VNR VJIET (EEE), [3]JNTUCEH (EEE), [3]VNR VJIET (EEE)
[1]giridhar9ambati@gmail.com,[2]poonampu@gmail.com,[4]megnamegha45@gmail.com

Abstract

Gas Insulated Substation has been more credible than Air Insulated Substation thus increasing its application in the electrical industry. Though being more advantageous there are some areas in the system where there is a need for study. Metallic particle contamination is one of the areas where there are chances for the risk or failure; the particles reduce the dielectric strength of the insulating medium i.e. the SF6 gas. The metallic particles can be formed from the enclosure, conductor or the insulating material during various operations such as assembling, operating, and transporting etc. The particles can exist anywhere on the enclosure, conductor and the spacer. In this paper a single phase Gas Insulated Busduct with conductor diameter of 55mm and outer enclosure of diameter 152 mm with a spacer inclined at an angle of 450 to the enclosure is considered. Movement of aluminum and copper particles are studied which are present on the spacer at a certain distance from the enclosure

Index Terms: *Dielectric, GIS, Metallic particle, SF6 gas*

1 Introduction:

Gas Insulated Substation is the high voltage station with the SF_6 gas as the dielectric medium having all of its parts enclosed in enclosure. In comparison with the Air Insulated Substations the Gas Insulated Substation is more advantageous in many of the aspects. The metallic particles formed during various processes in the GIB can decrease the dielectric strength of the insulating gas.

GIS at the starting stages were installed only for profit of less land requirement and the environmental advantages. Later as the technology increased the reliability of GIS raised a lot and became popular. GIS has advantages such as land cost is reduced, HV equipment can be installed, etc. All the parts are manufactured, assembled and transported to the area where the substation is to be installed. The entire parts of station are enclosed in an outer enclosure so it is protected from the outside atmosphere, salty and icy environment.

The GIS can be easily installed in the industrial and the highly populated areas and even on mountains.

SF_6 has many benefits as an insulating gas. It has a greater dielectric strength, non-toxic in nature, high arc quenching property. When used in the electrical equipment it protects from fire danger, allows reducing the size and increases the reliability of the system. SF_6 as a good dielectric has an

electron attachment property. Of the SF_6 gas produced in the whole about more than 75% is used in the GIS. SF_6 has also some disadvantages; it decomposes to fluoride under arc formation and produce toxic byproducts. Its dielectric strength is sensible to the non uniform fields.

Although the SF_6 has advantages the existence of free metallic particles in the GIS can contribute to the

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reduction in the dielectric strength of the gas and also on the various properties of the support insulators. The dielectric strength of

the gas is lessened by the particles formed from the conductor, enclosure and the insulator. The lower energy

particle discharge affects the insulating spacer mostly when there are lastingly present on the insulator or nearer to it. When the conductor is at high field regions the particles can turn out to be a cause of chemical and electrical byproducts of SF_6. If the free particles and the decomposed products of gas intrude on the spacer, depending on time and the type of particle involved the dielectric property of the insulating spacer change. The most factors guiding to the deterioration of the spacer are the humidity, physical, chemical and the contamination of the surface. The most serious threat is caused as the free moving particles gain acceleration by the increasing voltage in conductor and cause break down when they get in contact with the HV conductor.

In this work the particle movement is studied in a GIB of dimensions of diameter length 152/55 mm. The metallic particles investigated for analysis are aluminum and copper which is wire shaped present on the spacer inclined at an angle of 45^0. A particle of length 10mm is considered and of radius (0.3mm, 0.25mm).

2 Modelıng Movement Of The Metallıc Contamınant

Though having high reliability there are chances of formation of metallic particles from the distinct operations such as transporting, assembling, operating, and circuit breaker operations. In this study the spacer is considered to be inclined to the enclosure at an angle of 45^0. Various positions of the metallic particle on the spacer were considered for the study which is shown in fig.1. In the work a wire like particle is considered for study thus it has both friction forces acting on it due to the gas. The skin friction acting along the length of the particle and shock friction at the edges of the particle.

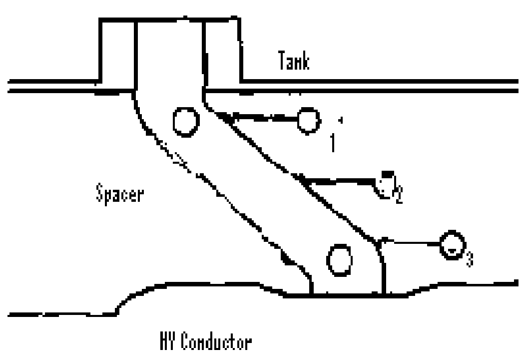

Fig. 1 . Various location of particle on spacer

By considering the different forces acting on particle we get the acceleration of particle as

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

'y' is the vertical movement of the particle ; 'F_d' is drag force and opposes direction of motion.

A. Drag force - By using stoke's theorem the drag force can be formulated as

$$F_d = F_{d1} + F_{d2} Sin\theta \qquad (2)$$

$$F_d = \dot{y}\pi r(6\mu K_d(\dot{y}) + 2.656(\rho_g l\dot{y}Sin\theta)^{0.5}) \qquad (3)$$

A. Gravitational Force

$$Fg = mgSin\theta \qquad (4)$$

B. Electrical Force

$$F_e = kQ_{net}E \qquad (5)$$

Fig .2 shows the various forces acting on the particle.

The various forces acting on the particle are considered in

eq (1) to get the movement of particle.

$$m\frac{d^2y}{dt^2} = F_e - mgSin\theta - F_{d1} + F_{d2}Sin\theta \qquad (6)$$

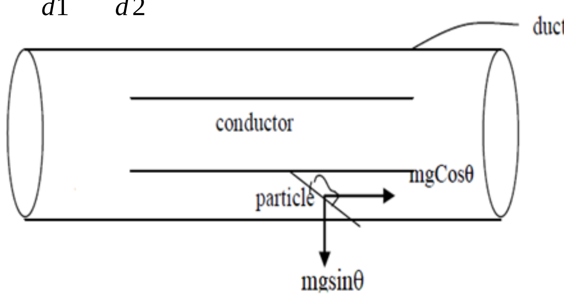

Fig .2. Different Forces acting on the particle present on spacer

By substituting various forces acting on metallic particle in the equation (6) we get equation (7) which is called as motion equation of particle.

$$m\ddot{y}(t) = \left[\frac{\pi \epsilon_0 l^2 E(t_0)}{\ln(\frac{2l}{r}) - 1} X \frac{V \, Sin \, \omega t}{[r_0 - y(t)] \ln(\frac{r_0}{r_i})}\right] - \pi r^2 l \rho g Sin\,\theta$$

$$- \; y(t)\pi r\left(6\mu K_d(\dot{y}) + 2.656[\mu \rho_g l \dot{y}(t) Sin\,\theta]^{0.5}\right)$$

(7)

By solving the above second order differential equation using RK 4th order method to get movement of particle

3 Results And Dıscussıons

The metallic particles that are considered for the study are aluminium and copper. The particle is considered at four different distance positions from the outer enclosure which is grounded. The maximum movement of the metallic particle is calculated for different voltages.

Table 1 Radial movement of Aluminium Particle for various voltages with the particle being on spacer particle near the enclosure. (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	0	30.923	30.922
2	145	0	39.045	39.045
3	160	0	46.091	46.091
4	200	0	61.297	61.297
5	245	0	OF	OF

Table 2 Radial movement of Aluminum Particle for various voltages with the particle being on spacer at 10mm distance from enclosure (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	10	10.261	0.261
2	145	10	10.510	0.510
3	160	10	10.629	0.629
4	200	10	11.398	1.398
5	245	10	12.634	2.634

Table 3 Radial movement of Aluminium Particle for various voltages with the particle being on spacer at 20mm distance from enclosure (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	20	20.049	0.049
2	145	20	20.765	0.765
3	160	20	21.216	1.216
4	200	20	22.292	2.292
5	245	20	28.785	8.785

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Table 4 Radial movement of Aluminum Particle for various voltages with the particle being on spacer at 30mm distance from enclosure (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	30	30.325	0.325
2	145	30	31.236	0.236
3	160	30	31.924	0.924
4	200	30	33.154	0.154
5	245	30	36.691	0.691

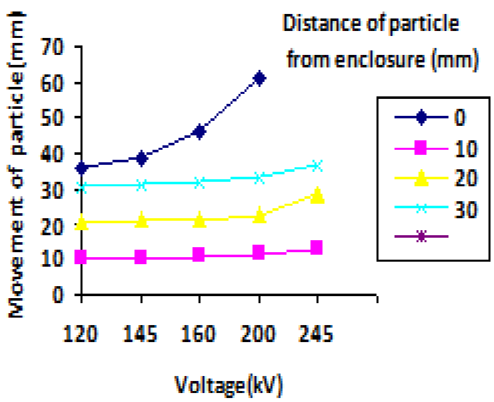

Fig 3. Comparing the radial movements of the aluminium particle at various positions of spacer for various voltages

The Tables 1, 2, 3 and 4 show the movement of aluminium particle at positions 0, 10, 20 and 30 mm distance from the enclosure.

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	0	10.214	0.214
2	145	0	10.843	0.843
3	160	0	16.853	4.258
4	200	0	19.793	9.793
5	245	0	25.406	5.406

Table 5 Radial movement of Copper Particle for various voltages with the particle being on spacer particle near the enclosure (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	10	10.010	0.010
2	145	10	10.054	0.054
3	160	10	10.189	0.189
4	200	10	10.257	0.257
5	245	10	10.448	0.448

Table 6 Radial movement of Copper Particle for various voltages with the particle being on spacer at 10mm distance from enclosure (l =10; r = 0.25 both in mm)

The Tables 5, 6, 7 and 8 show the movement of copper particle at positions 0, 10, 20 and 30 mm distance from the outer enclosure.

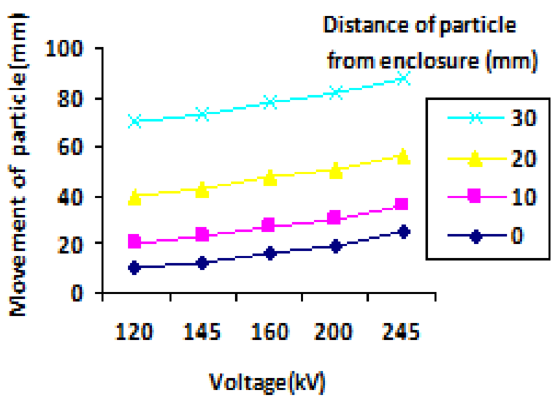

Fig 4. Comparing the radial movements of the copper particle at various positions of spacer for various voltages

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	20	20.019	0.019
2	145	20	20.145	0.145
3	160	20	20.206	0.206
4	200	20	20.348	0.348
5	245	20	20.633	0.633

Table 7 Radial movement of Copper Particle for various voltages with the particle being on spacer at 20mm distance from enclosure (l =10; r = 0.25 both in mm)

S.no	Voltage (kV)	Position of particle	Maximum Movement of Particle (mm)	Change in movement of particle compared to the before position(mm)
1	120	30	30.007	0.007
2	145	30	30.061	0.041
3	160	30	30.282	0.182
4	200	30	30.638	0.638
5	245	30	31.258	1.058

Table 8 Radial movement of Copper Particle for various voltages with the particle being on spacer at 30mm distance from enclosure (l =10; r = 0.25 both in mm)

From the Fig 3 and Fig 4 show the comparison of movement of particles for various voltages present at different positions on the spacer. It is observed that the movement increments as the voltage applied increases. The movement raised as particle goes near to the hV conductor as it gains acceleration as the electric force increased. Being lighter in weight the aluminium particle has more movement than the copper particle.

4 Conclusion

The metallic contaminants have been considered at different locations on spacer and the movement of them is observed. It is seen that the movement of the particle increments as it reaches a position near to conductor. It is necessary to study the particle movement on the spacer as the particle presence decreases the insulation of SF_6 gas

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