THE EFFECT OF MAGNETIC FIELD ON THE TRAJECTORY TRACED BY A METALLIC PARTICLE IN A GAS INSULATED BUS DUCT

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Abstract

A method based on particle motion is proposed in this paper to determine the particle trajectory in GIS or Gas Insulated Bus duct. In order to determine the moment of a particle in GIB, an inner electrode of diameter 55mm and outer enclosure diameter of 152 mm is to be considered. Aluminum, Copper and Silver wires of 0.5mm diameter and 10mm and 7mm lengths are considered to be present on the enclosure surface. The charge acquired by the particle is now under the influence of magnetic field set up by the conductor when electric current is passed through it. The particle that has acquired charge behaves as a moving charge & a moving charge placed in a magnetic field experience a force. The force acquired by the particle is additive as the magnetic force is due to the current flowing in the electrode and the moving charge is due to electrostatic force setup. The motion of the wire particle is to be simulated using the charge acquired by the particles at site, drag coefficient, Reynolds number and coefficient of restitution. The distance traveled by the particle is to be calculated using appropriate equations. The results are also to be presented for other set of parameters.

Keywords: lift of field, GIS, SF6, Metallic particles.

1. Introduction

GIS consists of SF6 gas insulated substations in which various equipments like circuit breakers , load break switches, CT and PT's , earth switches are enclosed in a metallic enclosed modules filled with SF6 gas. GIS basically consists of a conductor supported on insulator inside an enclosure filled with SF6 gas. The voltage withstand capability of SF6 bus duct is strongly depend on field perturbations such as those caused by conductor surface imperfections and by conducting particle contaminants. Contaminations can be produced by abrasion between the components during assembly or operations. The particles can be lifted by the electric field and migrate to the conductor and insulators where they initiate breakdown of voltages significantly below the insulation characteristics of SF6 gas. SF6 gas provides the phase to ground insulation as the dielectric strength of SF6 is higher than air, the clearance required is small, hence the overall size of equipment required and the complete substation can be reduced to as low as 10 % of conventional air insulated substations. Metallic particles in GIS have their origin mainly from manufacturing process or they may originate from the moving parts of the system such as breakers and disconnections. Metallic particle struck on insulator surface in a GIS also cause a significant reduction of breakdown voltage. Depending on the shape of the particle as well as the geometry and the voltage levels of the system the particles get more or less influenced by electric field which in turn makes them hazardous to the electric system in terms of partial discharges and breakdown. Several authors conducted experiments on insulating particles and found to have very little effect on the dielectric behavior of the gases. However the presence of atmospheric dust containing conducting particles especially on the cathode reduces the breakdown voltage. The breakdown voltage of sf6 is highly reduced in the presence of conducting particles especially at high pressures, in addition depending on the shape of the particles geometry and the voltage level of the system a particle gets more or less influenced by the field.

2. Problem Statement

The movement of the particle in a gas insulated bus duct will be influenced by electrical force, drag force and gravitational forces. As the electric and magnetic fields are cause and effect, therefore the effect of magnetic field can not be neglected. In this paper the influence of magnetic field on the particle movement is considered, and the influence of other factors like radius, length, voltage of different particles like copper, aluminum and silver under various values of above parameters are to be determined. For this analysis an inner electrode of diameter 55mm and outer enclosure diameter of 152 mm is to be considered. Aluminum, Copper and Silver wires of 0.5mm diameter and 10mm and 7mm lengths are considered and voltages of 100kv, 245kv, 400kv are considered.

3. Methodology

As the metallic particle movement depends on geometrical shape, here the particle is considered to be cylindrical and hence initially when it is on the surface of the enclosure it is considered to be horizontal and for the given conditions of radius and length, when the applied voltage level is greater than the lift of voltage the particle starts moving and the particle is considered to be vertical. Initially depending on parameters like radius, length, voltage the charge acquired by the particle and lift of voltage is calculated. As electromagnetic force depends on charge acquired by the particle the electromagnetic force is calculated. When the particle starts moving it is influenced by electromagnetic force in upward direction and simultaneously opposed by gravitational force, drag force in the downward direction. Since electric and magnetic effects are in same direction the magnetic force is assumed in upward direction. Now using the parameters the expressions for various forces in terms of displacement is to be determined. Finally the second order non linear differential equation in terms of displacement is obtained and solved using fourth order ranga kutta method.

4. Mathematical Modeling of particle movement

1) Charge acquired by a particle

In general for spherical particle

$Q_s = 2\,\pi^3\,\varepsilon_0\,r^2\,(Elo) / 3$

Q_s = Charge acquired by spherical particle

ε_0 = Permittivity of free space

r = Radius of particle.

Elo= Electric lift off voltage (The min voltage at which particle starts lifting)

$Elo=0.49\ r\ \rho g / \varepsilon 0$

ρg = gas density

Now for cylindrical Particle Horizontal

Qhw = 2 π ε_0 r l (Elo)

l = length of the particle

Elo= Electric Field Intensity (lift off field) = 0.84 $\sqrt{(r\ \rho g / \varepsilon 0)}$

Qhw = charge acquired by horizontal particle (initially)

Vertical

Qvw = π ε_0 l^2 (Elo) / ln (2l/r)-1

Qvw = charge acquired by vertical particle (finally)

Elo= (ln (2l/r)-1) $\sqrt{(r^2\ \rho g / \varepsilon_0\ l\ (\ln(l/r)-0.5)}$

2) Electric Field Intensity E(t) due to the charge acquired by the particle:

$$E(t) = \frac{V\sin\omega t}{r_0 - y(t)\ \ln[r_0/r_1]}$$

$V\sin\omega t$ = supply voltage on inner electrode

r_0 = Enclosure radius

r_1 = Inner Conductor radius

y(t) = Position of particle

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3) Electrostatic Force : $F_e = k\ Q_{net}\ E(t)$

4) k = factor smaller than unity

Q_{net} = net charge acquired by the particle

5) Drag Force : Drag force $F_d = \acute{y}\ \pi\ r\ (6\mu\ k_d(y) + 2.656(\mu\rho_g\ l\ y)\ 0.5$

6) ý =velocity of particle

7) μ = Viscosity of fluid (for SF_6 = 15.5 x 10-6 kg/ms at 200^0C)

8) r = radius of particle

ρ_g = gas density

l = length of particle

$k_d(y)$=drag force coefficient

<u>Initial Conditions:</u>-

m y(t=0+) = -R m y(t=0), y(t=0-) = 0

R = restitution coefficient = ratio of incoming to out going impulse

R = 0.7 – 0.95 (for Cu and Al)

9) Gravitational Force

$mg = \pi r 2 l \rho_g$

10) Magnetic force

11) F = BIL where B = magnetic field intensity

12) Net force equation

Net force = Fe – Fd – F g + Fm

The above equation is a second order non linear differential equation and is solved by Runga kutta fourth order method. The simulation is done in C- programming.

$V\sin\omega t = \pi\varepsilon l^2 E(t_0)/ \ln(2l/r)-1+ V\sin\omega t/ r_0 - y(t) \ln[r_0/r_1]* mg - \acute{y}(t) \pi r (6 \mu k_d(y) + \ldots\ldots\ldots 2.656[\mu\rho_g l\, y(t)]^{0.5} + \mu I^2 R^2 l/2(R^2+r^2)^{3/2} * ax$

The above equation is a second order non linear differential equation and is solved by Runga kutta fourth order method. The simulation is done in C- programming.

5. Results

The metallic particles like copper, silver and aluminum are considered and their displacements at different voltages and lengths under the influence of with and with out magnetic field and are analyzed.

Particle	Voltage (KV)	Length (mm)	Maximum displacement (mm)	
			Without M F	With M F
Copper	100	10	4.9	5.1
Copper	100	7	3.3	3.48
Copper	245	10	23	25
Copper	245	7	17.5	18.5
Copper	400	10	34	35
Copper	400	7	33	34.8

Particle	Voltage (KV)	Length (mm)	Maximum displacement (mm)	
			Without M F	With M F
Silver	100	10	3.9	4.05
Silver	100	7	3.8	3.9
Silver	245	10	20.5	21.5
Silver	245	7	17	19
Silver	400	10	32	38
Silver	400	7	27	36

Particle	Voltage (KV)	Length (mm)	Maximum displacement (mm)	
			Without M F	With M F
Aluminum	100	10	23	25
Aluminum	100	7	22	24
Aluminum	400	7	50	55

From the above analysis it is found that the effect of magnetic field has a considerable effect on the movement of the particle.

6. Conclusion

The results shows that the path traced by a particle increases with length of the particle, voltage and radius. The effect of magnetic field has positive effect on the trajectory motion. in case of magnetic field the axial components cancel each other and radial movement remains same. The net effect is increase in radial direction. In case of aluminum the movement is predominant as its density is less compared to copper and silver. The lift of field required for aluminum is least compared to copper and silver.

7. References

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