Effect of Dielectric Coating on Radial Movement of Metallic Particle in a Single Phase Enclosure Gas Insulated Busduct (GIB) under the Influence of Different Voltages

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ABSTRACT
Compressed gas insulated sub-stations (GIS) consist basically a conductor supported on insulators inside an enclosure which is filled with Sulphur-hexafluoride gas (SF6). Gas insulated sub-stations are high voltage substations, compact in nature, requires less maintenance when compared to air-insulated sub-stations. The compactness of GIS is due to use of SF6 gas, which has higher dielectric strength. Electrical insulation performance of compressed gas insulated sub-station (GIS) is adversely affected by metallic particle contaminants. Free conducting metallic particles, depending upon their location, shape and size, may lead to serious deterioration of the dielectric strength of the GIS system and also one of the major factors which causing breakdown of the system and leading to unexpected break in power.

Keywords--- GIS, CIGRE, Electrode system

I. INTRODUCTION
A CIGRE group is suggested that 20% of failures in Gas Insulated Substation are due to the existence of various metallic particle contaminations in the form of loose particles. Electrical insulation performance of gas insulated substation is adversely affected by metallic particle contamination. The random motion of the particle due to surface roughness, coefficient restitution, and angle of incidence when approaching an electrode increases with voltage. At a sufficiently high voltage the particles cross the gap [20-26]. These particles may exist on the surface of support insulator, enclosure or a bare electrode. Free conducting metallic particles, depending upon their location, shape and size, may lead to serious deterioration of the dielectric strength of the GIS system and also one of the major factors which causing breakdown of the system and leading to unexpected break in power.

II. DIELECTRIC COATED ELECTRODE SYSTEM
The main reason for coating an electrode surface with a dielectric material is to increase the break down voltage of the system. The dielectric coating decreases high local fields caused by conductor roughness. It impedes the development of pre-discharges in the gas due to the

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resistance of the coating. It increases the lift-off field of metallic particles. It reduces the charge, which a particle colliding with the coated enclosure will acquire, which in turn reduces the risk of a breakdown.

III. METHODOLOGY

Modeling of metallic particle movement on dielectric coated electrodes

The conductor in GIS system may be coated with a dielectric material to restore some of the dielectric strength of the compressed gas that is lost due to surface roughness and contamination with conducting particles. Coating reduces the degree of surface roughness on conductors, decreasing the high local electrical fields. Coating thickness has been varied from a few microns to several millimeters. Also the high resistance of the dielectric coating impedes the development of predischarges in the gas, thus increasing the breakdown voltage. The electric field necessary to left a particle resting on the inside surface of a GIS enclosure is much increased due to the coating.

The improvement in the dielectric strength of the system, due to coating, can be attributed to the following effects:

i. Coating reduces the degree of surface roughness on conductors thus decreasing the local electric fields which can be responsible for initiating a discharge. Experiments show significant improvement in breakdown strength due to coating.

ii. The resistance of dielectric coating impedes the development of pre-discharges in the gas, thus increasing the breakdown voltage.

Moreover, in the case of GIS, by using a coating with a light shade on the inside of the enclosure, it is easier to detect impurities such as metallic particles or pieces of dielectric material in the system. Charging of metallic particles in contact with a coated electrode is mainly based on two different charge mechanisms.

i) Conduction through the dielectric coating

ii) Partial discharges initiated at particle surface.

Fig: 1 shows the Charge mechanism of a metallic particle on a dielectric coating.

Conduction through a dielectric coating:
The geometry described in Fig: 1 can be represented by a circuit model as shown in Fig: 2.

For a parallel plate capacitor, G is given by

\[ G = \frac{S}{\rho_C T} \]

(1)

Where,

\[ S \] = Contact area between the particle and the coating

\[ \rho_C \] = Resistivity of the dielectric coating

\[ T \] = Coating thickness

The parallel plate capacitance \( C_c \) through the coating between the enclosure surface and the particle is given by

\[ C_c = \varepsilon_0 \varepsilon_r \frac{S}{T} \]

(2)
where,
\[ \varepsilon_0 = \text{Permittivity of free space} \]
\[ \varepsilon_r = \text{Relative permittivity of the coating} \]

In the case of spherical or vertical wire particles, the contact area can be expressed as
\[ S = \beta (2 \pi r^2) \quad (3) \]

For a horizontal wire particle,
\[ S = \beta (\pi r l) \quad (4) \]

Where \( \beta \) depends on the depth of the surface contact \( \Delta_r \) relative to the particle radius
\[ \beta = \left( \frac{2 \Delta_r}{r} \right)^{0.5} \quad (5) \]

The value of \( \beta \) in many cases is 0.001 approximately.

Now the capacitance \( C_g \):

i) For a spherical particle

\[ C_g = \frac{2 \pi^3 \varepsilon_0 r^2}{3 r_0 \ln \frac{r_0}{r_i}} \quad (6) \]

The main reason for coating the inside surface of a GIB enclosure with a dielectric material is to increase the break down voltage of the system. The dielectric coating decreases high local fields caused by conductor roughness. It also inhibits the movement of metallic particles.

The reduction in maximum particle movement would offer the possibility of operating at higher fields. It can lead to considerable reduction in GIS size with subsequent savings in the cost of manufacture and installation. In general, if the coating thickness is increased, the charge on the particle is reduced. For GIS of a given voltage class, the bus bar voltage and the clearance between bus bar and enclosure are generally fixed. Hence, the charge on the particle can be reduced by coating the enclosure inner surface by a suitable dielectric material. Several types of coating material used in GIS are epoxy, RT 481, GK 115, \( \text{Al}_2\text{O}_3 \) etc. In this work the epoxy coating is used for analysis.

To determine the movement of metallic particles like Aluminum, copper and silver of size 12mm in length with 0.2mm radius for applied voltages of 75kV, 100kV, 132kV, 145kV, 200kV and 245kV in a single phase Gas Insulated Busduct with 152mm/55mm dielectric coated enclosure (152mm diameter of the enclosure and 52mm diameter of the inner conductor) are considered. Monte-Carlo simulation is carried out to determine the axial and radial movement of the aluminum, copper and silver particles for the random solid angle of 1° for applied voltages of 75kV, 100kV, 132kV, 145kV, 200kV and 245kV respectively.

Table 1: Variation of Axial and Radial movement (mm) of Aluminum, Copper and Silver particles on coated enclosure in GIB with application of Power Frequency voltage considering electric field effect. Simulation time: 2 sec, l=12mm, \( r=0.2\text{mm} \), \( P=0.4 \), \( R=0.9 \)

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Type</th>
<th>Max. Radial Movement (mm)</th>
<th>Monte-Carlo(1 deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Axial movement (mm)</td>
</tr>
<tr>
<td>75</td>
<td>Al</td>
<td>0.336</td>
<td>20.499</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>0.313</td>
<td>0.555</td>
</tr>
<tr>
<td></td>
<td>Ag</td>
<td>0.008</td>
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<td>100</td>
<td>Al</td>
<td>0.744</td>
<td>49.549</td>
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<td></td>
<td>Cu</td>
<td>0.083</td>
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<tr>
<td></td>
<td>Ag</td>
<td>0.046</td>
<td>1.948</td>
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<td>132</td>
<td>Al</td>
<td>1.34</td>
<td>78.489</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>0.303</td>
<td>18.026</td>
</tr>
<tr>
<td></td>
<td>Ag</td>
<td>0.224</td>
<td>12.355</td>
</tr>
</tbody>
</table>
MOVEMENT PATTERNS IN GIB WITH ELECTRIC FIELD EFFECT

Fig: 3 Movement pattern for Power frequency/Al/75 kV/0.2 mm/12 mm/100 \( \mu \)m thickness

Fig: 4 Movement pattern for Power frequency/Cu/75 kV/0.2 mm/12 mm/100 \( \mu \)m thickness

Fig: 5 Movement pattern for Power frequency/Ag/75 kV/0.2 mm/12 mm/100 \( \mu \)m thickness
MOVEMENT PATTERNS IN GIB WITH ELECTRIC FIELD EFFECT

Fig: 6  Movement pattern for Power frequency /Al/100 kV/0.2 m/12mm/100 \( \mu \)m thickness

Fig: 7  Movement pattern for Power frequency/Cu/ 100kV/0.2mm/12mm/100 \( \mu \)m thickness

The main reason for coating the inside surface of a GIB enclosure with a dielectric material is to increase the
break down voltage of the system. The dielectric coating decreases high local fields caused by conductor roughness. It also inhibits the movement of metallic particles.

V. CONCLUSION

The reduction in maximum particle movement would offer the possibility of operating at higher fields. It can lead to considerable reduction in GIS size with subsequent savings in the cost of manufacture and installation. In general, if the coating thickness is increased, the charge on the particle is reduced. For GIS of a given voltage class, the bus bar voltage and the clearance between bus bar and enclosure are generally fixed. Hence, the charge on the particle can be reduced by coating the enclosure inner surface by a suitable dielectric material. Several types of coating material used in GIS are epoxy, RT 481, GK 115, Al₂O₃ etc., In this work the epoxy coating is used for analysis.

REFERENCES