ABSTRACT

The development of compressed gas insulated switchgear (GIS) and gas insulated transmission line (GITL) have progressed rapidly worldwide because of the excellent insulating and arc quenching properties of Sulphur Hexa Fluoride (SF$_6$) gas. However, free conducting particles lower the corona onset and breakdown voltage of these systems. Under the action of the applied electric field in a coaxial geometry, conducting particles acquire charge and lift off from the outer enclosure when the electrostatic force from the electric field becomes equal or larger than the force due to gravity. Metallic particles move randomly in gas insulated systems under the action of electric field. The particle may remain in mid-gap or stay around the central conductor for several voltage cycles. Particle movement therefore plays a crucial role in determining the voltage withstand capability of GIS/GITL systems.

Metallic conductors in gas insulated system are protected with a dielectric covering to mitigate the problem of particle initiated breakdown. Dielectric covering reduces the effect of surface roughness of conductors/duct and also increases the dielectric strength of the insulation system.

Several researchers have developed computational models for particle movement in co-axial electrode system. These models however make assumptions about the particle charging process and charge exchange mechanism when a moving particle returns to the dielectric coated enclosure. Many experimental techniques have been proposed by researchers to explain the movement of particles in a co-axial bus-duct system. The experimental observations are also compared with the computational model. However, particle contamination in GIS is not fully understood and explained satisfactorily.

Though SF$_6$ is accepted universally as the best gaseous dielectric, it is considered to be a Greenhouse Gas. Hence research worldwide focuses on alternatives to SF$_6$ gas without making much compromise on dielectric and other properties. In this context, use of SF$_2$-N$_2$ gas mixtures,
containing less than 10% of SF\textsubscript{6} gas is seen as a viable alternative for GITL. Hence the present study was taken up with this motivation.

In recent years, there has been an increasing demand for reduction in tolerance of insulation design of Power equipment. Even for extension of well known concepts for increasing the transmission levels to ±800kV dc and 1200kV ac, some of the fundamental studies of breakdown of air gaps under divergent field conditions have been repeated. Hence this work aims at re-establishing some of the known concepts of air breakdown under different field conditions and studies on SF\textsubscript{6}-N\textsubscript{2} gas mixtures.

The aim of the present work is to determine effect of metallic particle contamination on electrical breakdown of air and SF\textsubscript{6}-N\textsubscript{2} gas mixtures. An attempt is made to understand the Partial Discharge Characteristics of compressed gas consisting of SF\textsubscript{6}-N\textsubscript{2} in 10:90 ratio. The investigation is extended to study the effect of dielectric covering of electrodes. Extensive electric field modeling and computation have been carried out to support and supplement the experimental results.

Important results of this investigation are:

1. The results obtained in this investigation indicates that in 10:90 SF\textsubscript{6}-N\textsubscript{2} gas mixtures, the effect of N\textsubscript{2} gas is predominant and the discharge magnitudes become invariant with gas pressure but with particle, show dependence on voltage and pressure.

2. The number of PD events per second “n” is sensitive to presence of particles.

3. The discharge magnitude for a floating particle increases significantly with pressure whereas in case of fixed particle it increases to a lesser extent.

4. In presence of particle, the PD activity on the negative half cycle is significant than positive half of ac cycle.
5. The presence of conducting particles act as additional perturbation and it changes the pattern of variation of PD discharge magnitude with voltage.

6. A sharp increase in discharge magnitude with small increase in voltage is a significant feature of a particle in a duct.

7. Analysis of 2D/3D PD histograms of acquired PD data and the variation of statistical parameters with voltage and time are useful tools for understanding the gas discharge processes and the behavior of gas mixtures in the low PD regime.

The results obtained have clearly established the effects of particle contamination under uniform and non-uniform fields. With particles, the breakdown voltage decreases drastically since it increases the electric stress on the dielectric medium. The dielectric covering on the electrodes increase the breakdown voltage of insulation, depending upon the thickness of film coating used.

This work will be of benefit to compact design of GIS/GITL systems. It is also expected to contribute towards a better understanding of the mechanism of particle initiated breakdown in compressed gas insulation.