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Effect of Fixed Copper Particle on PD Characteristcs of Sf_6- N_2 (10:90) Gas Mixtures

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Abstract

Conducting particles on the insulator surfaces or splinters at the conductor in the proximity of an insulator can produce surface charges due to partial discharge activities. These surface charges accumulate on the insulator and can be considered as a type of contamination. The particles distort the electric field conditions thereby initiating partial discharge activities. This paper deals with the influence of conducting particle on the discharge characteristics of gas mixtures in a co-axial duct. Co-axial duct placed in a high pressure chamber is used for the purpose. Four different gas pressures of 0.1, 0.2, 0.3 and 0.4 MPa have been considered with a 10:90 SF_6 and N_2 gas mixture. The discharge characteristics as a function of the voltage and pressure are discussed in this paper.

Index Terms: Gas Insulated transmission Line, Sulphur Hexa Flouride, Metallic Particles, Partial Discharge (PD), Inception Voltage (Vi), Extinction Voltage (Ve), PD Statistical parameters

Introduction

Due to its excellent physical and chemical properties, SF_6 has become the most preferred insulation in gas insulated electric power transmission and distribution equipments [1]. SF_6 is one of the strongest man made green house gases. But the effect of Sulphur Hexa Flouride gas on global atmosphere has been intensively debated and discussed all over the world. The contribution of SF_6 gas to ozone depletion and the global green house effect and its high global warming potential have raised several questions about its future use Scientists feel that SF_6 can be used as insulator by the addition of some inert gases to it, so that the effect on the atmosphere is reduced.

The results of some investigations show clearly that nitrogen at high pressure is to be seen as one of the most pollution free insulating gases for the technological use in high voltage equipment [2]. The dielectric strength of nitrogen could be increased by the addition of a small amount of electronegative gas. N_2/SF_6 gas mixtures can be used instead of pure SF_6. This mixture has lower boiling temperature than pure SF_6. Diluted SF_6/N_2 mixtures promise reduction of the environmental impact [3]. The presence of conducting particles on the insulator surface can cause field distortions due to which the dielectric strength of the insulator get affected [4]. The contamination is also caused by trapped surface charges on the insulator. Conducting particles on the insulator surfaces or splinters at the conductor in the proximity of the insulator can produce surface charges by partial discharge activities. Moving particles firmly attached to the insulator surface are responsible for a large part of the failures registered in GIS and are especially critical with lightning and switching over voltages.

In this study, a mixture of SF_6 and N_2 gas in the ratio of 10:90 has been used to determine the effect of conducting particle on discharge characteristics in a co-axial duct and four different pressures of 0.1, 0.2, 0.3 and 0.4 MPa have been considered for the study.

Experimental Details

The test equipment consists of Advanced Partial Discharge Measuring and Analysis system.

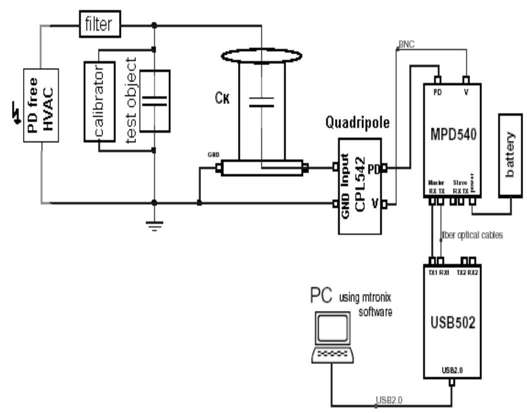

Figure 1: Circuit Connections for discharge measurements.

The circuit connection for the experiment is shown in figure 1. The acquisition Unit senses the discharges of test object connected across coupling capacitor connected through external coupling unit. The fiber optic controller is connected to Acquisition

Unit. The terminal of fiber optic controller is connected to the computer by using a standard cable.

The test object consists of a co-axial duct which is kept inside a high pressure test chamber which has a volume of about 3.5 litres and is fabricated with a material having sufficient tensile, compressive and shear strength.

The measurement of gas pressure was carried out directly at the test chamber with a digital pressure gauge with an accuracy of +/- 0.1%. The chamber is evacuated with a rotary vacuum pump. Pure and dry SF_6 gas and high purity N_2 from the gas cylinders are filled into the chamber directly to the required pressure and proportion, first with N_2 and then with SF_6 gas.

Copper particle of 0.8 mm diameter and 10 mm length is used in the study. No special tip geometry was used. The particle was fixed at the edge of the spacer surface with a small amount of silicon adhesive. Care was taken to ensure that no tip was covered with the adhesive.

Experimental Procedure

The PD measuring system is first calibrated by connecting a PD calibrator across the test object. The calibrator is disconnected and the sample is connected to a PD free, HVAC source across the test object, through a RC divider. The PD measuring system is calibrated for voltage measurement by applying a certain known voltage much below the inception voltage, across the test object. The voltage is then increased gradually until it reaches a value 20% above the discharge inception level and reduced gradually to zero to record the extinction voltage. For all the measurements, the discharge inception threshold was fixed at 5 pC.

Results and Discussions

The results of discharge inception measurements carried out on a clean co-axial duct at a pressure of 0.1 MPa with 10:90 gas mixtures of SF_6 and N_2 is shown in figures 2. The 3 D histogram for the same is shown in figure 3.

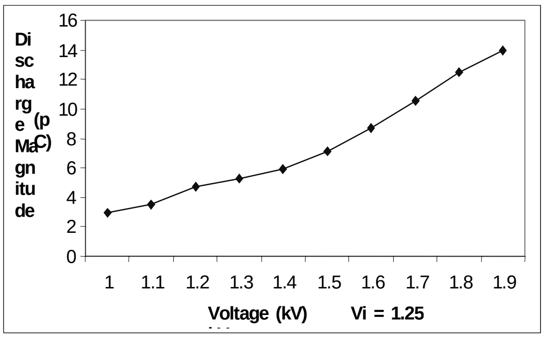

Figure 2: Variation of Discharge Magnitude in a clean duct at 0.1 MPa.

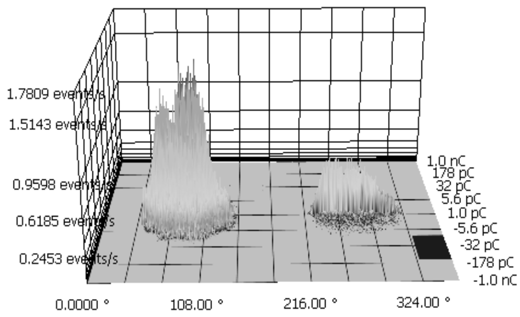

Figure 3: 3-D Histogram of a clean duct at 0.1 MPa.

From Figure 2, it can be seen that, at low pressure of 0.1 MPa, the discharge magnitude varies linearly with voltage.

The 3 D histogram at 0.1 MPa pressure for a clean duct shows that the PD events per second is much greater for the positive cycle compared to negative half.

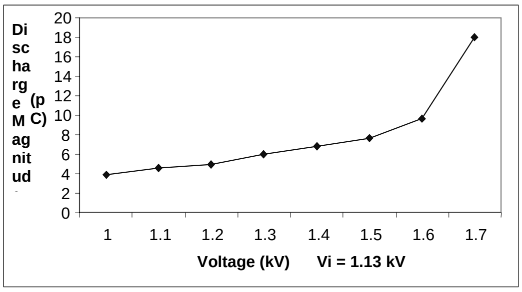

Figure 4: Variation of Discharge Magnitude in a clean duct at 0.2 MPa.

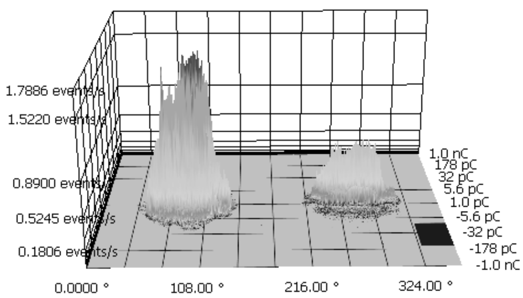

Figure 5: 3-D Histogram of a clean duct at 0.2 MPa.

As shown in figure 4, with increase in pressure to 0.2 MPa, up to 1.6kV, the discharge magnitude increases linearly, though the rate of increase of magnitude of discharge is not significant. But thereafter a sharp increase in discharge inception voltage is observed. A clear transition in discharge is evident at about 1.6 kV. The 3-

D histogram shows a similar trend as that of at 0.1 MPa with positive half more dominant than the negative half, as seen from figure 5.

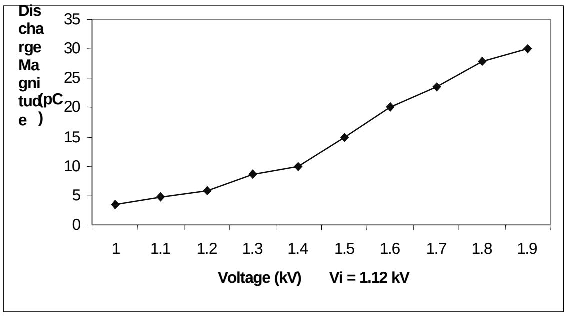

Figure 6: Variation of Discharge Magnitude in a clean duct at 0.3 MPa.

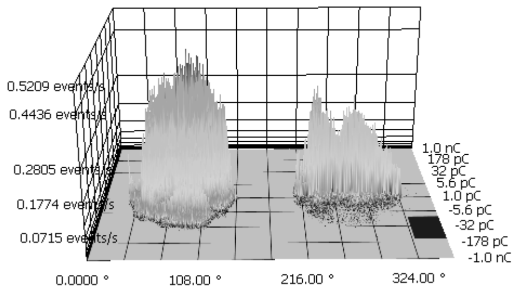

Figure 7: 3-D Histogram of a clean duct at 0.3 MPa.

For 0.3 MPa pressure also, we can see two regions, one, where the increase in discharge magnitude is linear between 1kV to 1.4kV, and second with a sharp rise in discharge magnitude between 1.4kV to 1.9kV. This variation is shown in figure 6. In this case, a transition in discharge at 1.4 kV is evident. Figure 7 which shows the 3- D histogram shows the similar pattern as in earlier two cases with positive half more significant than the negative half.

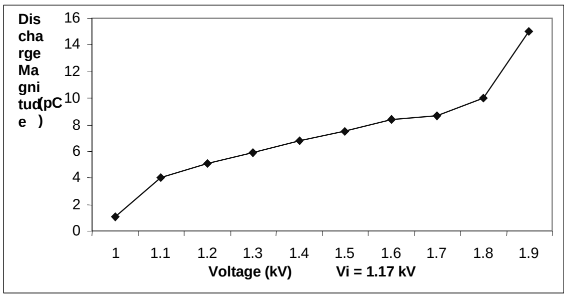

Figure 8: Variation of Discharge Magnitude in a clean duct at 0.4 MPa.

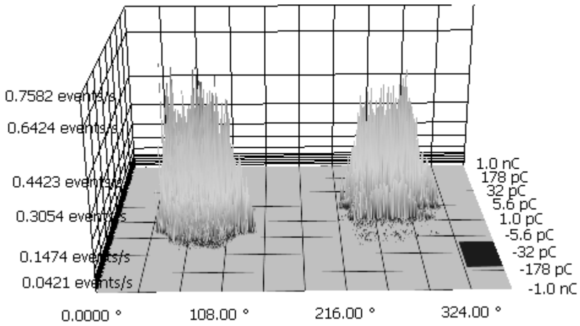

Figure 9: 3-D Histogram of a clean duct at 0.3 MPa

But in the case of 0.4 MPa pressure, the variation of discharge magnitude with voltage, shown in figure 8, has three regions. First region, from 1kV to 1.1kV, having a sharp rise, second region is between 1.1kV and 1.8kV, where the increase is linear and rate of rise of discharge magnitude is not significant. From 1.8kV to 1.9kV, there is very sharp increase in the discharge magnitude. Clearly three transitions one changing at1.1, the other at 1.8 kV is observed. From figure 9, the PD events per second is more visible in the negative half at 0.4 MPa compared to all other pressures, even though positive half is more dominant .

Thus the variation of discharge magnitude with pressure shows transitions whose number and occurrence depends on the gas pressure. Perhaps glow discharges, sparks or corona may be occurring at different voltages at different pressures and hence discharge transitions may be observed.

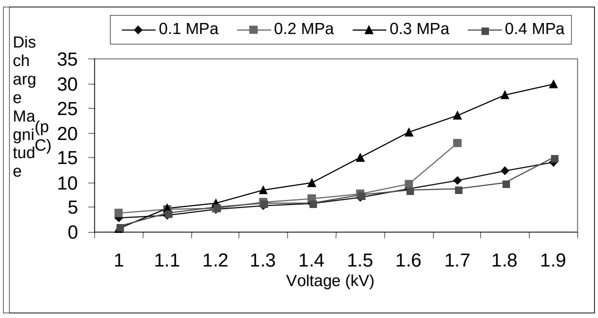

Figure 10: Comparison of Discharge Magnitude in a clean duct.

In Figure 12, a comparison of discharge magnitudes at different pressures is depicted. It is observed that except for 0.3 MPa, in all other cases the discharge magnitude increases linearly till the voltage reaches 1.6kV. The discharge at 0.3 MPa increases sharply right from 1.4kV. The same is seen at 1.6kVat 0.2MPa. This aspect needs closer examination keeping the corona stabilization factors in view.

In the next set of experiments, a copper particle with a diameter of 0.8 mm and length of 10 mm was fixed perpendicular the central conductor on the spacer. With the same gas pressure range of 0.1MPa to 0.4 MPa, experiments were repeated. The variation of discharge magnitude with the variation of voltage are shown in the figures 11,13,15 and 17 respectively. Corresponding 3D histograms are shown in figures 12,14, 16 and 18 respectively.

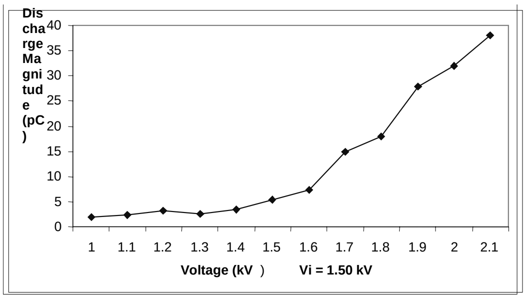

Figure 11: Discharge Magnitude in a duct with copper particle fixed to the spacer at 0.1 MPa.

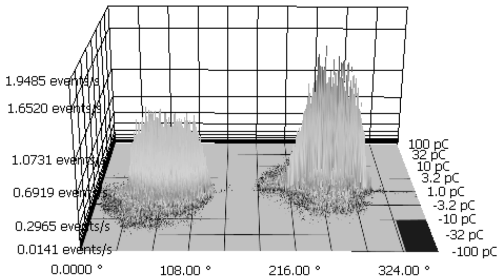

Figure 12: 3-D Histogram of a duct with fixed particle at 0.1 MPa.

It is observed that with the introduction of particles into the duct, with gas pressure being 0.1 MPa, predominantly there are two regions of discharges. The first region where there is a slight increase in the discharge magnitude with the voltage between 1 to 1.6 KV. Then a sharp increase is seen between 1.6 to 2.1 kV. The 3 D histogram shows the PD events per second taking place in the negative cycle is predominantly more when compared to a positive cycle.

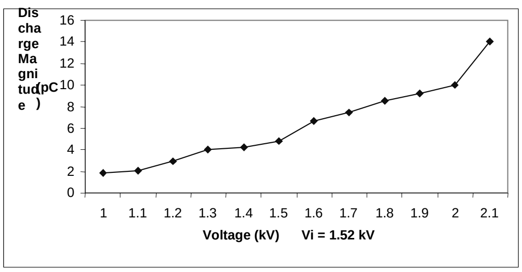

Figure 13: Discharge Magnitude in a duct with copper particle fixed to the spacer at 0.1 MPa.

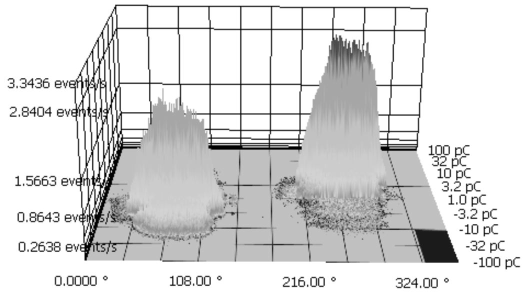

Figure 14: 3-D Histogram of a duct with fixed particle at 0.2 MPa.

For a pressure of 0.2 MPa, it is observed that, initially, the discharge magnitude increases linearly at a slow rate with increase in voltage, but a very sharp increase is seen at 2 kV. The intensity of PD events are more when compared to that at 0.1 MPa and the maximum intensity goes up to 2.8 events per second as seen from figure 16.

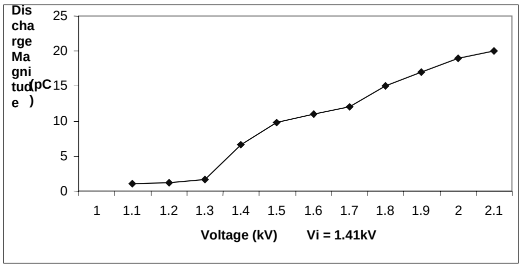

Figure 15: Discharge Magnitude in a duct with copper particle fixed to the spacer at 0.3 MPa.

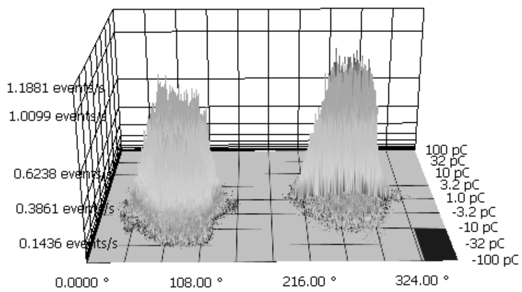

Figure 16: 3 D Histogram of a duct with fixed particle at 0.3 MPa.

The results obtained at 0.3 MPa, are shown in figure 17. The variation of magnitude of discharge with voltage as seen from the graph is not similar to the previous case. There is variation of steepness of rise of discharge magnitude from one voltage range to another. Though the overall variation looks similar to the previous case, there are more than three regions in this case. This looks complicated than the earlier cases. 3-D histogram for 0.3 MPa, as shown in figure 18, even though looks similar to that of the previous figure 16, the maximum intensity is only upto1.1 events per second.

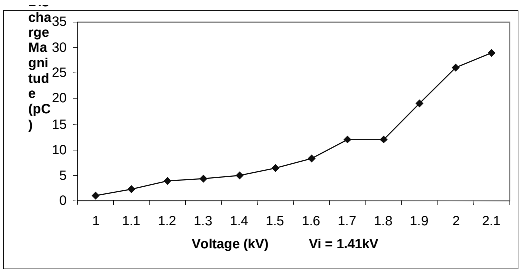

Figure 17: Discharge Magnitude in a duct with copper particle fixed to the spacer at 0.4 MPa.

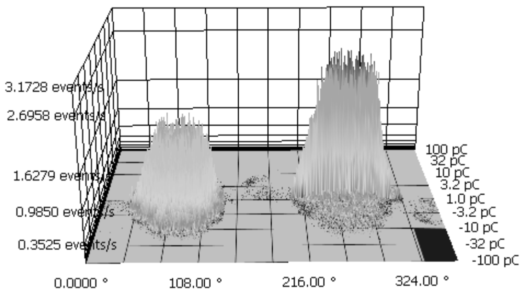

Figure 18: 3-D Histogram of a duct with fixed particle at 0.4 MPa.

The graph shown in figure 19, represents the variation of magnitude of discharge as a function of voltage at 0.4 MPa. The characteristics are similar to that seen in figure 17, except that the increase in the discharge magnitude in the final step beyond 1.8 kV shows a steep rise.

Table 1: Discharge inception voltages Vi in kV at different pressures at 5pC threshold value.

Pressure (MPa)	**Vi for a clean duct (kV)**	**Vi with fixed particle (kV)**
0.1	1.25	1.50
0.2	1.13	1.52
0.3	1.12	1.41
0.4	1.17	1.41

The results show that, the discharge magnitude of a clean duct is lower than that of a duct with particles. But as the voltage is increased, the discharge magnitude increases rapidly in case of a contaminated duct.

The existence of different mechanisms of discharges is evident from this study. The presence of one can also suppress the effect of the other. Hence a comparison of the case with and without particle may not be justified. However post discharge inception voltage regime would give us a lot of information for use of diagnostics of compressed gas insulation systems.

From the readings of Table 1, it is observed that the discharge inception voltage for a threshold level of 5 pC is nearly 1 kV for a clean duct and it is almost invariant with pressure of gas mixture. This is because the discharges are mainly due to the defects inside the spacer. To increase the discharge inception level of the clean duct, efforts were made to improve the quality of spacer, its contact with the conductor and the duct. For duct with particles the inception voltage is slightly higher for the same threshold level of 5pC.

Conclusions

1. The discharge inception voltage for a threshold level of 5 pC is invariant with gas pressure in a clean duct as well as for a duct with particles.
2. The discharge characteristics in case of a duct with particle show transitions with increase in voltage and pressure.
3. A sharp increase in discharge magnitude with small increase in voltage is a significant feature of a particle in a duct.
4. Presence of multiple regions in voltage vs. discharge magnitude plot indicates the presence of particles.
5. The roughness of the conductor and the duct may be influencing the discharge characteristics of a clean duct.
6. The presence of conducting particles act as additional perturbation to change the characteristics of voltage vs. discharge magnitude characteristic for the gas mixture studied.
7. For a clean duct, from the 3D histogram, it is observed that PD events in the positive cycle is more predominant than the negative cycle where as, for a duct with particle, it is in the negative cycle the PD is more predominant.

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