PD Characteristics of 10:90 SF_6- N_2 Gas Mixtures with Particle and Dielectric Coating of Metal Electrodes

B. Rajesh Kamath, *Member, IAENG* , J. Sundara Rajan, K. A. Krishnamurthy, M. Z. Kurian

Abstract— **The presence of particle in gas insulated systems impairs integrity of electrical insulation. On the insulator surface contamination can cause field distortions due to which the dielectric strength of the insulator gets affected. These particles get into the system accidentally during GIS assembly and they start vibrating during shipment. As free particles, they move under the action of electric field and then can adhere to the conductor or insulating spacers. These free conducting particles cause high field distortions. Moving particles which are firmly attached to the insulator surface are responsible for a large part of the failures registered in GIS. Thin insulating coatings are used in many high voltage applications to cover the central conductor of the duct to reduce the effect of particle contamination by decreasing the local electric fields. The thickness of these covering materials can vary from few tens of µm to few mm. This paper deals with the effect of dielectric covering on the central conductor introduced inside the co-axial duct on the Partial Discharge characteristics of the co axial duct with free copper particle in SF_6-N_2 gas mixture in the ratio 10:90.**

Index Terms— **Coaxial duct, Dielectric coating, Gas insulated system, Gas mixtures, metallic particle, Partial discharges, Histograms**.

I. INTRODUCTION

Electrical insulation performance of Gas Insulated Systems (GIS) is adversely affected by metallic particle contaminants [1]. These free conducting particles cause high field distortions [2]. Metallic particles however reduce the withstand voltage of gas insulated system considerably [3-5]. Many experimental studies were carried out to determine the role of these particles in initiating breakdown in the gaseous insulation. Presence of an insulator in the gas gap modifies the field distribution in the gap depending upon the dielectric constant and electric field conditions [6]. In addition to these factors, the dielectric strength is also influenced by the intrinsic properties of the insulating materials [7-8]. With the use of SF_6/N_2 gas mixtures as a replacement to SF_6 gas, the problem can be more complex and hence it is essential to repeat the studies on partial discharge characteristics in gaseous mixture [9-10]. In high voltage apparatus, insulating materials are used as shields or barriers to prevent flash over from high voltage points to nearby conductors in addition to their primary function of insulation. Conductors in a gas insulated system are coated with dielectric material to restore some of the dielectric strength of the compressed gas that is lost due to surface roughness on conductors, decreasing the high local electric fields [11].

In this study, the PD characteristics of a co-axial duct filled with 10:90 SF_6/N_2 gas mixtures at 0.4 MPa with the copper wire particle on the central conductor is presented and discussed and compared with covered conductor.

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II EXPERIMENTAL DETAILS

EQUIPMENTS USED

The heart of the experimental set-up is the high pressure test chamber as shown in Figure1. The epoxy high pressure chamber is designed mainly for studies on conical spacers. The volume of this chamber is about 3.5 liter and is fabricated with a material having sufficient tensile, compressive and shear strength to take care of all mechanical stresses that can be encountered during high pressure studies. The high voltage conductor is directly fixed to the top flange of the chamber and the other end is fixed to the lower fixed flange. The test object as shown in Figure 2, consists of a co-axial duct which is pressurized with the gas mixture. The coaxial duct with a central conductor of 17 mm diameter and outer cylinder of 45 mm inner diameter of non-magnetic stainless steel are used. The central conductor is directly coupled to the high voltage. The outer duct is connected to a separate terminal which is grounded. The outer duct is also free from sharp edges and micro protrusions. The conical spacer made of acrylic (PMMA) is fabricated from a molded 5 cm solid rod and the inner conductor is fitted into the conical spacer with great care using silver adhesive. This is for the better contact between the insulator and the conductor so that there are no voids.

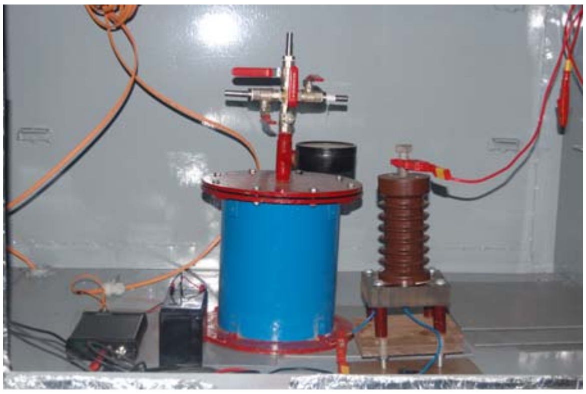

Figure 1. Photograph of the high pressure test chamber

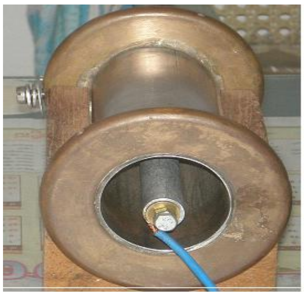

Figure 2. Photograph of the Co-axial Duct

In this study, combination of SF_6 gas and N_2 in the ratio of 10:90 has been used as gas mixture at a pressure of 0.4MPa in a co-axial duct. A polypropylene coating of 36 micron has been used as a dielectric to cover the central conductor of the co-axial duct.

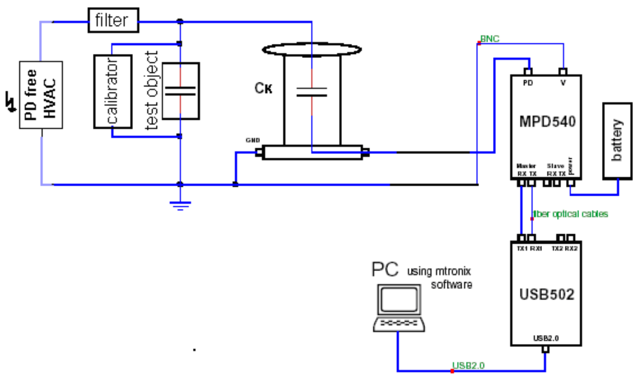

Figure 3. Circuit connections for discharge measurements.

The test equipment consists of MPD540 Advanced Partial Discharge Measuring and Analysis System of M/S Mtronix Precision Measuring Instruments. The circuit connection for the experiment is shown in Figure 3. It consists of MPD540 Acquisition Unit which senses the discharges of test object connected across coupling capacitor. USB502, the fiber optic controller is connected to Acquisition Unit. The USB terminal of fiber optic controller is connected to the computer's USB port by using a standard USB 2.0 cable.

EXPERIMENTAL PROCEDURE

The PD measuring system is first calibrated by the usual method using a standard pulse generator. The calibrator is then 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 less than 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.

III RESULTS AND DISCUSSIONS

The results of PD measurements carried out on a co-axial duct at a pressure of 0.4 MPa is discussed in terms of 2D and 3D histograms.

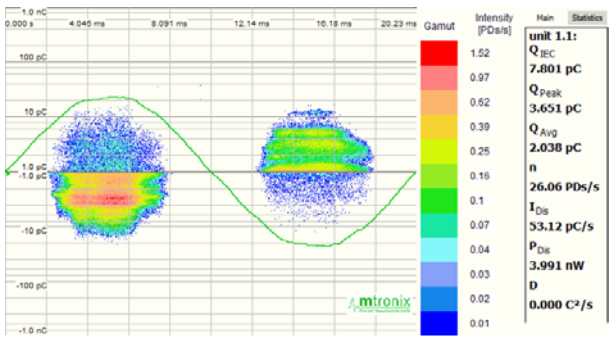

Figure 4. 2D PD histogram under clean conditions

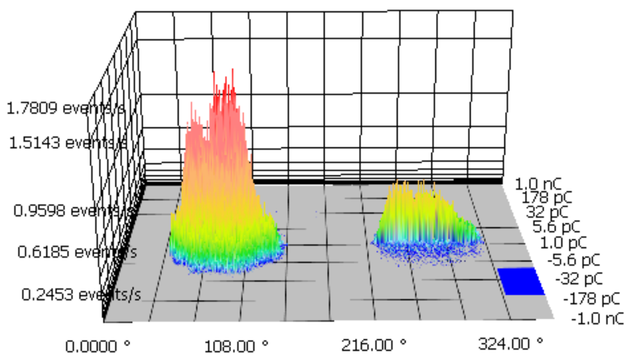

Figure 5. 3D PD histogram under clean conditions

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Figure 4, shows the 2D histogram of a clean co-axial system consisting of, SF_6 - N_2 (10:90) gas mixture at 0.4 MPa pressure and its 3D histogram is shown in Figure 5. At 0.4 MPa, the PD activity is observed to be more prominent under positive cycle of ac as seen in the histograms. Further, PD activity is confined to 36^0 and 144^0 and 216^0 and 324^0 on the two ac half cycles. The number of PD events is 1.8 PDs/sec (maximum) in case of the positive half cycle whereas, it is about 1 PD/sec in the negative half cycle. Even the spread of discharge magnitude is larger during the positive half cycle. If we consider Figure 4, in relation to the intensity chart furnished, the discharges seen having PD magnitude of 10 pC are due to PDs of intensity 0.97 PDs/sec to 1.52 PDs/sec. But corresponding values on the negative cycle are very insignificant. Hence, under the given experimental condition, PD during positive half cycle is very dominant. This may be attributed to the roughness of the central conductor. The results are duly supported by the 3D histogram in Figure 5. The pulse repetition rate "n" is only 26 PDs/s as seen from statistics display in Figure 4.

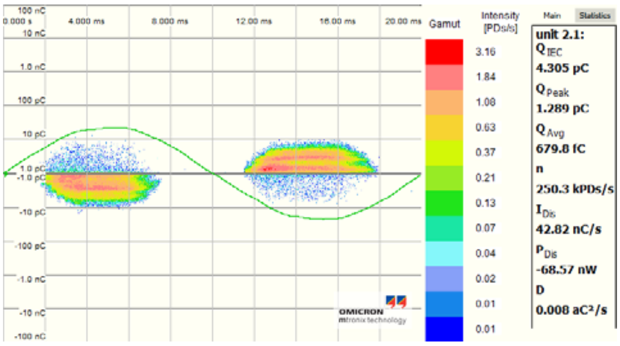

Figure 6. 2D PD histogram with copper wire particle

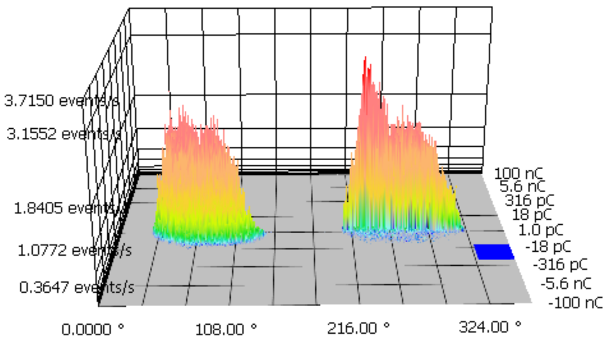

Figure 7. 3D PD histogram with copper wire particle

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With the insertion of particle inside the duct, as seen from 2D and 3D histograms (Figure 6 and Figure 7 respectively), the PD activity is more intense but predominant in the negative half cycle. This is because of the high stress due to the particle introduction. The sharpness on the two ends of the particle increases the PD activity, that too on the negative half cycle. From the intensity chart furnished in Figure 6, the discharges seen having PD magnitude of 10 pC are due to PDs of intensity 1.84 PDs/sec to 3.16 PDs/sec. as compared to their respective values of 1.8 and 1PDs/sec in the case of a clean duct. The number of PD events is 3 PDs/sec (maximum) in case of the positive half cycle whereas, it is about 3.7 PDs/sec in the negative half cycle. Further, PD activity is confined beyond 36^0 and 144^0 for positive half and beyond 216^0 and 324^0 for negative half on the two ac half cycles as seen from 3D histogram (Figure 7). Even the spread of discharge magnitude is larger during the negative half cycle. The pulse repetition rate "n" is 250 kPDs/s for a duct with particle when compared to 26 PDs/s for a clean duct.

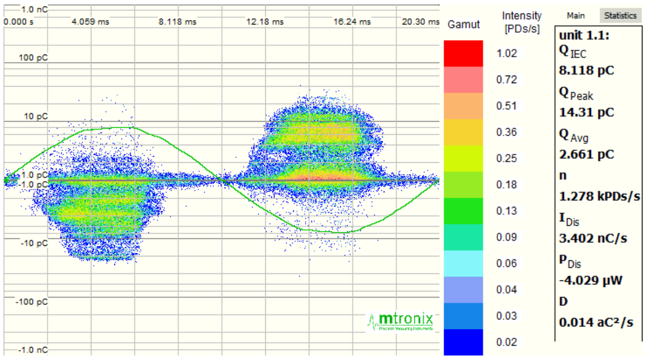

Figure 8. 2D PD histogram with copper wire particle polypropylene film covering the central conductor

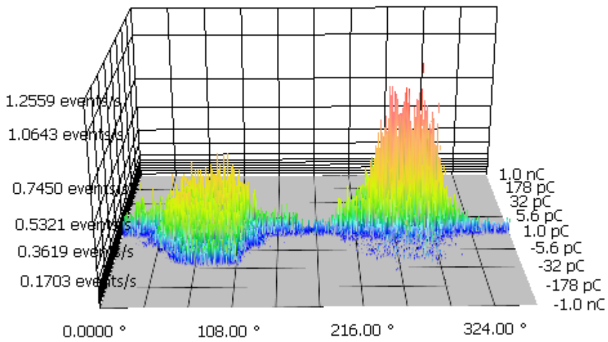

Figure 9. 3D PD histogram with copper wire particle polypropylene film covering the central conductor

With the central conductor covered with a polypropylene sheet and particle inserted inside the duct, the PD activity is observed to be less intense as in Figure 8. The number of PD events is 0.5 PDs/sec (maximum) in case of the positive half cycle whereas, it is about 0.7 PDs/sec in the negative half cycle. From the intensity chart furnished in Figure 8, the discharges seen having PD magnitude of 10 pC are due to PDs of intensity 0.72 PDs/sec to 1 PDs/sec. Further from Figure 9, PD activity is distributed from 0^0 to 360^0 for the positive half and the negative half on the two ac half cycles. After covering of the central conductor by the polypropylene film, the pulse repetition rate "n" is reduced to 1.27 kPDs/s

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IV CONCLUSIONS

1) With the particle in the duct, there is significant activity in the negative ac half cycle and relatively reduced activity in the positive half ac cycle. The pulse repetition rate “n” for a duct with particle is significantly higher when compared to a clean duct.

2) In presence of metallic particle with and without the central conductor covered, PD events are significant on the negative half of ac cycle. It has a distribution of large number of low magnitude PD and very few of large magnitude PD pulses.

3) The discharges seen are of varying intensity, low for a clean duct, high for a duct with particle and lower for a covered conductor with particle.

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