Partial Discharge Characterisation of Nichrome Particle in a Gas Filled Duct

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

***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. This paper deals with the influence of conducting particle placed in a co-axial duct on the discharge characteristics of gas mixtures. Co-axial duct placed in a high pressure chamber is used for the purpose. A gas pressure of 0.4 MPa has been considered with a 10:90 SF_6 and N_2 gas mixture. The 2D and 3D histograms of clean duct and duct with particle are discussed in this paper.**

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

I. Introduction

Sulphur Hexa Fluoride (SF_6) gas is one of the most extensively and comprehensively studied molecular gases to date largely because of its many commercial and research applications. Because of its basic physical and chemical properties such as nontoxic, nonflammable, non- explosive and thermal stability, it is widely used in the power industries [1]. SF_6 gas is a strong electronegative gas both at room temperature and at temperatures well above ambient, which principally accounts for its relatively high dielectric strength. The breakdown voltage of SF_6 gas is nearly three times higher than air at atmospheric pressure [2]. Even though SF_6 gas has outstanding electrical insulating properties, its impact on global atmosphere have been intensively debated and discussed. SF_6 gas forms highly toxic and corrosive compounds when subjected to electrical discharges. SF_6 gas is also an efficient infra-red absorber, and due to its chemical inertness is not rapidly removed from the earth's atmosphere. Environmentalists have seriously considered the contribution of SF_6 gas to ozone depletion and the global greenhouse effect. The high global warming potential of SF_6 gas has raised several questions about its use. The fear is about excessive release of SF_6 gas into atmosphere and the Power industry inherently bases its possible contribution to the greenhouse effect on the projections about the future consumption of SF_6 gas. The global production of SF_6 gas is very small and its effective contribution as a greenhouse gas is considered to be negligible. However efforts are made to minimize the use of SF_6 gas for electrical applications.

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 [3]. 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, as long as the SF_6 gas is not legally forbidden. As a further advantage, the N_2/SF_6 gas mixtures, with small amounts of SF_6, have lower boiling temperature values than pure SF_6.

The presence of particle in gas-insulated systems impairs integrity of insulation. On the insulator surface contamination can cause field distortions due to which the dielectric strength of the insulator get affected [4]. Contaminants at service voltage with superposed transient over voltages can cause a substantial reduction of the dielectric strength of the system, depending on the location and the geometric conditions of the conducting particle. Therefore, N_2/SF_6 insulated high voltage equipment must be dimensionalized in such a way that the reduction of the dielectric strength due to contamination does not lead to a flashover in the system for all types of possible over voltages.

In this study, combination of SF_6 and N_2 in the ratio of 10:90 has been used to determine the effect of conducting particle on Partial Discharge characteristics in a co-axial duct with Nichrome particle as contaminant.

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

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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.

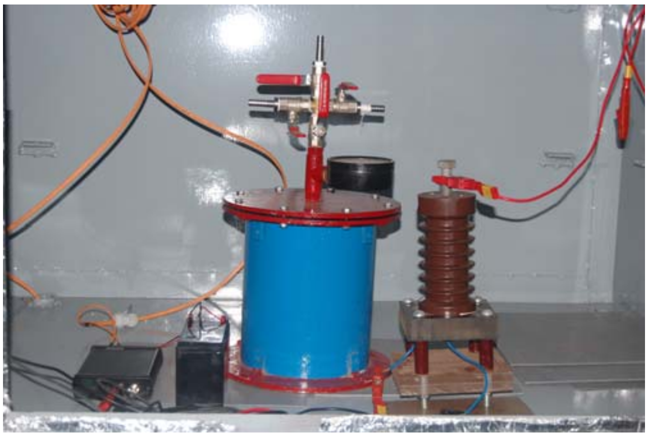

Figure1. Photograph of the high pressure test chamber

Figure2. Photograph of the Co-axial Duct

In this investigation, the measurement of the gas pressure was done directly at the test chamber with a digital pressure gauge with accuracy of +/- 0.1%. The chambers are evacuated with a rotary vacuum pump, up to 10^{-2} tor. Pure and dry (99.9%) SF_6 gas confirming to IEC 376 and high purity N_2 (99%) from the gas cylinders are filled into the chamber directly to the required pressure and proportion, first with nitrogen and then with Sulphur Hexa Fluoride gas. The inlet connection for vacuum pump N_2 and SF_6 gases is through 3 different control valves made of steel. Within the chamber, drying agents are placed at the inlet line as well as within the chamber. The filling of test vessel up to the desired gas pressure was always performed after a preceding evacuation to a pressure less than 10 Pa.

After each experiment, the gas mixture is retrieved in an empty cylinder, which is at a very low pressure and used for further experiments. The gas mixtures in the storage cylinder are preserved at ambient temperature in the gaseous state.

The conducting particles of 0.3 mm diameter and 10mm length of bare Nichrome conductor was used for the purpose. No special tip geometry was used. The particle was fixed vertically on the central conductor. A small amount of silicon adhesive was used for the purpose. Care was taken that no tip was covered with adhesive.

METHOD OF MEASUREMENT:

The test equipment mainly consists of MPD540 Advanced Partial Discharge Measuring and Analysis System of Mtronix Precision Measuring Instruments as shown in the Figure 3. The circuit connection is as shown in figure 4.

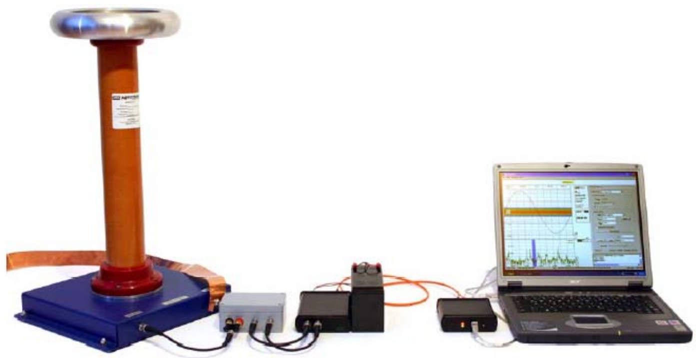

Figure1. MPD540 advanced PD measuring system with coupling capacitor

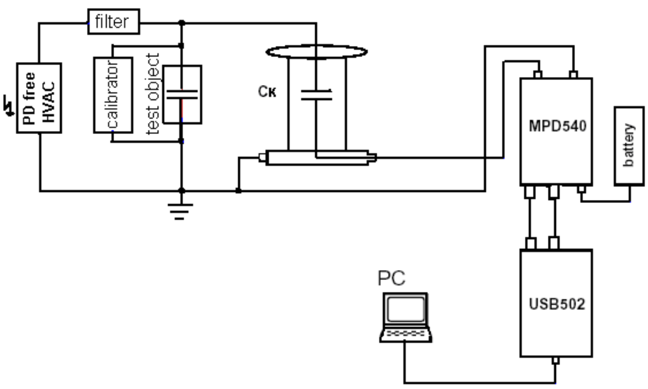

Figure2. Circuit connection

The PD measuring system is calibrated by connecting a PD calibrator across a test object and the measuring system is calibrated at the frequency where noise level is low (< 1

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pC). 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 first at a frequency where noise level is low (< 1 pC) and then 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 30% above the discharge inception level and reduced gradually to zero to record the extinction voltage. For the complete voltage cycle, the visualization display is as shown in the Figure 5. From large scope view, the high voltage waveform and the phase resolved histogram of PD acquisition unit are observed. From small scope view, the time variation of the input signal and corresponding discharges can be seen. In this screen, in a different mode, the threshold discharge, the corresponding inception and extinction voltages are also displayed.

III EXPERIMENTAL RESULTS:

PD measurements were carried out on a co-axial duct with particle fixed to the central conductor. For each condition, experiments were conducted for a pressure of 0.4 MPa.

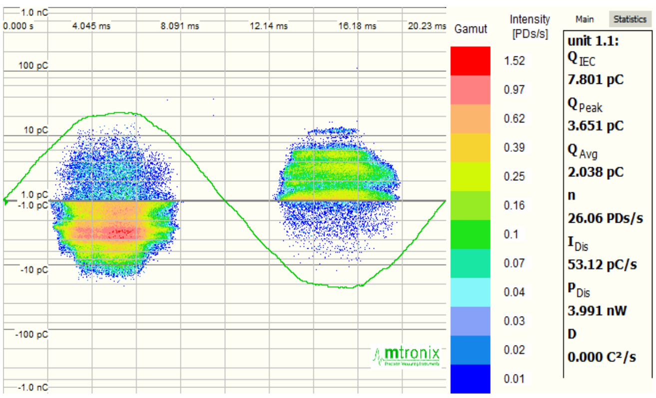

Figure 5. 2D PD Histogram of a clean duct at 0.4 MPa

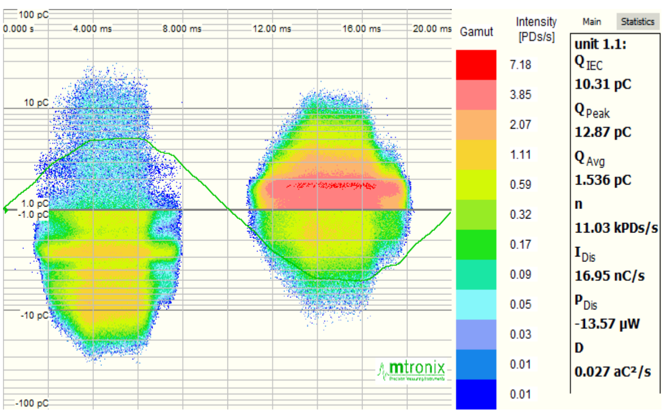

Figure6. 2D PD Histogram of duct with Nichrome particle at 0.4 MPa

In figure 5 is shown the 2D PD histogram of a clean duct at 0.4 MPa and in figure 6 is shown the 2D histogram of the duct with Nichrome particle fixed to the central conductor. The discharge current in the duct with the particle on the conductor is 16.95 nC/s whereas for the duct with particle on the central conductor is 53.12 pC/s. For a clean duct the number of events/second "n" is 26.06 PD's/s whereas for a duct with particle, it is very high and is of the order of 11.03 kPD's/s.

The PD Histograms also reaffirms that the PD is always more for a duct with particle than the duct with particle on the central conductor for the given voltage. The Qpeak takes place at the value 3.651pC for the former case whereas for the latter case it is as high as 12.87pC. The intensity of PD's per second is only 1.52 for a clean duct and for a duct with particle it is 7.18 which are nearly 5 times.

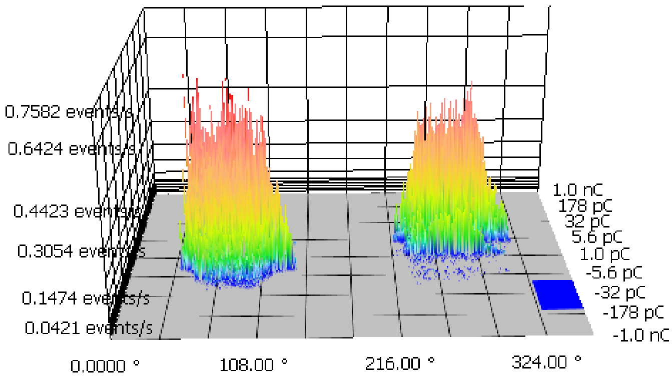

Figure7. 3D PD Histogram of a clean duct at 0.4 MPa

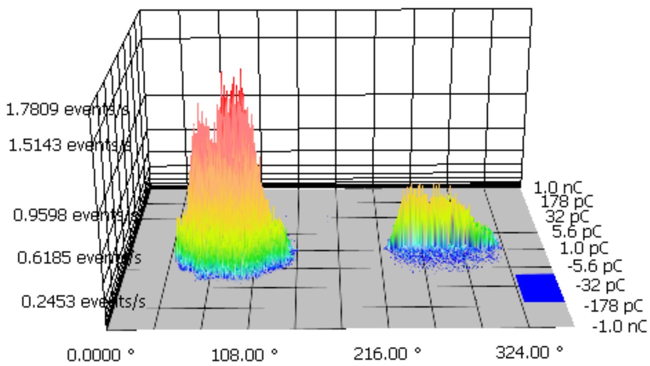

Figure 8. 3D PD Histogram of duct with Nichrome particle at 0.4 MPa

Figure 7 and figure 8 show the 3D histogram of a clean duct and the duct with Nichrome particle on its central conductor respectively. The 3D histogram clearly shows the change in the magnitude of the events/s for a duct with and without the particle. For a clean duct, the event/second is only 0.7582 whereas for a duct with Nichrome particle it increases to 1.78 events/second. The 3D histogram in figure 8 clearly shows the presence of a particle.

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IV CONCLUSIONS

1. The discharge current in a clean duct is 16.95 nC/s, whereas for the duct with Nichrome particle on the central conductor is 53.12 pC/s. That means, with particle, the discharge current in a duct increases 3 times when compared to a clean duct.
2. The number of events/second increases abnormally with the particle. i.e. from 26.06 PD's/s to 11.03 kPD's/s.
3. For a clean duct, the event/second is only 0.7582 whereas for a duct with Nichrome particle it increases to 1.78 events/second.

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