Partial Discharge Characteristics of Micro-gaps

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Abstract – ***Partial discharge characteristics of multiple micro-gaps formed by using blade electrodes are studied in series and parallel configuration. The air-breakdown characteristics of different micro-gap configurations are compared and discussed. The breakdown strength of series gap is significantly higher than the parallel configuration. However, the partial discharge activities are found to be higher in series configuration than the parallel configuration. The observed PD characteristics of series gap are discussed in relation to electrostatic induction on the floating electrodes. The effect of applied voltage and the number of series gas on the PD characteristics is also studied and discussed in relation to charge formation and distribution.***

I. INTRODUCTION

Partial discharges (PD) are one of the major causes of electrical equipment or system failure and hence, significant attention was given on the same in the past [1-6]. PD is normally caused by higher electric field at the electrodes or dielectrics. The higher field in dielectrics occurs due to structural defects such as voids, cracks, and interfaces etc., where air or gas is entrapped. These defects essentially affect the reliability of the dielectrics and hence often lead to catastrophic failure of the electrical systems. Despite significant studies carried out in the past ambiguity with regard to the physics of PD still exists [4-7]. Recently, Poornima etal [8] reported that the magnitude of non-uniform electric field reduces significantly, as the electrode gap is reduced below 1mm. The present work is therefore aimed at understanding the PD behavior of micro-gaps below 1mm.

II. EXPERIMENTAL PROCEDURE

Micro air gaps, formed by using blade electrodes possessing a large aspect ratio (20µm thickness and 15mm length) are used in the present study. The blades are fixed appropriately in a fixture to attain the desired configuration as discussed elsewhere [8]. The distance between the electrodes (i.e, air gap) is adjusted accurately to the desired level by using spacers and is subjected to the breakdown and partial discharge measurement. The PD measurements across the micro-gaps are performed by ICM-Power Diagnostix system as shown in Fig. 1. The voltage was raised slowly till 90% of the breakdown voltage. The PD patterns are recorded at different voltages levels and studied.

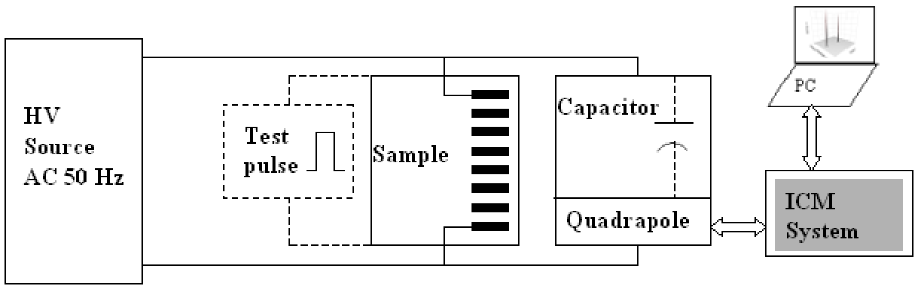

Fig. 1 Schematic diagram for partial discharge measurement

III. RESULTS AND DISCUSSION

Three types of micro-gap configurations, single, series and parallel gaps are studied. As a first step, the breakdown characteristics for different electrode configurations under DC field are studied and compared in Fig. 2. Note that the series gap results shown in the figure correspond to the total gap that is formed with the multiplicity of 50µm gap. Similarly, 5 electrodes in parallel with the help of 1mm spacer form the parallel gaps. The voltage in the former is divided across 50µm gaps and in the later the voltage across each gap is same. As can be seen in Fig. 2 that the breakdown strength of single or parallel electrode configurations are similar. Contrarily, the breakdown strength of series gap is

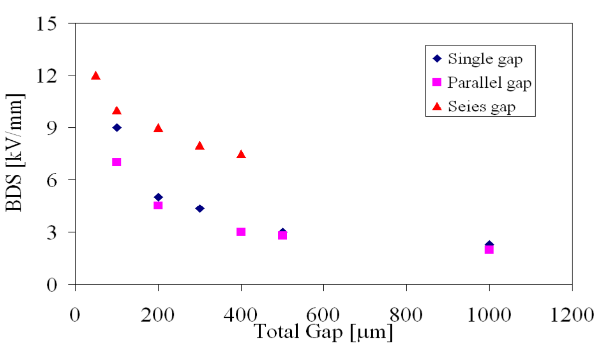

Fig. 2 Breakdown strength of different electrode configurations

increased significantly. However, in all the cases, the breakdown strength increases as the gap is decreased. The observed trend is attributed to the fact that the extent of e-field non-uniformity reduces as the gap is decreased [8]. Fig. 3 compares the waveforms obtained for single and series gap of 200 µm. The inception stage of breakdown of single gap display more oscillations compared to that observed in series gap. Higher oscillation may be attributed to (a) power supply parameters and (b) charge formation due to ionization near the vicinity of the electrodes. Note that the discharge involves one set of electrodes and hence the charges formed on the electrodes may be non-uniform. In the case of multiple / series gap, the voltages are divided equally. As stated earlier the e-field across smaller gap is uniform and hence charges are distributed uniformly near the vicinity of all the electrodes. The waveform at the inception stage of the breakdown of the series gap therefore exhibits no oscillation. Note that the voltage collapse time in single gap is faster (< 0.5µs) compared to the series gap (2µs), which substantiates the argument that the former exhibits non-uniform field and non-uniform charge distribution compared to the series gap. Note that the probability of secondary electron generation and the avalanche formation is much lower when the multiple gaps are connected in series compared to single gap [9-11]. Because, the energy acquired by a field-emitted electron in series gap is lower than the electron in single gap as the energy and hence, the number of electron-collisions in series gap is lower than that of single gap. Hence, the breakdown time in series gap is longer than the single gap.

The Partial discharge in the case of single gap is found to be absent whilst PD activities are observed in series gap despite the fact that the breakdown strength is higher. Typical PD pattern observed in series gap at 1kV is shown in Fig. 4. The PD activities in general are found to be significant when the series gaps exceed 3 gaps. Note that when the series

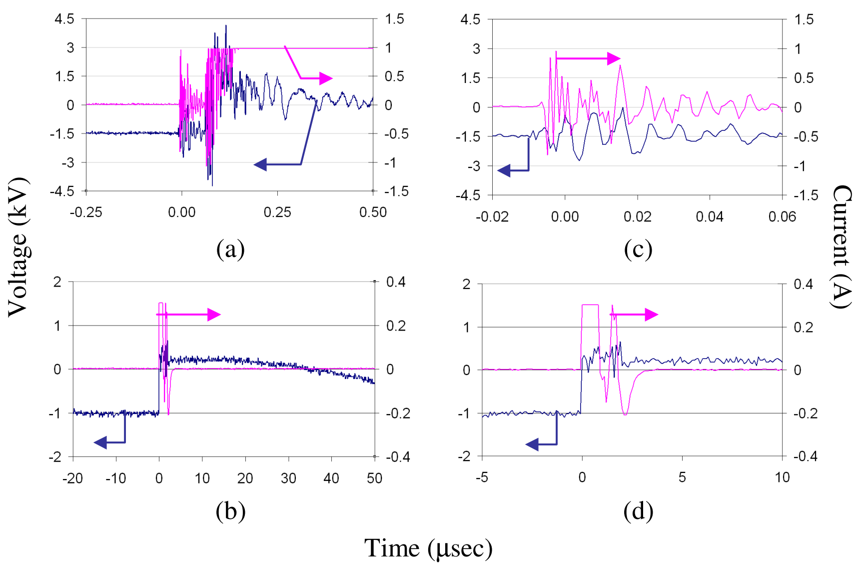

Fig. 3 Breakdown waveforms of (a) single and (b) series gap of 200 µm gap. Note (c) and (d) represent the expanded portions respectively.

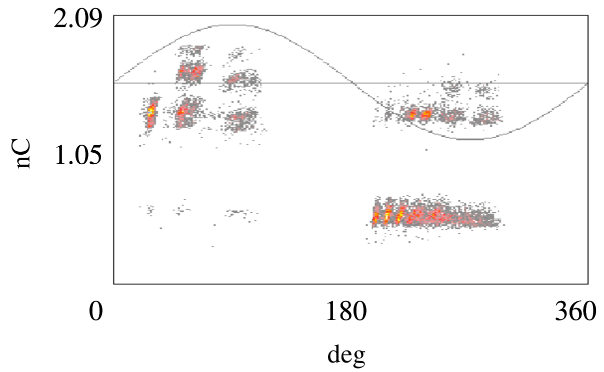

Fig. 4 PD pattern observed in 4 series gap

configuration constitutes above 3 gaps at least one set of positive and negative electrodes are floating. Note that the PD magnitude of 1.5nC is abnormally higher at 1kV voltage, which clearly suggests that the observed PD is attributed to electrostatic induction on the floating electrodes that are not linked with the terminal electrodes. Interestingly, the PD phase angle increases with an increase in the number of series gap as summarized in Table 1. Similarly, for a given series gap PD phase angle changes with applied voltage though significant variation in the PD magnitude is not observed with applied voltage. However, the pulse counts vary significantly though the magnitude does not change appreciably as shown in Fig. 5. These results indicate that the PD observed in the series gap is largely due to electrostatic induction on the floating electrodes.

IV. Conclusion

The partial discharge characteristics of multiple micro-gaps in series and parallel configurations are different from that of conventional macro-gaps. Though the breakdown strength is found to be higher in series configuration PD activities are observed. However, the variables such as applied voltage and number of series gaps do not influence the PD magnitude appreciably. On contrast, these variables influence the partial discharge pulse angle and the pulse count. The parallel configuration does not display any PD ac-

TABLE I PHASE ANALYSIS OF PD DATA FOR DIFFERENT GAPS IN SERIES

No. of gap	Phase angle (degree)					
	Positive Cycle			Negative Cycle		
	Start	End	Peak	Start	End	Peak
4	44	68	53	223	252	230
6	45	71	58	217	242	230
8	51	84	63	212	260	230

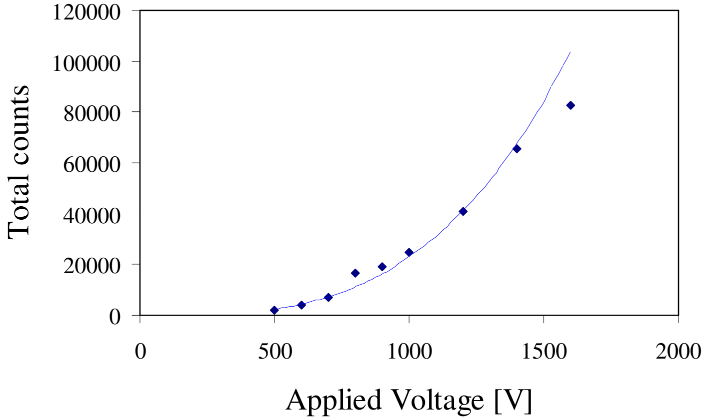

Fig. 5 PD pulse count as a function of applied voltage

tivities.

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