Study of Partial Discharges between Plane – Plane/Point Electrode Configurations at Different Gap Lengths

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Abstract: **Insulation between the high voltage electrodes employed in circuit breakers, Gas insulated substations plays a important role in the operation of power system. The main cause of failure of an insulation starts from partial discharge and ends up with the breakdown of insulation. Therefore its necessary to make a study of existence of partial discharges and its magnitude and measure the impact on the power system to take the remedial action. The partial discharges exist because of the defects in the insulation media. The local electrical breakdown is also called as partial discharge (PD) which occurs due to high voltage stresses. Due to this continual occurrence of PD leads to breakdown of the system. It's the high task of the electrical engineers to monitor the PD activity of the high voltage system and take the possible preventive steps. In this paper the experimental results of the PD activity between plane – plane/pointed electrodes with and without spacers have been presented. OMICRON MPD 600 software and hardware setup has been used to capture the 3D histogram files for the evaluation of partial discharges in the system.**

Keywords**: Surface discharge, Corona discharge, Partial Discharge (PD), Inception Voltage and Extinction Voltage.**

I. INTRODUCTION

Transmission of Electric Power at high voltages has gained a considerable prominence in recent years. It is essential to design and develop a compact, cost effective and reliable insulation system. The use of gas insulated transmission and distribution and substation equipments have gained a lot of importance because of its compactness and maintenance free, safe and reliability. All over the world the researchers have identified SF_6 gas has better performance at high voltages. But its performance is adversely affected by the presence of foreign particles like metal; voids in the spacers between the electrodes which initiate the partial discharges leading to the catastrophic failure of insulation structure [1-3]. Depending on the size and shape of the particles and the type of voltage profiles the local electric field is influenced, which in turn leads to breakdown of the system. In inhomogeneous electric fields, a self-sustained propagating discharge is called partial discharge. It may not lead to flashover between the electrodes immediately but as the time progresses it leads to breakdown. PD is the most unwanted phenomenon in high voltage insulation system. It causes degradation to the equipment insulation leading eventually to the breakdown and system failure. The phase resolution of the discharge pattern may lead to clues about the nature of the discharge. The corona discharge occurs due to the ionization of the air in between the high voltage electrode and the ground electrode or any sharp point under high voltage stress. For negative corona, Trichel pulses are observed above a certain voltage stress. If the voltage is constant, Trichel pulses have constant peak values, repetitive frequency and pulse shape. Trichel pulses may be observed while there are no discharges in the positive half cycle since the negative corona has lower inception voltage when compared to positive corona. With increase in voltage it will transit to negative glow discharge. Then there may be formation of luminous spot may be observed at cathode. If the field is inhomogeneous discharges called feathers or negative streamers are observed in the transition region between glow discharge and breakdown. Whenever the insulation in between the electrodes become weak, the first observation is the occurrence of partial discharge pulses in the negative half cycle and if it predominates it will occur in positive half wave also and as time progresses the partial discharge lead to breakdown [4-7].

There will be four types of discharges, noise, surface discharge, corona discharge, and internal partial discharges. The magnitude of noise discharges will be of low value and can be eliminated by selecting the suitable value as threshold discharge. Surface discharges occur when the spacers are introduced in between the electrodes. Corona discharge is a continuous phenomenon once the applied voltage reaches a discharge voltage. Above all these the partial discharge occurs when which appears like a pulse of spike occurs at certain angles in the waveform.

II. EXPERIMENTAL PROCEDURE

The MPD 600 Partial Discharge Analysis System is an acquisition and analysis tool kit for detecting, recording, and analyzing partial discharge events in many applications. It is controlled by the integrated MPD/MI software featuring real-time visualization and analysis options of PD detection and system parameters. The circuit connection for the experiment is shown in Figure 1. It consists of MPD 600 data acquisition Unit which senses the discharges of test object connected across coupling capacitor.

1. MPD 600 acquisition unit is connected to the MCU 502/504/550 (1) control unit using fiber optical cables to the plugs of color-coded.
2. The MPP 600 battery pack is connected to the MPD 600 acquisition unit using the battery cable. The red LED at the MPD 600 unit starts flashing, indicating that the acquisition unit is ready for operation.
3. The CPL 542 quadripole / measuring impedance unit is connected in between the coupling capacitor and the MPD 600 as shown in the one line diagram.
4. The MCU unit is connected to the computer using the USB cable.

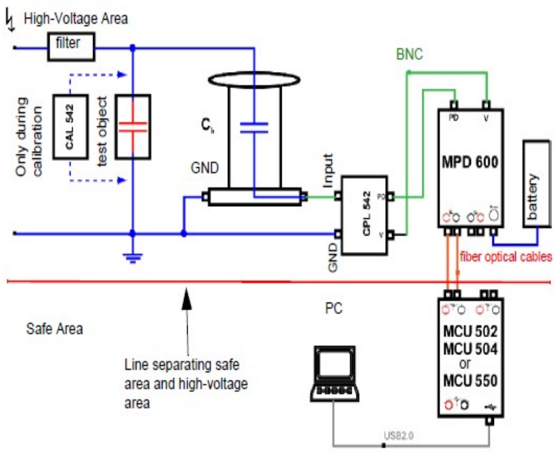

Figure 1: The connection diagram of MPD 600 for acquiring PD signals.

At the beginning the PD measuring system is first calibrated by connecting a PD calibrator across the test object. 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 calibrator is disconnected and the sample is connected to a PD free, HVAC source across the test object, through a RC divider.. 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.

To start the system connections are made as shown in the circuit diagram, and we have to make the calibration of voltage and charge selecting the calibration in the basic mode. The calibration gives the multiplying factors for voltage and charge. After calibration the software is shifted to expert mode and made the selection of settings of frequency, charge and voltage. Now the test cell is connected to the system and voltage is applied gradually to observe the discharges occurring between the electrodes.

III. RESULTS AND DISCUSSION

The following histograms and the final PD graphs of phase, charge and number of discharges (Φ, Q & n).

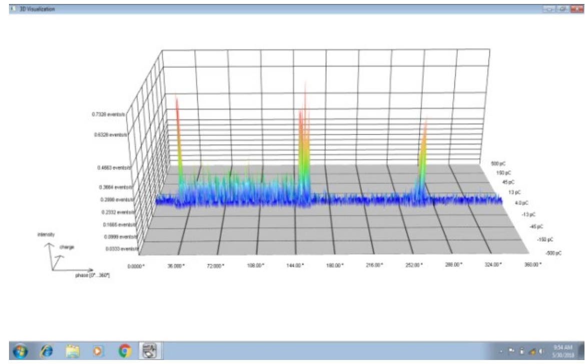

Figure 2: Histogram for a plane - plane electrodes with applied voltage of 7.271kV, for a gap length of 10 mm.

It is observed that the partial discharge pattern seems to be corona discharge between the electrodes with a partial discharge occurring more in the positive half cycle at an angle of 30 degrees and 150 degrees the PD is occurring at a magnitude of 0.29 events/second and 0.55 events/second. Partial discharges are occurring in both +ve and –ve half cycles.

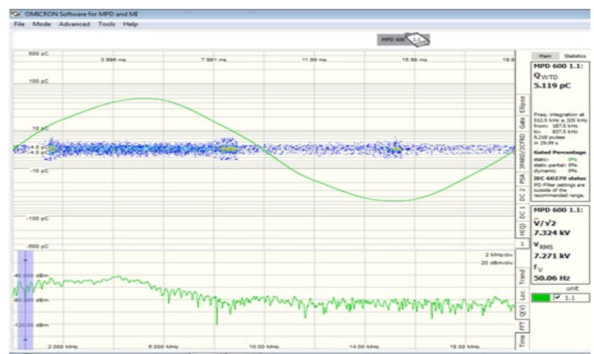

Figure 3: PD graphs for a plane - plane electrodes with applied voltage of 7.271kV, for a gap length of 10 mm.

In the negative half cycle at a phase angle of 270 degrees with a PD a magnitude of 0.36 events/ second. The inception voltage of PD is 4.23kV and PD extinction voltage is 3.1kV.

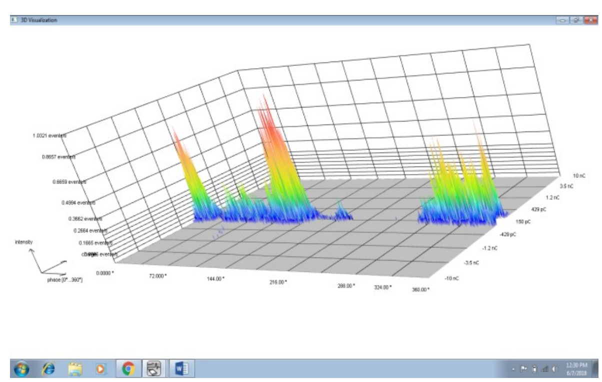

Figure 4: Histogram for a plane – pointed electrodes with a 10mm PMMA spacer, with applied voltage of 4.247kV,

It is observed from the figure 4, 3D histogram that for a plane – pointed electrodes the pd is taking place at a lower voltage and the magnitude is 0.866 events/sec in the positive half cycle at an angle of 125 degrees and a magnitude of 0.25 events/sec in the negative half cycle at an angle of 320 degrees with a PMMA spacer in between the electrodes. It is like a surface discharge at the surface of the spacer along with a PD pulses at different angles. Because of the presence of spacer the pd is starting at a lower voltage when compared to without spacer.

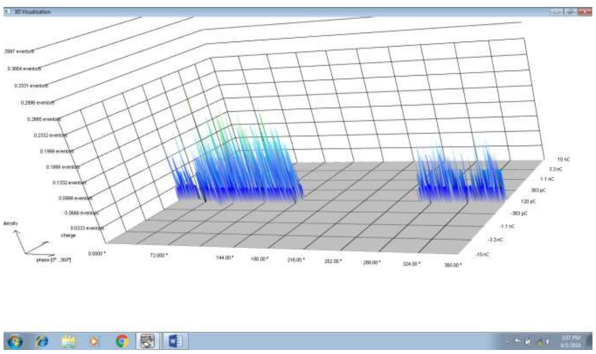

Figure 5: Histogram for a plane – pointed electrodes with applied voltage of 2.57kV, with a 10mm PTFA spacer.

It is observed from the figure 5, 3D histogram that for a plane – pointed electrodes the pd is taking place at a voltage of 4.37kV with inception voltage of 2.1kV. The pd magnitude of 0.1664 events/sec in the positive half cycle at an angle of 140 degrees and a magnitude of 0.05 events/sec in the negative half cycle at an angle of 288 degrees with a PTFA spacer in between the electrodes. It is like a surface discharge at the surface of the spacer along with a PD pulses at different angles. Because of the presence of spacer the pd is starting at a lower voltage when compared to without spacer. When the spacers are introduced between the electrodes it is observed that a bunch of pulses are occurring at both positive and negative half cycles with low magnitude in the negative half compared to positive half cycle.

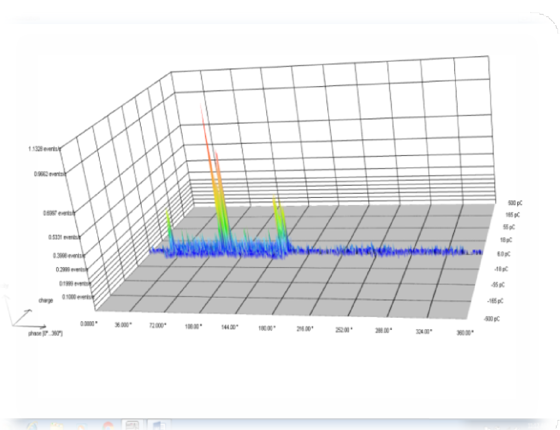

Figure 6: Histogram for a plane - plane electrodes with a gap length of 12.5 mm with applied voltage 8.75kV.

If we observe the histogram for a gap length between the electrodes as 12.5mm, the pd has increased when compared to 10 mm gap length. The pd events have been increased to 0.83 events per second at an angle of 90 degrees in the positive half cycle and there is very low pd in the negative half cycle.

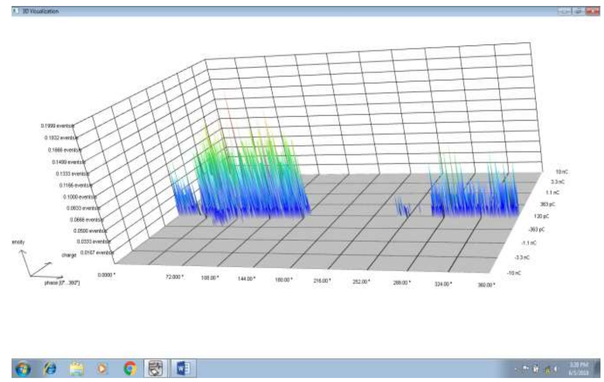

Figure 7: Histogram for a plane - pointed electrodes with a spacer PTFA of 12.5mm thickness with applied voltage of 4kV.

In the pd graph of PTFA spacer the applied voltage of 4kV, the inception voltage of 2.33kV and the pd magnitude is 0.133events/sec in the positive half cycle and 0.05 events/sec in the negative half cycle. The discharge is like a corona discharge.

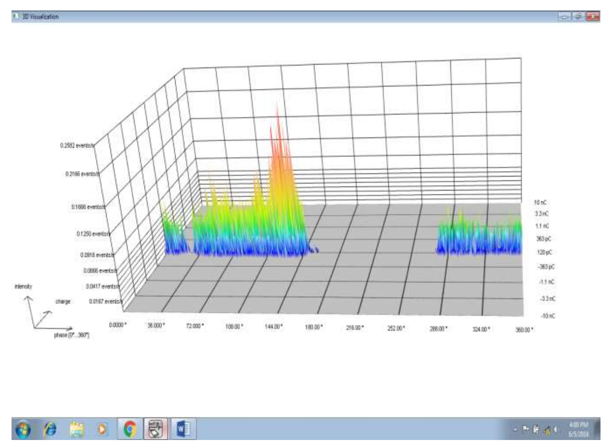

Figure 8: Histogram for plane – pointed electrodes with a PMMA spacer of 12.5mm thickness.

In the pd graph of PMMA spacer the applied voltage of 3.8kV, the inception voltage of 2.36kV and the pd magnitude is 0.2events/sec in the positive half cycle at an angle of 130 degrees and 0.0167 events/sec in the negative half cycle at an angle of 300^0 The discharge is like a corona discharge

The figure 9 shows the 2d pd graph of 12.5mm gap between the electrodes with applied voltage 8.16kV.

The 2D graph of plane – plane electrode shows the variation of charge with phase angle. Partial discharge is present in the positive half cycle more predominant rather than in the negative half cycle.

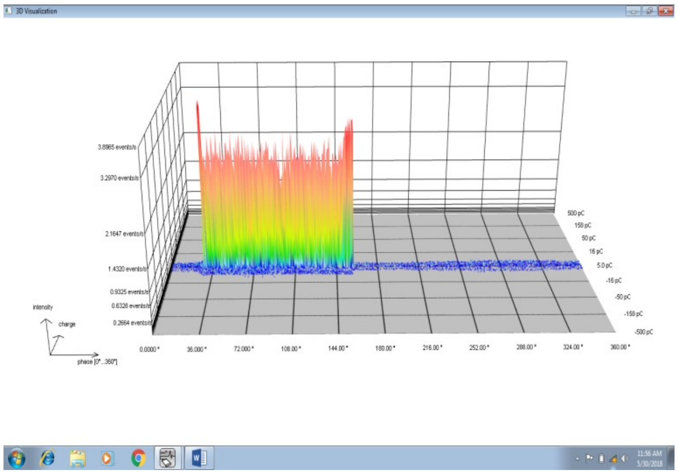

Figure 10: Histogram for a plane - plane electrodes with a gap length of 15 mm.

The pd graph shows that PD is taking place in the positive half cycle and it is increased to 0.3 events/sec at the applied voltage of 15.2kV. The pattern it shows that it is continuously taking place and so it will be a corona discharge. The pd is not more predominant in the negative half cycle when compared to positive half cycle.

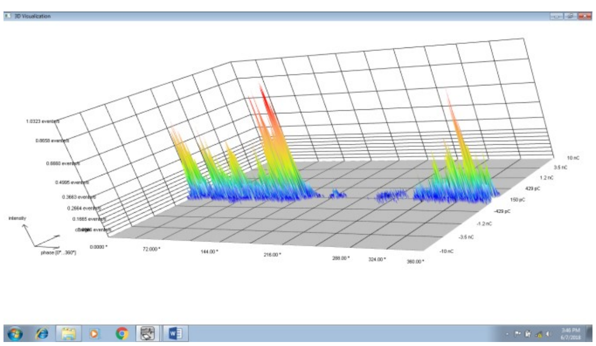

Figure 11: Histogram for a plane - pointed electrodes with PMMA gap length of 15 mm.

When the spacers are introduced in between the electrodes the pd is increasing when compared to without spacer. The pd has increased to 0.865events per second with the applied voltage of 3.69kV and the inception voltage of 2.89kV for PMMA spacer. It indicates that the pd is more predominant in the presence of spacers. It is taking place at lower voltage when compared to without spacer for the same gap lengths. In the case of PTFA spacer also 0.116 events/sec with applied voltage of 2.8kV and inception voltage of 2.3kV

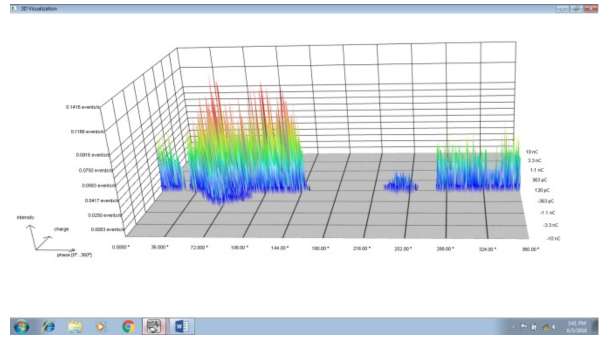

Figure 12: Histogram for a plane - pointed electrodes with PTFA gap length of 15 mm

The figure 13 shows the 2d pd graph of 15mm gap between the electrodes with applied voltage 15.2kV.

From the figure 13, 2d pd graph the inception voltage for plane-plane electrodes with a gap of 15mm is 10kV and at 2 MHz frequency. The charge is around 7.99pC. It is observed that pd is occurring in the positive half cycle and their number of discharges has been increased to 3events/sec. The charge is varying from 0 to 8 pC and it also increased from pervious values for 10mm and 12.5mm gap lengths. The reason for the increase is because of the increase in the applied voltage and the media in between the electrodes may get ionized because of the high voltage applied between them and discharges taking place on the surface of the plate electrodes. The discharge is more predominant in the positive half cycle and very small in the negative half cycle for the gap of 15mm and it is present for the other two gap lengths as shown in figures 2 and 6.

IV. CONCLUSIONS

1. The partial discharge takes place between the electrodes when the insulation between the electrodes becomes weak.
2. The magnitude of the discharge mainly depends on the applied voltage with respect to the gap length.
3. With variation in the electrode configurations the intensity of pd varies and it is observed that plane pointed electrodes gives more pd than plane- plane electrodes.
4. The partial discharge studies clearly indicate that the life of insulation is getting reduced.

5. The intensity of pd can be easily identified by the variation in the color of the pd pulse.
6. The pd inception voltage is lower in case of plane-pointed electrodes compared to plane -plane electrodes.

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