Simulation of Partial Discharge inside the Solid Insulation in High Voltage Equipment

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Abstract---Solid dielectric materials are used in all kind of electrical apparatus and devices to insulate one current carrying part from another when they operate at different voltages. But it is found that most of the insulators are manufactured without avoided a small amount of impurity inside the insulator. The impurity of such insulating material is in the form of solid, gas or liquid. During the manufacturing process it is found that most of the solid insulation has impurity in the form of air bubbles (void) which creates a small weak zone inside the insulator [4]. In high voltage power equipments, the insulation failure takes place is due to presence of PDs inside the void enclosed model. Due to above reason PD detection and measurement is necessary for prediction and reliable operation and increase the life time of insulation for HV power apparatus [2]. Accurate simulating of PD is more important for insulation study. In this paper, the mechanism of PD has been simulated by using MATLAB
Keywords: Partial Discharge, Void, Simulation, Insulation, MATLAB.

I. BACKGROUND

Discharge (PD) generally begins within voids, cracks, at conductor-dielectric interfaces within a solid Insulation system, or in bubbles within liquid dielectrics. Since discharges are limited to only a portion of the Insulation, the discharges only partially bridge the distance between electrodes. PD can also occur along the boundary between different insulating materials. Partial discharges within an insulating material are usually initiated within gas filled voids within the dielectric. Because the dielectric constant of the void is considerably less than the surrounding dielectric, the electric field (and the voltage stress) appearing across the void is significantly higher than across an equivalent distance of dielectric [5]. If the voltage stress across the void is increased above the corona inception voltage (CIV) for the gas within the void, then PD activity will start within the void.

Once begun, PD causes progressive deterioration of insulating materials, ultimately leading to electrical breakdown. PD can be prevented through careful design and material selection. In critical high voltage equipment, the integrity of the insulation is confirmed using PD detection equipment during the manufacturing stage as well as periodically through the equipment's useful life using On-Line Partial Discharge surveys. PD prevention and detection are essential to insure reliable, long-term operation of high voltage equipment. Error in such equipments causes in outgoing and many economical disadvantages. Many errors that result in power system apparatus outgoing is related to insulation system and partial discharge that destroy the insulation gradually, in the most important fault resource in insulation of power system equipment [1-3]. Location techniques of this phenomenon are very important in maintenance and reparation of equipment. Many researches are done in this domain [1-9]. Accurate modeling and simulating PD mechanism is the first stage for all PD localization studies. In most done researches, the simulations produced current Impulses are used. But the mechanism of PD cannot be simulated in these researches. In this paper accurate mechanism of PD is simulated in MATLAB software. The response of simulation is like results of laboratory experiments.

II. PD MECHANISM

PD usually begins within voids, cracks, or inclusions within a solid dielectric, at conductor-dielectric interfaces within solid or liquid dielectrics, or in bubbles within liquid dielectrics. Since discharges are limited to only a portion of the insulation, the discharges only partially bridge the distance between electrodes. PD can also occur along the boundary between different insulating materials.

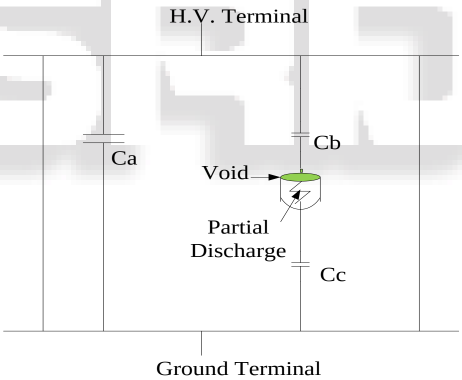

Fig. 1: An infected insulation

III. VOID MODEL OF THE EPOXY RESIN INSULATOR

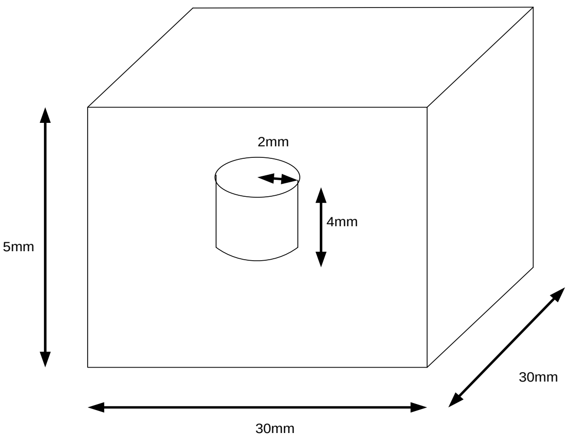

Fig. 2: Void model of the epoxy resin insulator

The most important factor for partial discharge characteristics is void parameters. Partial discharge characteristics changes accordingly, with the size of void. There are several types of voids as such as cylindrical, cubical, rectangular, etc. So the main parameters which are required for the analysis are height, length, breadth, diameter and volume of the void. The test object used is made up of epoxy resin and consists of three capacitors. Among three capacitors, two are connected in series with parallel to the other. Where, C_a is the capacitance of the healthy part of the test object, C_c is the capacitance of the void present in the test object and C_b is the capacitance of the part of the test object leaving C_a and C_c [6].

IV. CIRCUIT MODEL FOR PD MEASUREMENT

The behavior of internal discharges at AC voltage can be interpreted using the well known a-b-c model which is shown in Fig.3 Different models are used for partial discharge phenomenon which is compared with experimental data .The Pedersen model is established to get better accuracy

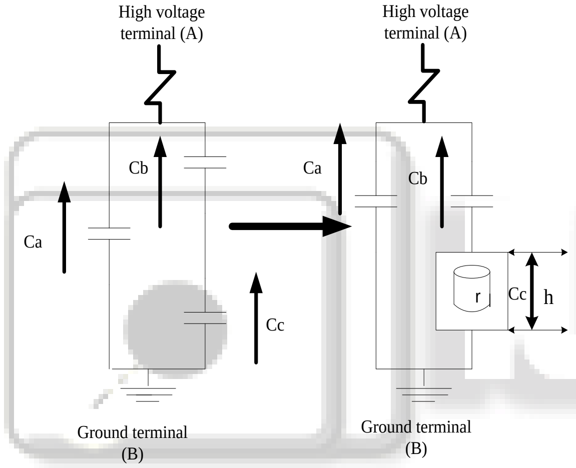

Fig. 3: a-b-c Circuit model

In the equivalent circuit the capacitance C_c corresponds to the cylindrical void present inside the solid insulation, C_b corresponds to the capacitance of the remaining series insulation with void (C_c) and Ca corresponds to the capacitance of the remaining discharge-free insulation of the rest of the solid insulator. Generally, (C_a>>C_b>>C_c). According to the size of void in insulation sample (epoxide resin), a cylindrical void of height of 4 mm and a radius of 2 mm is used in a cube sample (30mm ×30mm ×5mm) in this model. The void is located in the centre of the insulation sample.

$$C_a = \frac{\varepsilon_0 \times \varepsilon_r \times (a-2b) \times b}{c} \quad (1)$$

$$C_b = \frac{\varepsilon_0 \times \varepsilon_r \times r^2 \times \pi}{c-h} \quad (2)$$

$$C_c = \frac{\varepsilon_0 \times r^2 \times \pi}{h} \quad (3)$$

The applied voltage to the insulation sample is 5 kV and frequency of 50 Hz. The capacitance value of sample is calculated as C_a= 4.81×10^{-12} F, C_b= 3.87×10^{-13} F, C_c= 2.76×10^{-14} F.

V. ELECTRICAL CIRCUIT FOR ILLUSTRATION FOR PD MEASUREMENT

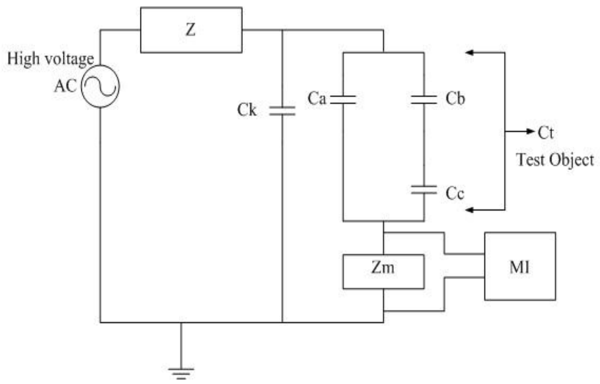

Fig. 4: Schematic circuit for PD measurement

VI. SIMULATION

It is observed from the Fig. 5 that with increase of the cylindrical void height from 0.002 to 0.008 mt, the apparent charge will increase from 0.0034×10-18 to 0.8695×10-18 pC.

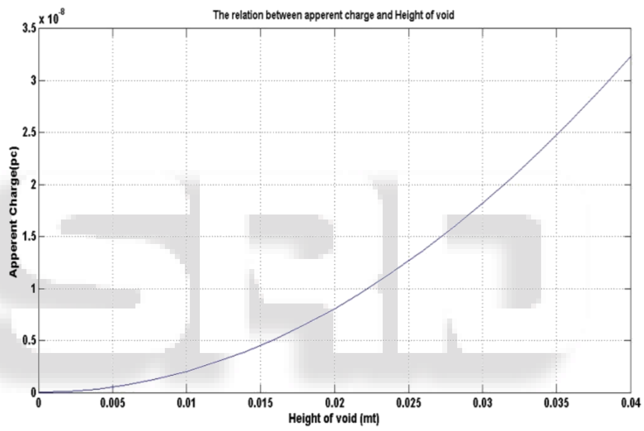

Fig. 5: The relation between apparent charge and height of void

Another study has been made in this work which is the relation between the apparent charge and the volume of the void. It is observed that the apparent charge is also a function of volume geometry of the cylindrical void model. It is also observed that, the volume is directly related to apparent charge which is shown in Fig. 6. It is observed from simulation result that the relation between void volume and apparent charge curve is a linear one.

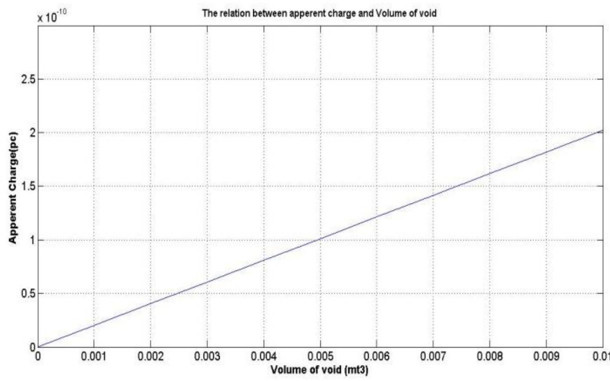

Fig. 6: A linear relationship of volume of void with apparent charge

To study the PD activity due to presence of cylindrical void inside the solid insulation, apparent charge and size of the void is also considered in this work. In Fig.7 it is observed that with the increase of the diameter of the cylindrical void apparent charge is increase. It is observed from the Fig.7 the diameter of the cylindrical void varies from 0.01 mt.-0.08 mt. And the corresponding value of the apparent charge is varies from 0.034×10-18 to 0.8695×10-18 pC.

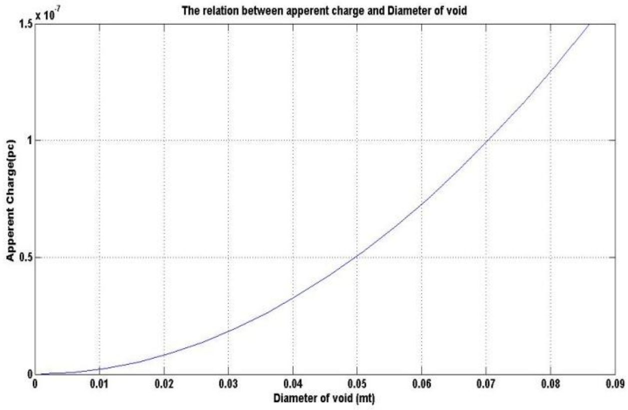

Fig. 7: The relationship of diameter of void with apparent charge

VII. RESULTS FOR PARTIAL DISCHARGE PULSE GENERATION

To find out the partial discharge characteristics due to the presence of cubical void inside a solid epoxy resin insulator, a high voltage of 0-15 kV is applied. The partial discharge characteristics cannot be measured directly in high voltage power equipment system. Hence it is necessary to see the characteristics of partial discharge.

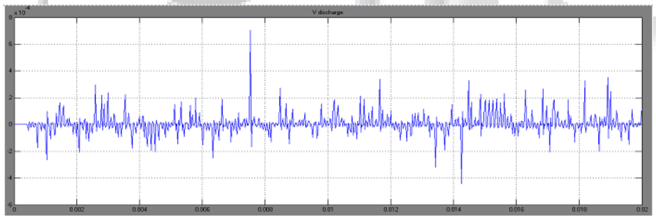

Fig. 8: The Observed Partial Discharge Pulse at 5 KV

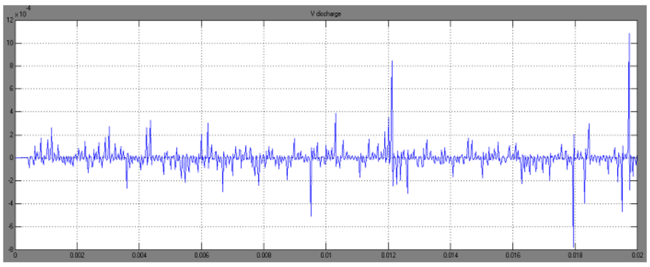

Fig. 9: The Observed Partial Discharge Pulse at 10 KV

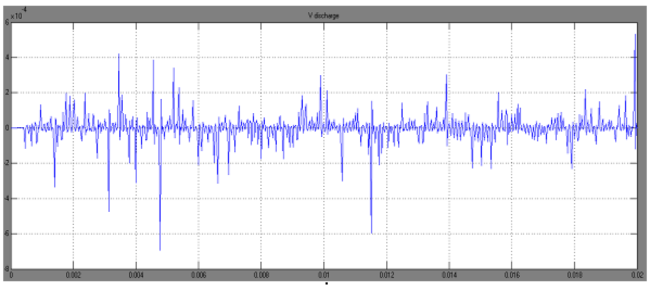

Fig. 10 :The Observed Partial Discharge Pulse at 15 KV

The Fig.8 shows the partial discharge characteristics at 5 kV; Fig. 9 shows the partial discharge characteristics at 10 kV and Fig.10 shows the partial discharge characteristics at 15 kV applied voltage. The partial discharge characteristic inside a solid insulation is found out using MATLAB Simulink model.

VIII. CONCLUSION

The Partial discharge (PD) that damages insulation because of the gradual erosion is the major source of the insulation failure. Techniques for locating a PD source have the major importance in both the maintenance and repair of a high power apparatus [1-3]. Accurate modeling and simulating PD mechanism is the first stage for all PD localization studies. In this paper accurate mechanism of PD is simulated in MATLAB software. The response of simulation is like results of laboratory experiments.

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