Journal of Novel Applied Sciences
Available online at www.jnasci.org
©2013 JNAS Journal-2013-2-11/640-643
ISSN 2322-5149 ©2013 JNAS

Partial Discharge Behavior in Solid Insulation

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ABSTRACT: Most serious failure of power apparatus is due to the insulation breakdown. Partial Discharge (PD) that damages insulation by gradual erosion is major source of insulation failure. They cause damage to the insulation of electrical equipment and often start from the enclosed voids in solid insulations. Partial Discharge (PD) is a localized dielectric breakdown of a small portion of a solid or fluid electrical insulation system under high voltage stress, which does not bridge the space between two conductors. PD can occur in gaseous, liquid or solid insulations. Partial discharges in air are visible but within solid insulation system are not visible. Accurate simulating of PD is more important for insulation study. In this paper Behavior of a discharge involving solid insulation is investigated. In this paper, PD mechanism in solid dielectric material has been modeled using EMTP software. This paper focused on the results of the partial discharges in solid dielectric with a single cavity as defect. AC source with 50Hz frequency voltage was applied to infected solid insulation. The discharge current amplitude has been registered. All discharge currents and discharge voltages occur in nano-seconds.

***Keywords*:** Partial Discharge , solid Insulation , EMTP, Simulation, modeling.

INTRODUCTION

Partial discharge (PD) is defined as localized discharge within only a part of the solid insulations between two separated conductors. In the real applications, PD is caused by the existence of voids in the solid insulation. Even if the local electrical field in the void exceeds a threshold and a discharge occurs, it is limited within the void due to the strong surrounding insulation, enough to avoid a complete breakdown. PD in voids is considered harmful, especially in high-voltage systems from the electrical engineering viewpoint as they cause energy loss and gradually degrade the insulation.

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. 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 (Zhao et al., 2011; Gutfleisch et al., 1995; Horvath et al., 2000). Location techniques of this phenomenon are very important in maintenance and reparation of equipment. many researches are done in this domain (Wang et al., 2000; Islam et al., 1996; Jufeng et al., 2003; Smith et al., 2002; Nikolay et al., 1999; Jeon et al.,1995). 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 EMTP software. The response of simulation is like results of laboratory experiments.

Modeling of PD in Solid Insulations

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.

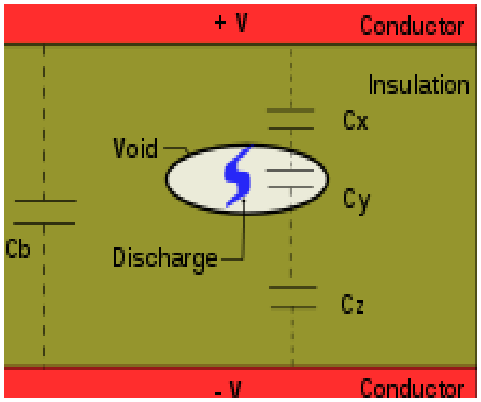

Figure 1. An infected insulation

A partial discharge within solid insulation When a spark jumps the gap within the gas-filled void, a small current flows in the conductors, attenuated by the voltage divider network Cx, Cy, Cz in parallel with the bulk capacitance Cb

In most done researches, the simulations produced current Impulses are used. But the mechanism of PD cannot be simulated in these researches. So, Generally, a 3-capacitance model as shown in Figure 2 is used to analyze the PD pulse current that appears at outer electrodes. Cg is the capacitance of the region where the discharge takes place. Cb is the capacitance of the region which is in series with Cg. Ca is the capacitance of the rest region in the dielectric. Rest region of dielectric (Ca) is the region of insulator that is not infected by PD and also it is not series with the cavity. When discharge takes place in Cg, the current Id will be produced in external terminals (Jufeng et al., 2003).

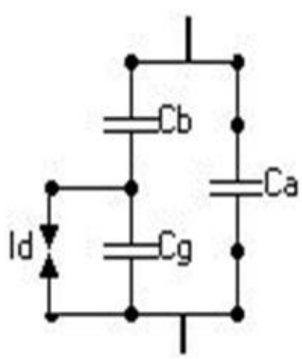

Figure 2. Three-capacitance model of PD

In Figure2 $C_a >> C_g > C_b$

In this model Partial Discharge Inception Voltage (PDIV) can be calculated by the following equation (Kreuger, 1989; Wang et al.,1998; Jafari et al., 2007; Fuhr 2005; Hettiwatte et al., 2002).

$$PDVI = 26.5 \times p \times t + 0.55 \quad (1)$$

In this equation p is the pressure in the void[atm] and t is its thickness [cm].

SIMULATION

Figure 2 has been modeled using the EMTP Tools (MODELS, TACS) that shows partial discharge mechanism. In this model PDVI can be calculated by equation (1) or it could be determined directly.

For testing the safety of PD model, an infected disk considered under sinusoidal voltage is compared with (Smith et al., 2002). Figure 3-a illustrates the voltage of Cg under the sinusoidal voltage. Figure 3-b shows the current id that is generated in external terminals under sinusoidal voltage.

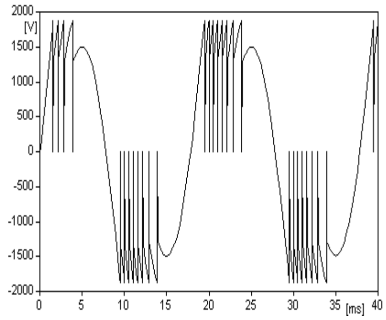

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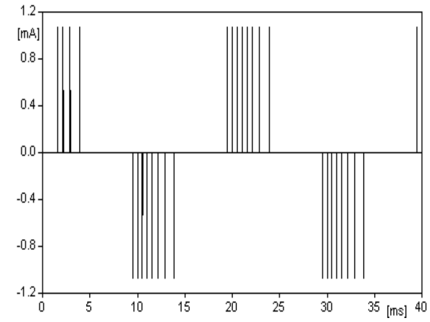
Figure 3. Voltage of Cg under sinusoidal voltage



b

Figure 3. Current id that act on external terminals under sinusoidal voltage

For show the accuracy of PD model, an infected disk considered under impulse voltage is compared with (Smith et al 2002). Figure 4-a illustrates the voltage of Cg under the impulse voltage. Figure 4-b shows the current id that is generated in external terminals under impulse voltage.

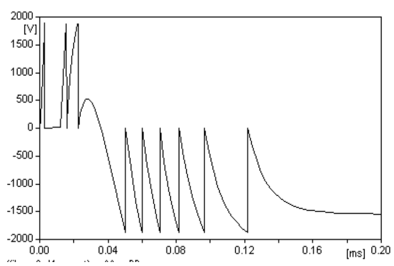


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Figure 4. Voltage of Cg under impulse voltage

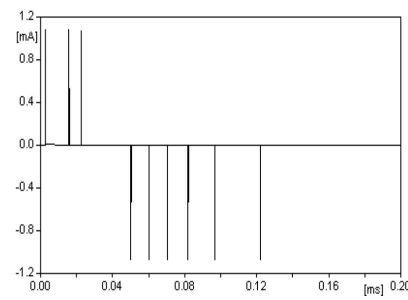

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Figure 4. Current id that act on external terminals under impulse voltage

It could be seen that PD model can simulate the mechanism of PD correctly, therefore, for any PD studies; this model could be located in any power apparatus winding easily.

CONCULSION

The Partial discharge (PD) that damages insulation because of the gradual erosion is the major source of the insulation failure. Accurate modeling and simulating PD mechanism is the first stage for all PD localization studies. In this paper accurate mechanism of PD is investigated and simulated in EMTP software. The simulation showed that the extended PD equivalent model was able to represent the behavior of PD in solid dielectrics. This model is more accurate because it considered the influence of local charge accumulations generated by preceding discharges.

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