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MODELING AND SIMULATION OF PARTIAL DISCHARGE AND CALIBRATION CIRCUIT FOR VOID IN SOLID INSULATION

Dr. Mahesh Kumar K M
Associate Professor, Department of Electrical & Electronics Engineering, PES College of Engineering, Mandya

Abstract: With the rapid growth of electrical energy consumption over the years, has led to the development of many high-voltage transmission and distribution system. But as in case with almost all equipment, continuous use of the instrument inevitably leads to the failure of insulation. So, as is clear, it becomes quite important to periodically assess the insulation's condition. One of the many techniques used to assess the lifespan of insulation is partial discharge (PD) measurement. Some forms of impurities such as air bubbles always present during the manufacturing process. The presence of these impurities weakens the insulation and is responsible for the occurrence of partial discharge. In this paper, solid insulation with void is modeled in Matlab Simulink and the calibrator circuit is modeled in orcad pspice circuit and results are obtained for variation of charge with voltage, No. of counts vs voltage and max. PD magnitude with an increase of voltage is plotted

1. Introduction: PDs are frequently brought on by flaws in the insulation system, which invariably results in the breakdown of the high voltage apparatus. [2] The equipment's lifespan is significantly influenced by insulation. Thus, high-quality insulation is required to preserve efficiency. The ability to recognise PD is crucial. Present contaminants might be solid, liquid, or gaseous. It is well known that when solid insulations are manufactured, air bubbles cause the insulation to degrade when high voltage is applied. A related electrical quantity called apparent charge q is utilised to quantify the PD phenomena because it is nearly difficult to quantify the PD that manifests in the insulation defect. The charge that, when applied across the Device Under Test (DUT) in a predetermined test circuit, generates the same results as the PD pulse is known as the apparent charge, or q. A suitable calibrator in the test circuit is used to determine the scale factor, often known as the ratio of the input quantity to the instrument reading. The accuracy of the PD measurement is largely dependent on the precision of the PD calibrator employed in the circuit. Continuous use of the instrument predictably lands to the loss of insulation due to heat, vibration, thermal cycle, and the presence of dielectric system. Thus the major problem is associated with increasing levels of complexity, efficiency, reliability, and lifetime of the instrument.

2. Literature Review

Even though high voltage technology for electrical power generation and transmission networks was first developed in the early 20th century, partial discharge was already known to be a dangerous cause of insulation ageing in high voltage equipment by that time. Many methods for the detection, measurement, and behaviour analysis of PDs in insulation have been developed over time. The very first mention of partial discharge dates back to 1777, when

Lichtenberg presented ground breaking findings from experimental research at a Royal Society meeting in Gottingen. Since then, other writers have presented their research on PD measurement and detection as well as PD characteristic studies. Since then, many authors have presented their work about the detection of PDs, also to plot the variations of PDs. Before it could be understood that Lichtenberg dust figures show electrical discharge channels on the surface of the dielectrics, it had been close to a century. The level of HV transmission voltage was rapidly rising, necessitating a significant improvement in the insulating materials. Hence, the first electrical PD facilities recognition were introduced during the start of the previous century, which aided in the ongoing advancement of information regarding PDs. Industrial PD detectors were created in the middle of the 20th century as PD identification knowledge increased, thereby opening the door for later advancements in the sector.

The measurement of PDs down to the pC range was necessary due to the development of extruded materials for the insulation of power cables in the 1970s since PDs of few pc may definitely result in an insulation failure. This compelled the creation of better PD measuring devices that could also detect PD points in long-distance power connections. Moreover, PD tests in accordance with IEC 60270 were compelled to be used for power transformer quality assurance checks.

To meet the ever-increasing technological demands in 1970s, digital instruments have been replacing traditional analogue ones, more and more due to research interest in the stochastic nature of PDs. These instruments are more powerful and produce better findings. Multi-channel pulse height analyzers were utilised for the first few years, but they were later replaced by computerised PD measuring devices that could process, acquire, and visualise phase-resolved very complicated PD data. [1-12]

3.1 Selection of Void Parameter: Three capacitors make up the insulation test object. Two of the three capacitors are connected in series with one in parallel. Ca represents the capacitance of the test object's healthy portion, Cb represents the capacitance of the portion of the test object that excludes Ca and Cc and Cc represent the capacitance of the void contained within the test object.[12]

3.2 Electrical Circuit Model for PD Measurement:

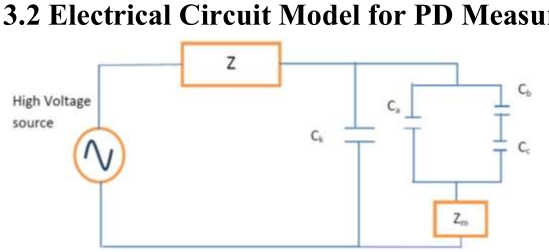


Fig.1: PD Circuit model

Three capacitors are used in the partial discharge modelling of insulation in Fig. 1. The capacitance of the void present in the test item is represented by capacitor Cc. The capacitance of the healthy section connected in series with the vacuum is represented by capacitor Cb. The healthy portion's capacitance, which excludes Cc and Cb, is represented by capacitor Ca. Discharge happens when the circuit model receives a high voltage source. With such a high

voltage, breakdown begins when the vacuum charges up. To receive this pulse from the test object through the detector circuit, a measuring device is attached across the detector circuit. Considered is an epoxy resin insulator having the following measurements: 40mm, 40mm, and 10mm. There is a cubical void in that insulator. The vacuum has a radius of 4 millimetres. [13]
$C = [(\varepsilon_0 \varepsilon_r A)/d]$
Where, C represents capacitance ε_r relative permittivity, ε_0 permittivity of free space and distance between the electrodes is d.

3.3 Simulink Model for Detection of Partial Discharge

Simulink verification and validation makes it possible to validate models systematically by validating the modelling style, tracing requirements, and analysing model coverage. Simulink Design Versifier creates test case scenarios for model checking within the Simulink environment and employs formal approaches to uncover design problems including integer overflow, division by zero, and dead logic. Here, the partial discharge pulses are evaluated using an equivalent solid insulator circuit with a cubic void. The void in this insulator is located in the middle of the insulation medium and Simulink circuit in Figure 2.

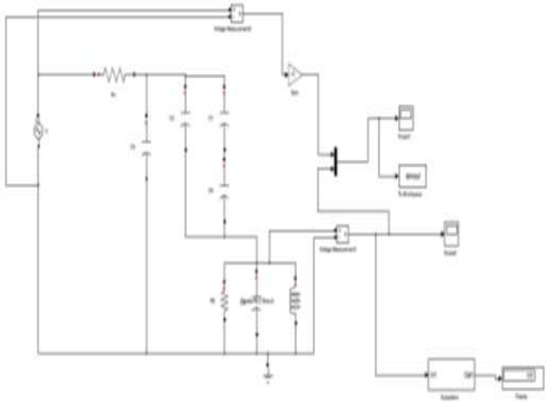


Fig. 2 Matlab Simulink PD model

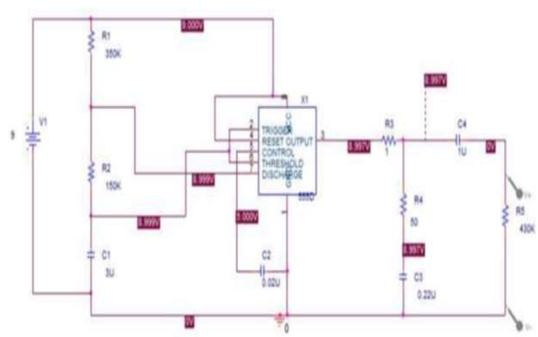
3.4 ORCAD model of the calibrating circuit: The PSpice orcad simulation tool is used to analyze PD calibrator circuit. The Fig.3 show calibrator circuit designed to verify PD pulse waveform at different capacitor values. Its rise time, fall time, PD magnitude can be studied.

Fig.3: Calibrator circuit Orcad model

4. Results and Discussions:

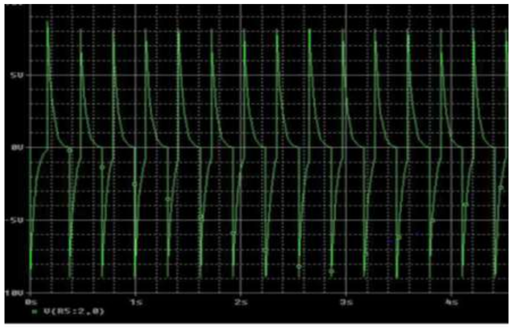
4.1 Results for Physical Calibrator Model

The most crucial aspect is experimental results since they support simulation results in validating a project's model. The experimental results of the Matlab Simulink model, orcad pspice calibrator model are presented.



4.2 Orcad Result Observed For Partial Discharge Single Pulses:

Fig. 4 : PULSE FOR PD FOR 0.1µF



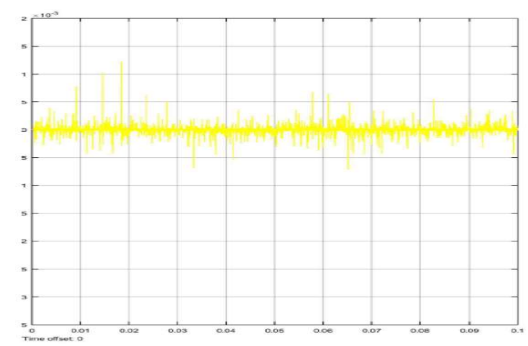


Fig.5: PULSE FOR PD FOR 0.5µF

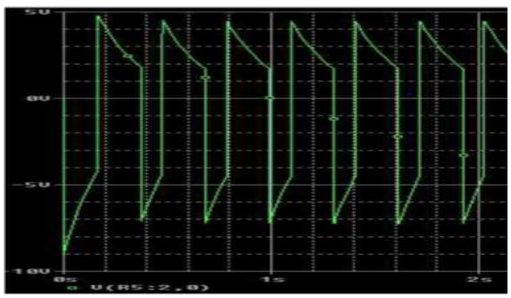
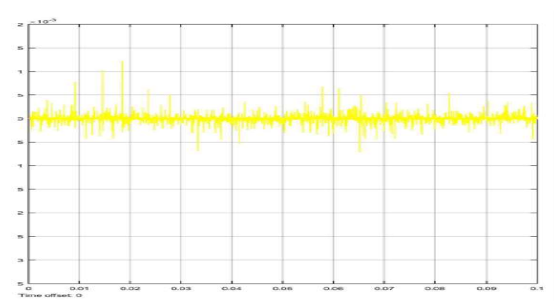


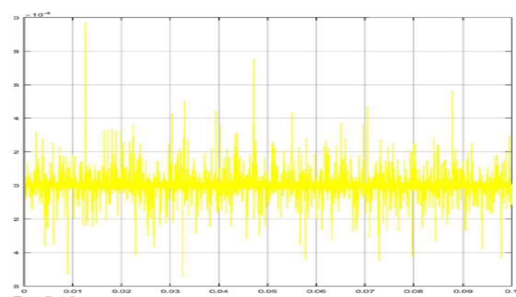
Fig 4 shows the Output of PD pulse when 1µF capacitor was connected which produces Peak Output Voltage of 8V. Fig 5 shows the Output PD pulse when 0.5µF capacitor was connected. Significant difference is observed with a change in void dimension PD behaviour which is illustrated with capacitor model

4.3 simulation for PD detection result:

Fig. 6: The Observed PD variations at 5KV

A high voltage of 0-25kV is varied across the test object to determine the partial discharge phenomena caused by the presence of a void inside a solid insulator. Figure. 6 shows the PD





characteristic for different applied voltages across the test object. Since PD is random phenomenon, the obtained pulse amplitude is also random nature

Fig. 7: The Observed PD variations at 10KV

The Fig. 6 shows the partial discharge waveform at 5 kV; Fig. 7 shows the partial discharge waveform at 10 kV applied voltage. The partial discharge characteristic inside a solid insulation increases with increase of voltage as shown in Simulink waveforms.[14]

4.4 Maximum partial discharge amplitude at different applied voltage

To analyses the PD characteristic it is necessary to observe the maximum partial discharge values at different applied voltages. The maximum amplitude of PD pulses with an increase in applied voltage is shown in Fig.8. The number of pulses neglecting distortion is shown in Fig.9, the variation of apparent charge with respect to the applied voltage is shown in Fig.10

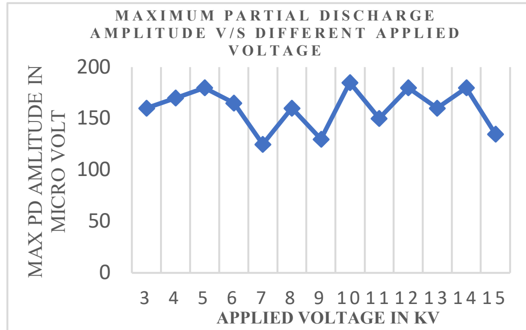


Fig.8: Max PD with increase of voltage in kV

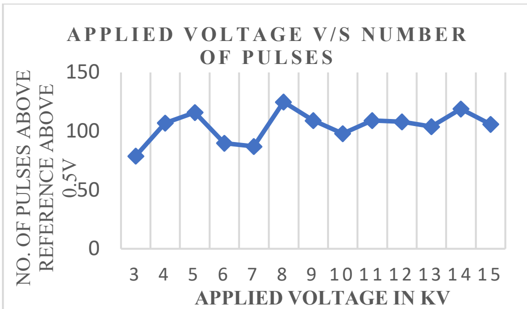


Fig. 9: No. Pulses with respect to voltage

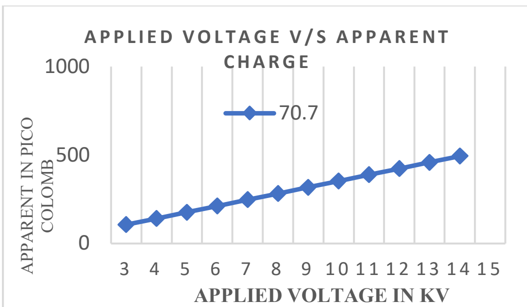


Fig. 10 Apparent Charge variation with voltage

5. Conclusion: The fundamental issue with high voltage power equipment systems is partial discharge. In order to keep the equipment in good shape while it is operating, partial discharge must be detected and measured. To produce the PD pulses in this work, a solid insulation material with a vacancy is modelled in MATLAB Simulink. Plots and comparisons of the PD pulse count results for 5 KV and 10 KV were made. In ORCAD SOFTWARE, a calibrating circuit was modelled to provide the requisite output PD pulses with the necessary charge levels, such as 0.1uF and 0.5uF. The calibrator circuit was linked across the test object, and the measurement circuit detected output pulses. The needed output pulses were comparable to the calibrating pulses. The calibrator's physical model was created, and the output waveforms.

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