Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 8, August -2017

Analysis of Partial Discharge Activity in Pressboards Using MATLAB SIMULINK

S.K. Girish[1], Dr. B.V. Sumangala[2]

[1]*Assistant Professor, E &EE Department, Sri Siddhartha Institute of Technology, Tumakuru*
[2] *Professor, E &EE Department, Dr. Ambedkar Institute of Technology, Bengaluru*

Abstract-*In high voltage (HV) power equipment the quality of insulator plays vital role in power systems. For insulation purpose various type of materials are used in different states like solid, liquid and gaseous form. Due to the application of high voltages, aging factor and cumulative effect of electrical, chemical and mechanical stresses, the quality of these materials degrades with the passage of time. These insulators are not in pure form and have some impurities, due to which small air bubbles are created inside the insulator which are called voids in case of solid and liquid insulators. Due to these voids the strength of insulators weakens and become the cause of Partial Discharge (PDs) [1]. Due to the presence of PDs originated at voids in insulators, the quality of such insulation degrades which results in the insulation failure in HV power equipment. In this work, the PD activity of an equivalent electric model circuit having void inside the pressboard material has been studied using MATLAB Simulink software.*

Keywords-*Partial Discharge, Void, MATLAB, Permittivity,* C_a, C_b, C_c

I.INTRODUCTION

Partial discharge is a phenomenon in high voltageinsulation system. This phenomenon is a discharge ina void or cavity in an insulation layer. The dischargedoes not break the full mass of the dielectric layer. The dielectric strength and breakdown voltageof the dielectric layer are affected and lowered bysubsequent partial discharge activities. These longtermPD activities will be monitored and the resultwill be used for diagnostic purposes and for maintenance [2]. Partial discharges are defined in IEC60270 as localized electrical discharges that onlypartially bridge the insulation between conductorsand which can or cannot occur adjacent to aconductor. Partial discharges are in general aconsequence of local electrical stress concentration inthe insulation or on the surface of the insulation.Generally, such discharges appear as pulses having duration of much less than 1 µs. Hence most effective way to assess the insulation condition of high voltage equipment is monitoring of Partial Discharge activity. In this work, the PD activity of an equivalent electric model circuit having void inside the pressboard material has been studied using MATLAB Simulink software. Also the maximum amplitude of PD, PD pulses at different applied voltages, number of PD’s with respect to phase angle and apparent charge transfer for different applied voltages are studied.

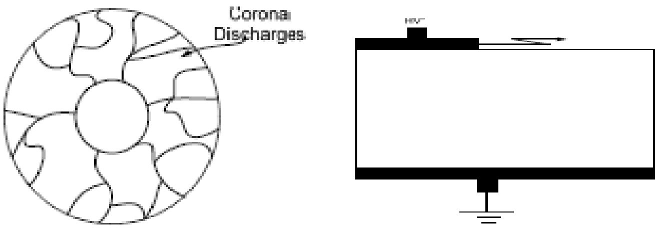
II. PARTIAL DISCHARGE

A. Classification of partial discharge:

Partial discharge phenomenon is divided into two types:
i. External Partial Discharge: External Partialdischarge is the process which takes place outside of the power equipment. Such typeof discharges occurs in overhead lines, onarmature etc [3].
ii. Internal Partial Discharge: This is the PD whichoccurs inside a system. It arises incavities or voids which lie inside the volumeof the dielectric or at the edges ofconducting inclusions in a solid or liquidinsulating media [3].

B. Type of Typical Partial Discharge:

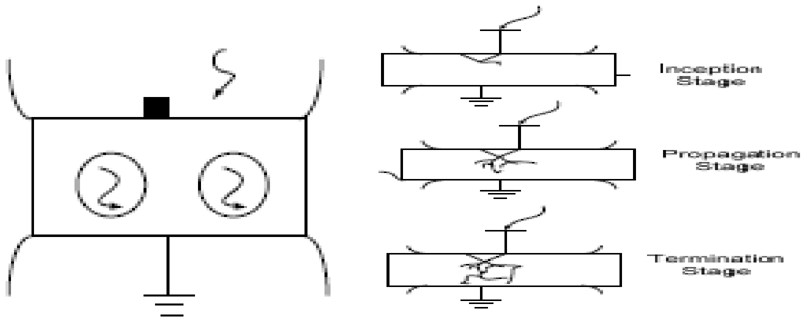
i.Corona Discharge: PD around a conductor in free space is called corona discharge. Corona discharge takes place due to non-uniform field on sharp edges of the conductor subjected to high voltage. The insulation provided is air or gas or liquid.
ii. Surface Discharge: Surface discharge takes place on interfaces of dielectric material such as gas/solid interface as gets over stressed times the stress on the solid material.



Corona discharge Surface discharge

Figure 1: Corona and Surface discharge

iii. Cavity Discharge: The cavities are generally formed in solid or liquid insulating materials. The cavity is generally filled with gas or air. When the gas in the cavity is over stressed such discharges are taking place.
iv. Treeing Channels: High intensity fields are produced in an insulating material at its sharp edges and it deteriorates the insulating material. That is responsible for production of continuous partial discharge, called as treeing channel.



Cavity discharge Treeing channel

Figure 2: Cavity discharge and Treeing channel

III. EXPERIMENTAL SETUP FOR PD MEASUREMENT

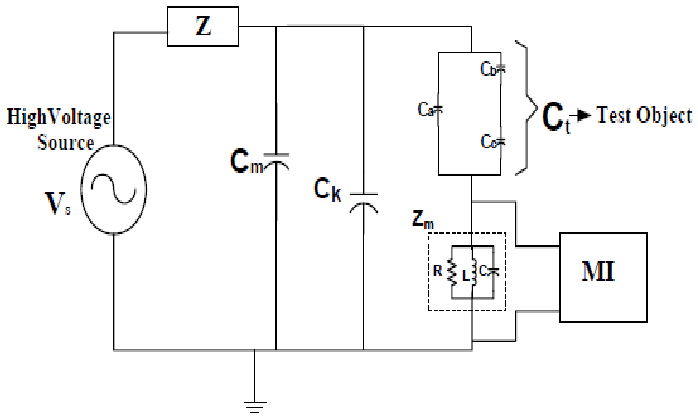


Figure 3: Experimental setup for PD Measurement

The schematic diagram for detection of partial discharge inside the insulation is shown in Fig.3. It is consists of high voltage transformer (*Vs*), filter unit (*Z*), high voltage measuring capacitor (*Cm*), coupling capacitor (*Ck)*, void model of solid insulation called as test object (*Ct*), detector circuit for measurement of partial discharge (*Zm*) and the measurement instrument (*MI*). The detector circuit for measurement of PD is a parallel combination of the resistor, inductor and the capacitor. The cylindrical void model (test object) of the insulating material is represented as '*abc*' diagrams. In the equivalent circuit the test object is represented in the form of small capacitance and the capacitance *Cc* corresponds to the void present inside the insulation, *Cb*corresponds to the capacitance of the remaining series insulation with void (*Cc*) and *Ca*corresponds to the capacitance of the remaining discharge-free insulation of the rest of the pressboard insulator. Such circuit is energized with AC voltage, a recurrent discharge occurs *Cc* is charged, reaches thebreakdown voltage of the cavity, is charged again and breaks down. The voltage across the cavity Cc is

$$V_c = \frac{V_a \times C_b}{(C_a + C_b)}$$

where, *Va*, *Vb*and *Vc*are the voltage across the corresponding capacitance *Ca*, *Cb*and *Cc* respectively [4] . The apparent charge *q* across the test object is measurable during the PD activity inside the insulation which is calculated by the empirical Equation: *q = Cb× Vc*

Sample Preparation:
Pressboard insulator with void inside is considered having dimensions of 100mm X 100mm with thickness of 10mm. The void is having dimensions of 10mmX10mm with thickness of 1mm. As the electrical circuit model consists of three capacitors the values of these capacitors are calculated by the following equations:

$$C_a = \frac{\varepsilon_0 \times \epsilon_r \times A}{d}$$

$$C_b = \frac{\varepsilon_0 \times \epsilon_r \times A}{d - t}$$

$$C_c = \frac{\varepsilon_0 \times A}{t} \qquad [5]$$

Where ε_0 = absolute permittivity
ε_r = relative permittivity

Ca	$3.5416\text{x}10^{-11}$
Cb	$3.935\text{x}10^{-11}$
Cc	$8.854\text{x}10^{-13}$

IV. SIMULINK MODEL FOR PD MEASUREMENT

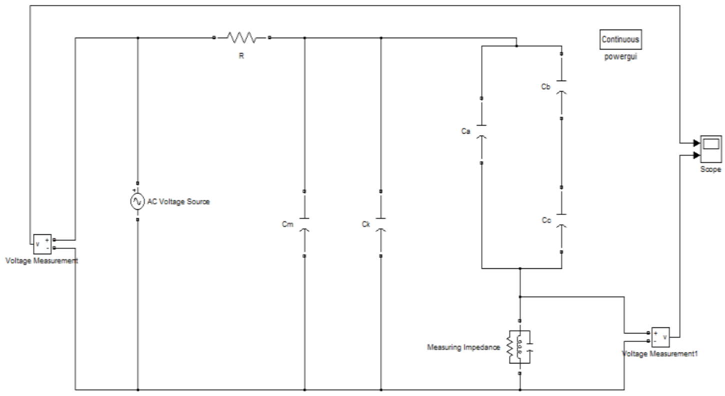


Figure 4: Simulink model for PD Measurement

The calculated values of capacitances are essential to obtain the partial discharge characteristics. Fig 4 shows the Simulink model for detecting the partial discharge characteristics. The capacitances C_a, $C_b$and C_c constitutes the test object (pressboard). C_m refers to the measuring capacitor and C_k refers to the coupling capacitor. The model drawn is simulated using MATLAB. When high voltage is applied across the test object, voltage across the dielectric V_a is increased thereby voltage across the cavity V_c also increases. When V_c reaches breakdown voltage, discharge will occur in void. The voltage across the test object at which discharge begin to occur is called the Inception voltage [6].

Table 1: Parameters used for Simulation

Sl. No	Parameter	Symbol	value
1	HV measuring capacitor	C_m	1000pF
2	Coupling capacitor	C_k	1000µF
3	Permittivity	ε_0	$8.854\text{x}10^{-12}$ F/m
4	Relative permittivity	ε_r	4
5	Resistance	R	50Ω
6	Inductance	L	0.6mH
7	Capacitance	C	0.45µF

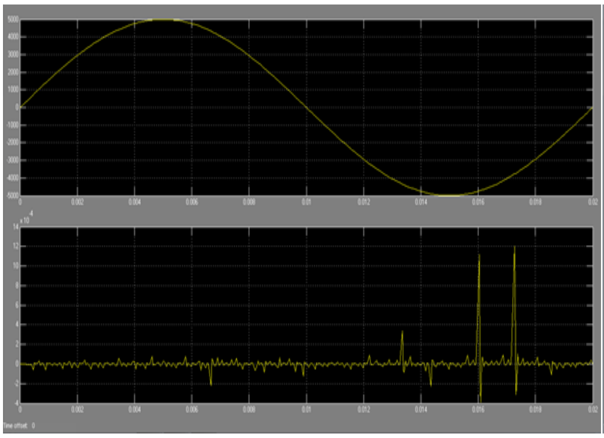
V.RESULTS

The PD pulses produced in the void are measured and captured.Figures 5, 6 and 7 shows the Partial Discharge characteristics for the applied voltage of 5kV,10kV and 15kV respectively.

When 5kV is applied across the test object, it is observed that the maximum amplitude of PD pulse correspond to 1.2mV is between the time period 0.016 to 0.018 second.

When 10kV is applied across the test object, it is observed that the maximum amplitude of PD pulse correspond to 600µV occur at 0.014 second.

When 15kV is applied across the test object, it is observed that the maximum amplitude of PD pulse correspond to 750µV is between the time period 0.002 to 0.004 second.



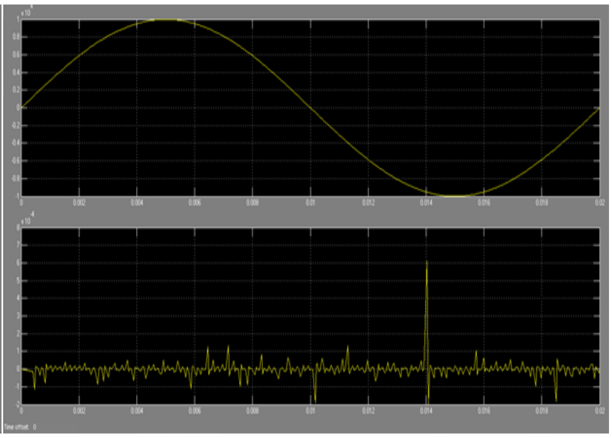
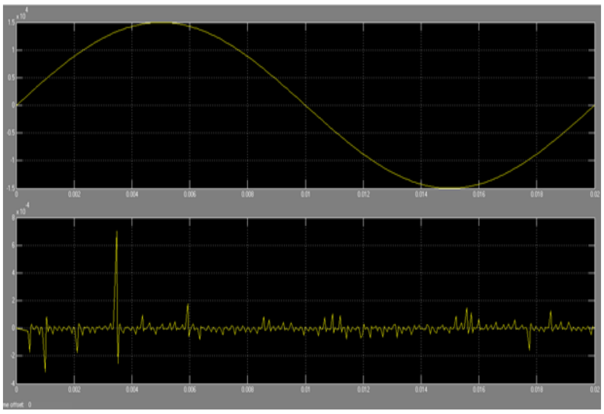


Figure 5: Input Voltage and PD pulse at 5kV Figure 6: Input Voltage and PD pulse at 10kV



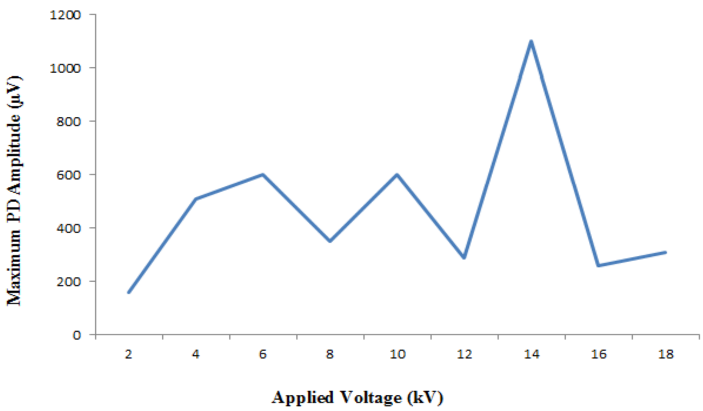


Figure 7: Input Voltage and PD pulse at 15kVFigure 8: Max. PD amplitude at different applied voltages

The applied voltage is increased in steps of 2kV upto 18kV to observe the maximum amplitude of PD pulses across the test object. The corresponding data shown in table 2 and graph has been plotted as shown in fig 8. From the graph it is observed that the maximum amplitude of 1100µV is obtained at 14kV of applied voltage.

Table 2: Max. PD values at different applied voltages

Sl. No.	**Applied voltage in kV**	**Max. PD amplitude in µV**
1	2	160
2	4	510
3	6	600
4	8	350
5	10	600
6	12	290
7	14	1100
8	16	260
9	18	310

The partial discharge pulses are analyzed by dividing single applied sinusoidal cycle of 50Hz into 10 equal parts. Each part has 36^0 phase angle interval. Thenumber of PD pulses for each interval is plotted for different applied voltages. Figures (9, 10, 11 and 12) shows graph for number of PD pulses with respect to phase angle for different applied voltages. The partial discharge phenomenon is random in nature hence the number of PD pulses is not constant for every cycle.

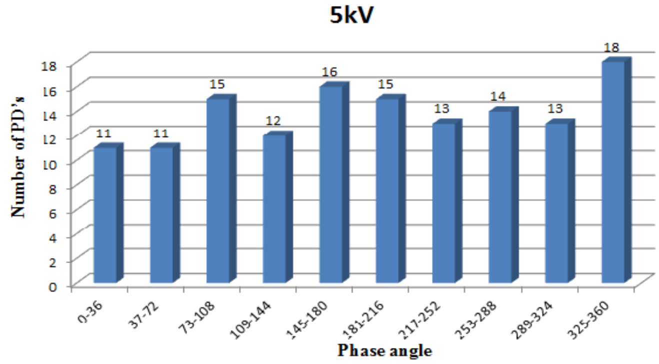


Figure 9: PD pulses at different phase angle with applied voltages of 5kV

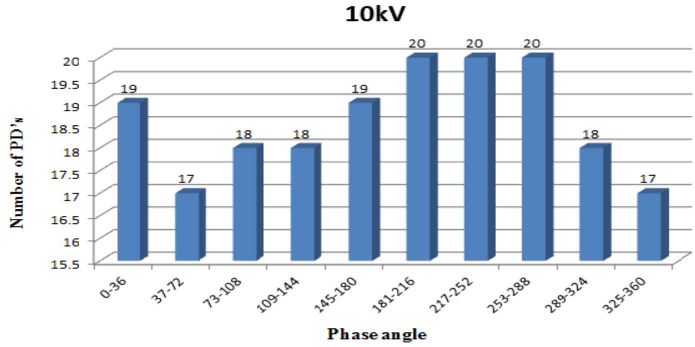


Figure 10: PD pulses at different phase angle with applied voltages of 10kV

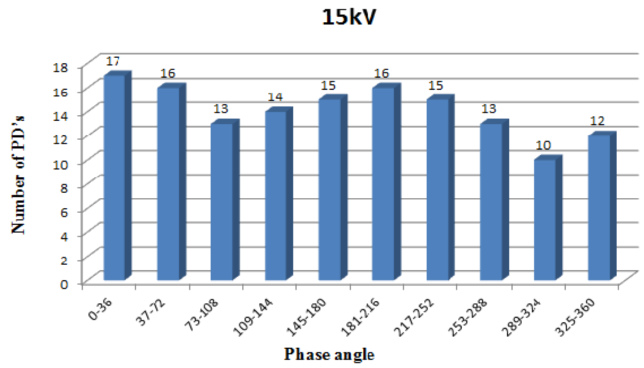


Figure 11: PD pulses at different phase angle with applied voltages of 15kV

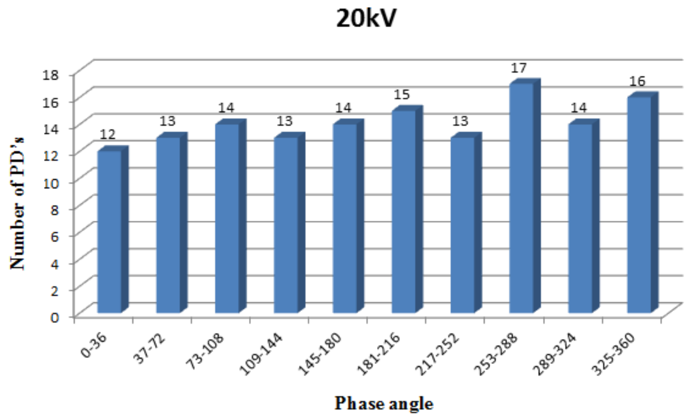


Figure 12: PD pulses at different phase angle with applied voltages of 20kV

The calculated apparent charge is shown in table 3 and graph is plotted with respect to the applied input voltages. From Fig. 13, it is observed that as the applied voltage increases, the apparent charge transferred increases linearly.

Table 3: Apparent charge transfer at different applied voltages

Sl. No	Applied Voltage (kV)	Apparent Charge (nC)
1	2	2.58
2	4	4.97
3	6	7.87
4	8	10.76
5	10	12.63
6	12	16.15
7	14	18.63
8	16	21.12
9	18	25.26
10	20	27.74

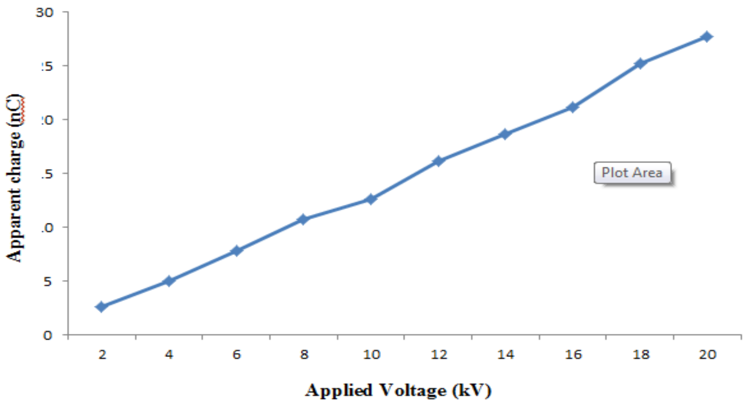


Figure 13: Charge transfer with respect to applied input voltage

VI. CONCLUSIONS

In this work void in pressboard insulation is considered and MATLAB Simulink based model has been adopted to observe the partial discharge activity. It is found that with increase in applied voltage across the void, partial discharge increases. This study is employed to find out the maximum partial discharge, Charge transfer with respect to applied voltage, number of PD pulses with respect to phase angle, number of PD pulses for different applied voltage. From the plot of phase angle versus applied voltage, it is concluded that the partial discharge phenomenon is random in nature. Based on the SIMULINK modeldeveloped, partial discharge characteristics are plotted.

REFERENCES

[1] Manzoor Ahmad Khan and Amjadullah, “Measurement of Partial Discharge in High Voltage Power Equipments”, International Conference on Emerging Trends in Engineering, Management and Sciences (ICETEMS-2014), Peshawar, Pakistan.

[2] Josef V Edral, Martin Kriz, “Signal processingin partial discharge measurement”, Metrol.Meas. Syst. Vol. XVII (2010), pp. 55-64.

[3]C. L. Wadhwa, “High voltage engineering”,New Age International Publishers, SecondEdition.

[4] AsimaSabat and S. Karmakar, “Simulation of Partial Discharge in High Voltage Power Equipment”, International Journal on Electrical engineering and Informatics, volume 3, no.2, 2011.

[5] E.Kuffel, W.S. Zaengl and J. Kuffel, High Voltage Engineering: fundamentals, second edition.

[6] F.H. kreuger, Partial Discharge Detection in High Voltage Equipment, London, United Kingdom: Butterworths and Co Limited, 1989.