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Comparison of PD Activity in Cubical Void for Different Dielectrics using MATLAB Simulink

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Abstract: Partial discharge represents a physical phenomenon. In high voltage (HV) electrical power system, different kinds of solid, liquid and gaseous materials are being used for insulation purpose to protect the incipient failure inside the HV power equipment. Among these the solid insulation is widely used for high voltage power equipments. Partial discharge is nothing but localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor [3]. It indicates the presence of an imperfection within the insulation. The magnitude of these discharges though small, can cause progressive deterioration and ultimate failure.In this paper, simulation work is done with the solid insulation material, simulation of partial discharge is done using MATLAB with different insulation material.. In this paper, the dependency of partial discharge on the permittivity of the insulation material is tried to be analyzed with the help of cubical void model made in the very well-known software "MATLAB". The simulation process is meant tocreate a better understanding of the characteristic of partial discharge in solid dielectric material. This project is focus on the result of the partial discharges indifferent insulation material.

Keywords: Partial Discharges, Solid Insulation, Cubical Void, Apparent Charge, C_a, C_b, C_c.

INTRODUCTION

Partial discharge (PD) is described as localized electrical discharge within only a part of the insulation between two separated conductors. In the real applications, PD is caused by the presence of voids in the insulation. Even if the local electrical field in the voidsurpass 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 cubical voids is considered harmful, mainly in high-voltage systems from the engineering viewpoint as they cause energy loss and continuously degrade the insulation [1]. PD may arise in solid, liquid and gaseous insulation media and are generally initiated by an excessive localized electric field. The PD produces current in an external circuit depends on the nature of the discharge and the geometry of the system [2]. In many instance, where there are electrically weak areas in solid dielectric materials, PD can be measured when enough voltage is applied. PD phenomenon causes degradation in insulated materials.

The insulations used in high voltage equipment are generally not in pure form, it contain some impurities in the form of voids. These voids may be of any shape like spherical, cylindrical, cubical, irregular shape etc. These voids are formed during the manufacturing process. Generally, these voids are filled with a medium such as gas, which has lower breakdown strength than the solid insulation. The permittivity of the filling medium is frequently lower than that of the solid insulation, which causes the field intensity in the void to be more than in the dielectric.

1. Partial Discharge:

Partial discharge is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not appear adjacent to a conductor [3]. In general partial discharges are a significance of local electrical stress absorption in insulation or on the surface of insulation. Such electrical discharges are arises as impulses i.e., various types of voltage impulse and current impulse having duration of much less than 1sec[3-4].

PD activity usually observed in high voltage power equipment like transformer, circuit breakers cable, bushings etc.PDnormallystarts within voids, cracks, or addition within a solid dielectric, at conductor-dielectric interfaces within solid or liquid dielectrics, or in bubbles within liquid dielectrics. The partial discharges bridge the gap distance between electrodes andalso occur along the boundary between different insulating materials

Sample preparation: As the electrical circuit model consists of three capacitors the values of these capacitors are calculated by following equations.[5][8][7].

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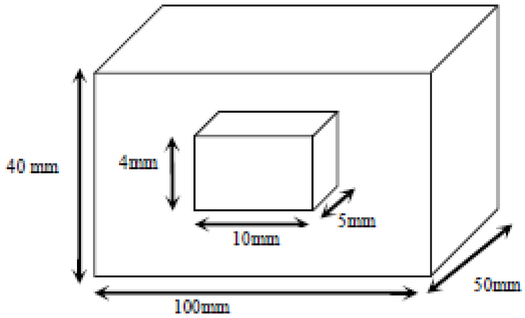

Fig. 1. Void model for Different Insulator with cubical void

Formulas for Cubical void:

$$Ca = \frac{\in o \times \in r \times A}{d}$$

$$Cb = \frac{\in o \times \in r \times A}{d - t}$$

$$Cc = \frac{\in o \times A}{t} \quad [3]$$

Where ε0 = absolute permittivity
εr= relative permittivity

Calculated capacitance	Epoxy Region	Polyethylene	Impregnated Paper
Ca	$3.8736*10-^{14}$	$2.5450*10^{-14}$	$5.5337*10^{-13}$
Cb	$4.3040*10-^{14}$	$2.8283*10^{-14}$	$6.1486*10^{-14}$
Cc	$1.1067*10-^{13}$	$1.1067*10^{-13}$	$1.1067*10^{-13}$

Void may be defined as electrical breakdown incident which occurs in solid insulating materials, when rapidly changes in the electrical activities that causes a current flow into the material to external world [2]. Partial discharge is the group of breakdown phenomenon i.e. this phenomenon may starts as many ways like (1) From a bubble in gas (2) as corona in air and liquids (3) from void in solid dielectric (4) as floating discharge (5) due to surface discharge etc. but we are focused on this paper only void in solid dielectrics or solid insulating materials.

2. EXPERIMENTAL SETUP

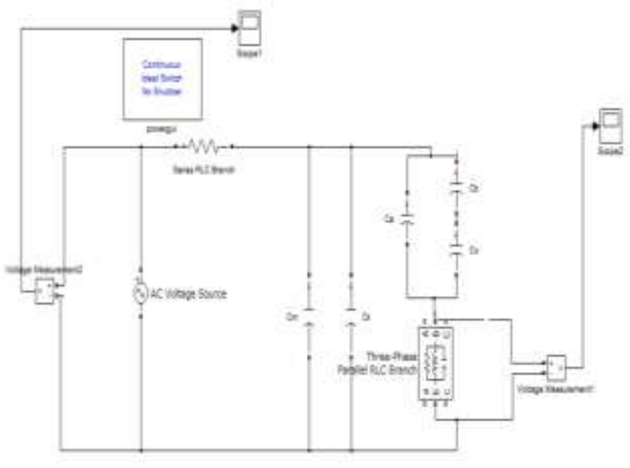

Fig2: Simulink model [6]

The deliberate capacitance values are required to get desire partial discharge characteristics. Here an equivalent circuit of solid insulator having a cubical shape void is taken to evaluate the partial discharge characteristics. Generally (Ca<<Cb<<Cc). The Simulink model for detecting partial discharge characteristics is shown in figure2.

The model drawn in figure 3 is simulated using MATLAB. When high voltage is givento the test object, voltage across the dielectric is increased thereby the voltage across the cavity also increases. When reaches inception voltage, discharge in the void occurs. The voltage across the sample at which discharges begin to occur is called **Inception voltage [4]**.

From the Fig.2, Ca, Cband Cc together constitutes test object. Where the capacitor Cc represents capacitance of the void in the test object. Capacitor Cbrepresents capacitance of the healthy part connected in series with the cubical void. Capacitor Carepresents the capacitance of the healthy part leaving Cc and Cb. $C_m$represents the measuring capacitor and C_k refers to the coupling capacitor.

In this study the values of HV equipments used for the measurement of PD inside the solid insulation is taken as depicted in Table1.[7][8].

Table1: Parameters used for simulation

Sl. No	Parameter	Symbol	Value	Dimension
1	HV measuring capacitor	C_m	1000	pF
2	Coupling capacitor	C_k	1000	µF
3	Permittivity	ε_0	8.85X 10-12	F/m
4	Resistance	R	50	Ω
5	Inductance	L	0.60	mH
6	Capacitance	C	0.45	µF

Table1.1 Permittivity of Different Dielectric

Solid Dielectric	Permittivity ε_r
Epoxy resin	3.5
polyethylene	2.3
Impregnated paper	5

3. RESULT AND DISCUSSIONS

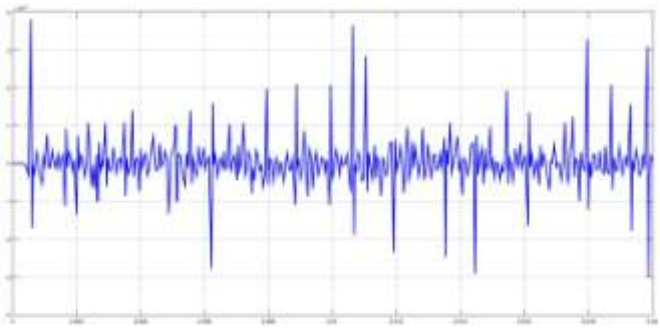

Fig3: observed partial discharge pulse in epoxy resin at 15kV

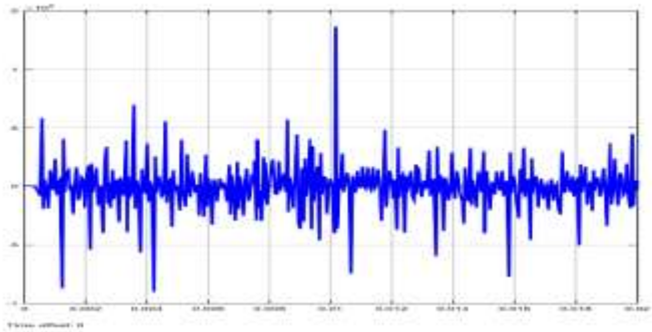

Fig4: observed partial discharge pulse in Polyethylene at 15kV

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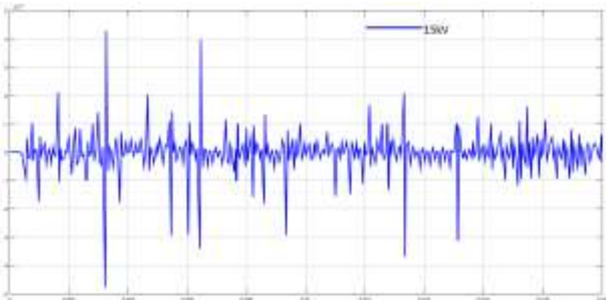

Fig5: observed partial discharge pulse in Impregnated paper at 15kV

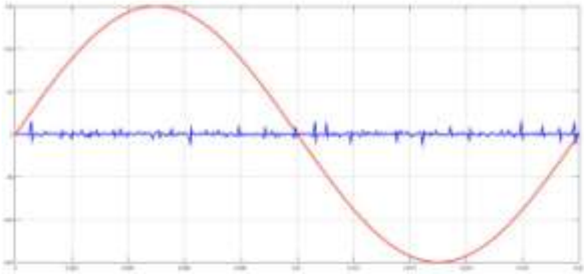

Fig6: Merged input and output PD pulse of in Epoxy resin at 15kV

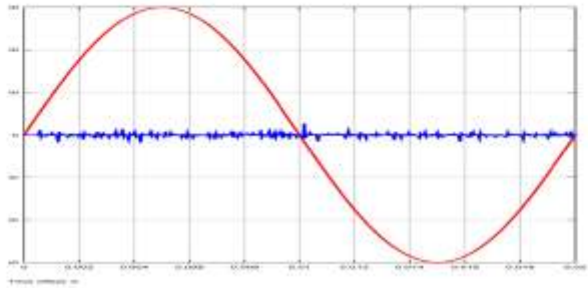

Fig7: Merged input and output partial discharge pulse in Polyethylene at 15kV

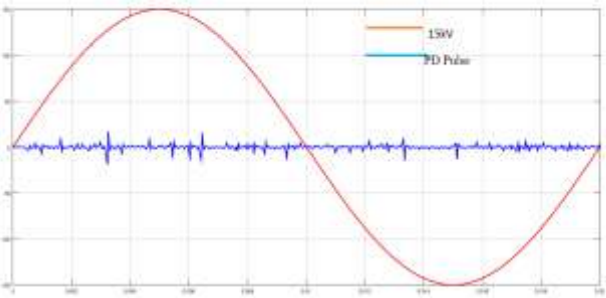

Fig8: Merged input and output partial discharge pulse in Impregnated paper at 15kV

It is observed that the region in which the PD activity is higher differs in polyethylene, epoxy resin and impregnated paper from fir 6, 7 and 8.

Table2: Maximum PD values with Different Applied Voltage

Applied voltage in KV	Max.PD amplitude in micro volts		
	Epoxy Resin	Polyethylene	Paper
5	4.008	3.71	5.13
10	12.55	3.09	3.012
15	3.632	3.41	4.283
20	3.16	3.84	3.047
25	3.492	13.92	8.133
30	13.46	15.46	2.65

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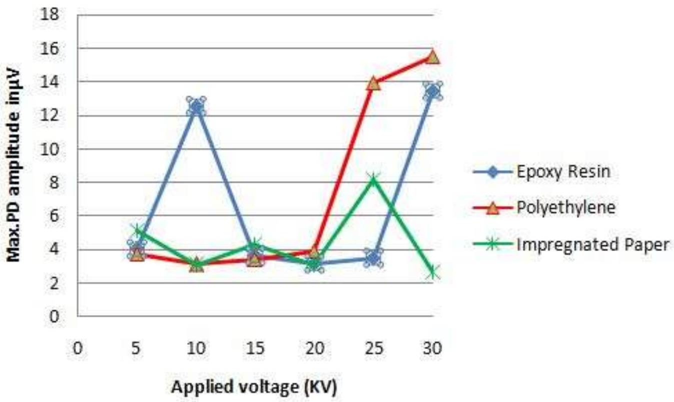

Fig 9: PD Amplitudes of cubical void with different applied voltages

It is observed that amplitude of PD is maximum in case of epoxy resin when compared to that polyethylene and impregnated paper.

The partial discharge pulses are analyzed by dividing single sinusoidal applied cycle of 50 Hz into eight equal parts. Each part has 45^0phase angle interval. The numbers of PD pulses for each interval are plotted for different applied voltages. Figures 10, 11 and 12 shows graph for number of PD pulses v/s different phase angle for different applied voltages (i.e, 5kV, 10kV and 15kV) in epoxy resin, polyethylene and impregnated paper respectively. The partial discharge phenomenon is random in nature so the numbers of PD pulses are not constant. [7].

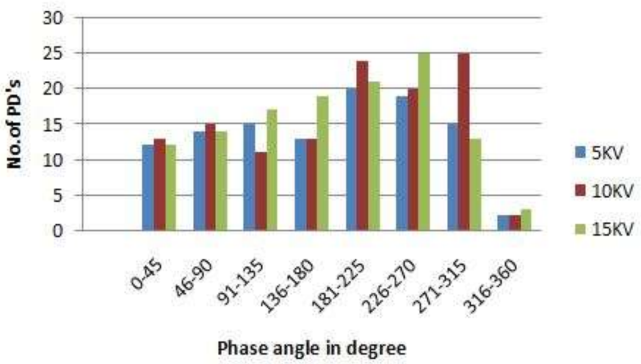

Fig 10: Partial discharge pulses at different phase angle with different applied voltages in epoxy resin.

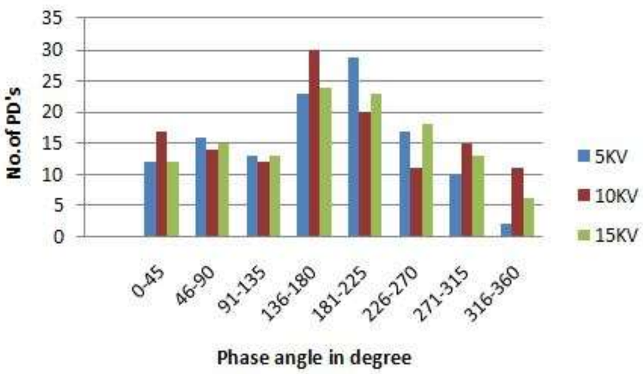

Fig 11: Partial discharge pulses at different phase angle with different applied voltages in polyethylene.

It is observed that the PD activity is higher for applied voltage of 15kV when compared to the PD activity for applied voltages 5kV and 10kV. Also there is decrease in the number of PDs in case of applied voltage being 15kV after phase angle exceeds 315^0as indicated from figure 10, 11 and 12.

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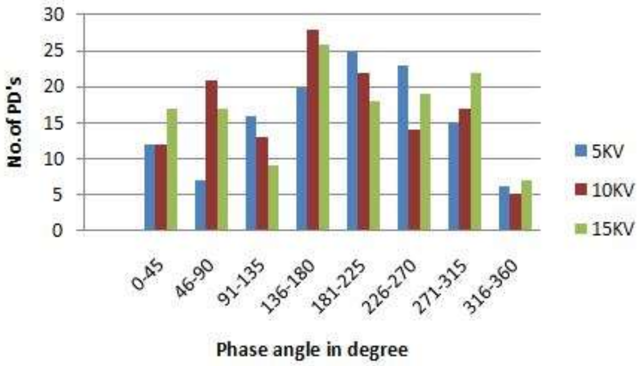

Fig 12: Partial discharge pulses at different phase angle with different applied voltages in impregnated paper.

Table 3: Number of PD's at different applied voltages at different phase angles at 5kv, 10kv and 15kv applied voltage for epoxy resin

Phase angle in degree	**5KV**	**10KV**	**15KV**
0-45	12	12	17
46-90	7	21	17
91-135	16	13	9
136-180	20	28	26
181-225	25	22	18
226-270	23	14	19
271-315	15	17	22
316-360	6	5	7

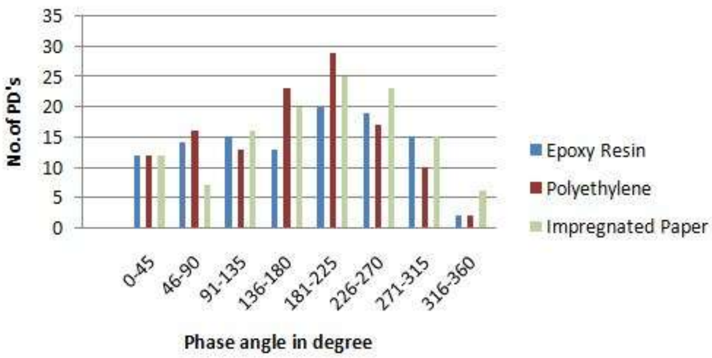

Fig 13: Partial discharges pulses at different phase angle of epoxy resin, polyethylene and impregnated paper at 5kV of applied voltage

Table 4: Number of PD's at different applied voltages at different phase angles at 5kv, 10kv and 15kv applied voltage for polyethylene

Phase angle in degree	**5KV**	**10KV**	**15KV**
0-45	12	13	12
46-90	14	15	14
91-135	15	11	17
136-180	13	13	19
181-225	20	24	21
226-270	19	20	25
271-315	15	25	13
316-360	2	2	3

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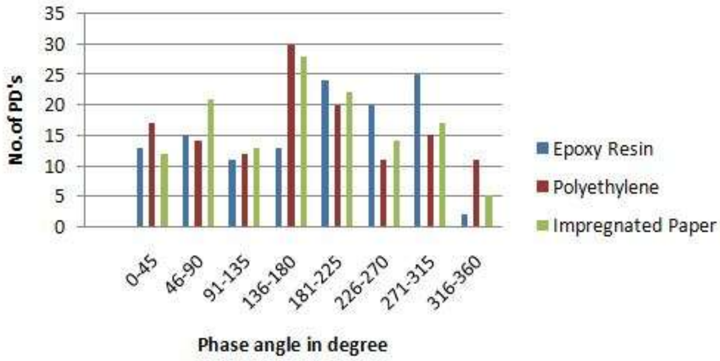

Fig 14: Partial discharges pulses at different phase angle of epoxy resin, polyethyleneand impregnated paper at 10kV of applied voltage

Table 5: Number of PD's at different applied voltages at different phase angles at 5kv, 10kv and 15kv applied voltage for impregnated paper

Phase angle in degree	**5KV**	**10KV**	**15KV**
0-45	12	17	12
46-90	16	14	15
91-135	13	12	13
136-180	23	30	24
181-225	29	20	23
226-270	17	11	18
271-315	10	15	13
316-360	2	11	6

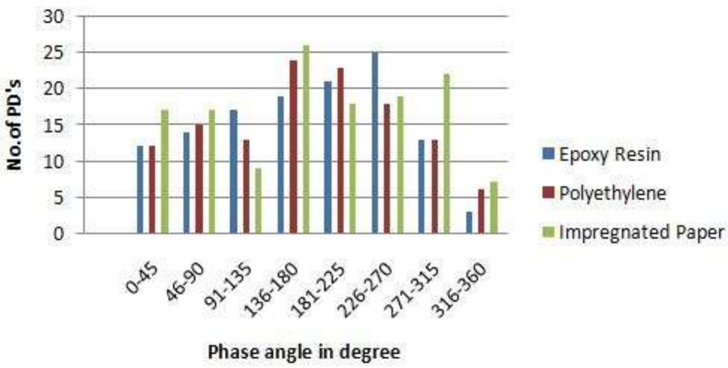

Fig 15: Partial discharges pulses at different phase angle of epoxy resin, polyethyleneand impregnated paper at 15kV of applied voltage

It is observed that between the phase angle from 180^0 to $315^0$the number of PDs is greater in polyethylene compared to epoxy resin and impregnated paper. Whereas between the phase angle $315^0$to $360^0$the number of PDs is greater in impregnated paper compared to epoxy resion and polyethylene.

Voltage across the test object (Vc) is measured and applied to a subsystem in MATLAB simulink created as per the formula below.

Voltage across the cubical void Cc is given by

$$V_c=\frac{V_a*C_b}{C_a+C_b} \quad [3]$$

The apparent charge transferred is calculated by

$$Q=Cb\times Vc. \quad [3]$$

Table6: Apparent Charge for Different Applied Voltage

Applied voltage in KV	Apparent charge (pC)		
	Epoxy Resin	Polyethylene	Impregnated Paper
5	0.36	0.236	0.515
10	0.721	0.473	1.03
15	1.08	0.71	1.545
20	1.44	0.947	2.06
25	1.8	1.184	2.575
30	2.16	1.421	3.09

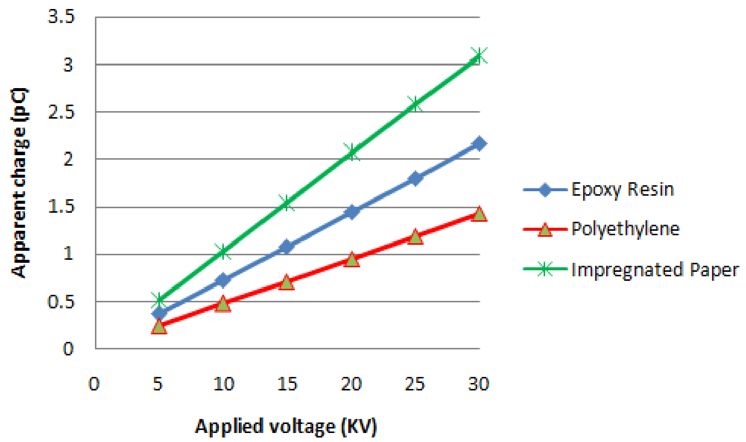

Fig 16: Apparent charge transfer in epoxy resin, polyethylene and impregnated paper at different applied voltages.

The obtained apparent charge through MATLAB subsystem is tabulated and graph is plotted against applied input voltages. It is seen that as the applied voltage increases, the apparent charge transferred increases linearly [6].

4. CONCLUSION

Partial discharge is the main problem in high voltage power equipment systems. Hence detection and measurement of it is necessary to keep the power equipment in healthy condition during their operation. Its major sources are impurities and voids inside the insulation material. In this study, three different insulation materials have been taken to obtain the partial discharge pattern. All sample considered for thesimulation are cubical and the void in each sample is cubical. Each insulation material has different permittivity or dielectric strength and hence their void model capacitances are also different, due to which different partial discharge pattern has been obtained for different material at different voltage. The observation shows that the permittivity of the insulation material is also anmain important parameter of partial discharge. It shows that partial discharge is function of permittivity of the insulation material, void geometry enclosed in the insulation. All the simulation is done on MATLAB software package. It can be further extended to derive the Some other parameters on which partial discharge depends and can be made more accurate.

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