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

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Abstract: An important tool for improving the reliability of high voltage (HV) insulation systems are partial discharge (PD) measurements. Partial Discharge (PD) that damages insulation by gradual erosion is major source of insulation failure. In electrical engineering, 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. So, an important tool for improving the reliability of HV insulation systems are partial discharge (PD) measurements. Accurate simulating of PD is more important for insulation study. In this paper, the mechanism of PD has been simulated by using MATLAB simulink.

Keywords: Permittivity (**ε_r**), Partial Discharge (PD), Void model, MATLAB, Solid insulation sample, HV (high voltage), Ca, Cb, Cc.

I INTRODUCTION

In HV power system, the insulating tools used, is not pure in every aspect and holds impurities. The presence of air particles is a major contaminations in insulating equipments and extremely unwanted as it causes a local region inside the insulator which is very weak as compared to its surroundings. The types of faults created because of insulation breakdown as an outcome of localized electrical strain inside the insulation, whether solid or fluids is broadly pervasive and it is known as partial discharge (PD). The high voltage equipments have to be tested for PD to ensure its present quality.

PARTIAL DISCHARGE

Partial discharge is defined as a localized electrical discharge that partially bridges the insulation gap between the electrodes and which may or may notoccur adjacent to a conductor[1]. The high voltage equipments have to be tested for PD to showsits present quality. PD technology used for diagnosing the state of such equipment has been of extreme importance. Thus, exactness should be increased and uncertainty should be decreased in the measurement of PD. The reliability of the measurement results is strongly depends on the calibration of the PD measurement system .A PD detector is being modeled in SIMULINK to generate PD pulses having identified charge and maximum amplitude.

Sample Preparation:

Presence of void inside the solid dielectric insulator with a cubical void inside is considered having the dimensions 100mm,50mm,40mm.The dimension of the cubical void considered is 10mm ,5mm, 4mm.As the electrical circuit model used in the simulation consists of three capacitors Ca, Cb, Cc. Two are connected in series with parallel to the other. The series capacitances are the capacitance of the void and the capacitance of the healthy insulator in series with the void. The parallel capacitor to the above two is the capacitance of the remaining parts of the insulator.

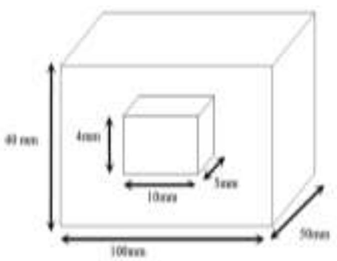

Fig1: void model of Solid insulator.

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The capacitors mentioned above in the void model is shown below with equivalent circuit of connections of C_a ,C_b ,C_c.

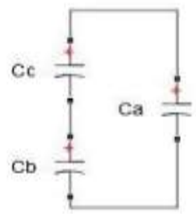

Fig2: equivalent circuit of the test object

The values of the Capacitors can be found using the formulas given below for a cubical void:

$C_a=\frac{\varepsilon_0 * \varepsilon_r * A}{d}$

$C_b= \frac{\varepsilon_0 * \varepsilon_r * A}{d-t}$

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

Where, ε_0 = absolute permittivity=$8.854*10^{-12}$
ε_r = relative permittivity [8]

Capacitor	Epoxy Resin	Rubber	Teflon
C_a	$3.873*10^{-14}$	$3.3202*10^{-14}$	2.213×10^{-14}
C_b	$4.304*10^{-14}$	$3.689*10^{-14}$	2.459×10^{-14}
C_c	$1.1067*10^{-13}$	$1.1067*10^{-13}$	$1.1067*10^{-13}$

EXPERIMENTAL SETUP

For the above calculated values of capacitances are used to get the required partial discharge characteristics. The equivalent circuit of having a cubical shape void for different solid dielectrics is taken to evaluate the partial discharge characteristics. The Simulink model for detecting partial discharge characteristics is shown in figure 3.

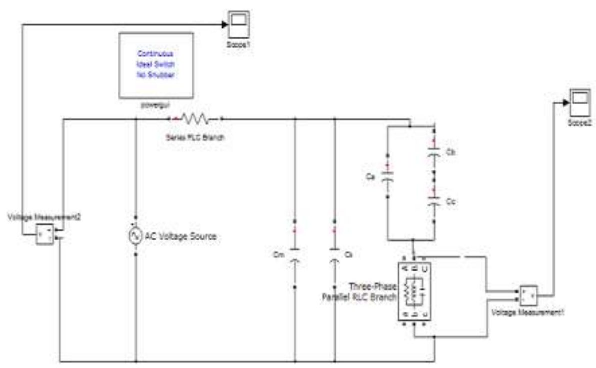

Fig3: Simulink model[4]

Generally (C_c>>C_b>>C_a) for a cubical void. The Simulink model for obtaining partial discharge characteristics is shown in figure3. Ca, Cb and Cc together constitutes the test object .Cm refers to the measuring capacitor and Ck refers to the value of coupling capacitor.

The circuit model drawn in Fig.3 is simulated using MATLAB software. When the voltage across the dielectric V_a is increased thereby the voltage across the cavity V_c also increases. WhenV_c reaches breakdown voltage, discharge in the void occurs. The voltage across the sample at which discharges begin to occur is called **Inception voltage**[4].

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In Fig. 4 the partial discharge pulses in µv are seen in scope2 which is connected through voltage measurement 1 across matching impedance. The applied input voltage is measured through voltage measurement 2 and witnessed in scope 1.
In this study the value of void model and the other HV equipment for the measurement of PD inside the solid insulation is taken as depicted below in Table1[6].

Table1.1 shows the permittivity for different dielectrics

Table1. Parameters used in Simulation

Parameter	Value	Symbol	Dimension
HV Measuring capacitor	1000	Cm	pF
Coupling Capacitor	1000	Ck	µF
Relative Permittivity	8.854×10^{-12}	ε_0	F/m
Resistance	50	R	Ω
Inductance	0.60	L	mH
Capacitance	0.45	C	µF

Table1.1 Permittivity of different dielectrics

Solid Dielectrics	Permittivity ε_r
Epoxy resin	3.5
Rubber	3
Teflon	2

RESULTS AND DISSCUSSIONS

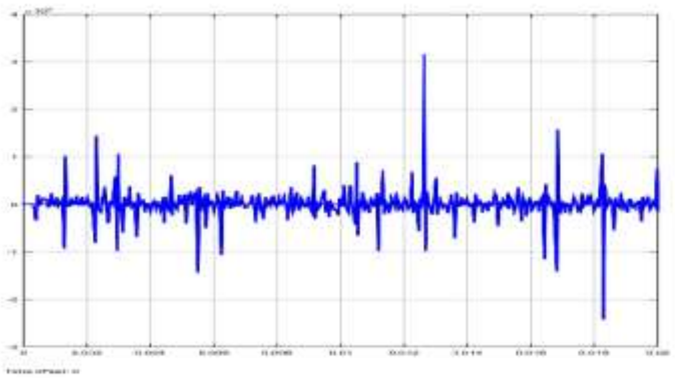

Fig4: Observed Partial discharge pulse at 10KV of epoxy resin

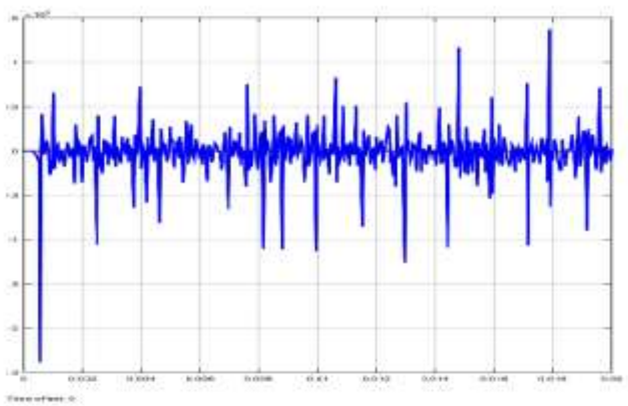

Fig5: Observed Partial discharge pulse at 10KV of Rubber

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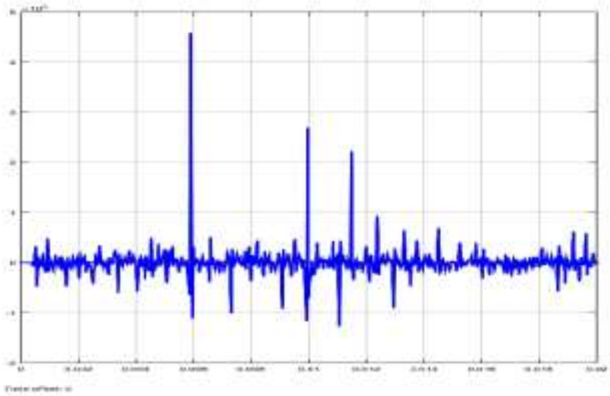

Fig6: Observed Partial discharge pulse at 10KV of Teflon

Fig4,5,6 shows the PD characteristics of output obtained from scope1 for applied voltages of 10KV for Epoxy resin , Rubber ,Teflon. It is observed that at 10KV the amount of Partial discharge for different solid dielectrics at different dielectrics.The input, output graph of PD characteristics are shown in Fig7,8,9 at voltage 10KV for different dielectrics.

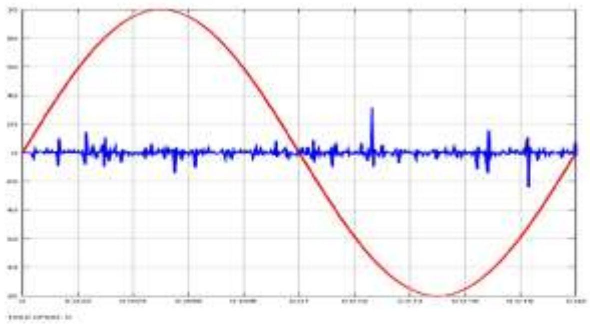

Fig7. PD characteristics along with input at 10KV for epoxy resin

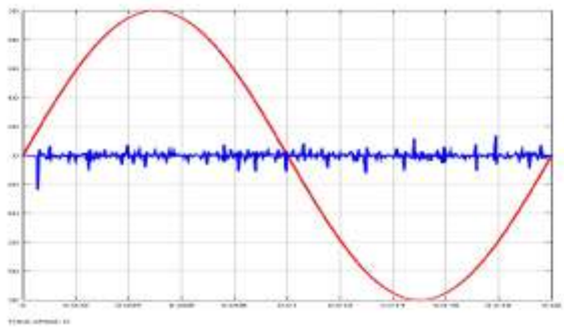

Fig8. PD characteristics along with input at 10KV for Rubber

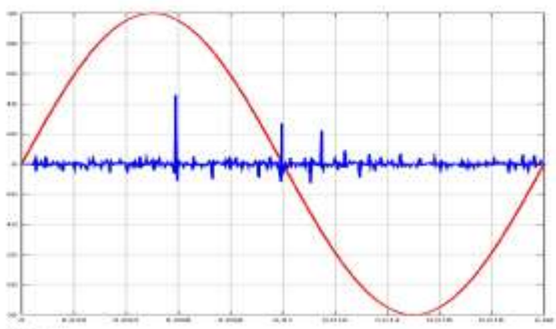

Fig9. PD characteristics along with input at 10KV for Teflon

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The Maximum PD amplitude at different applied voltages is shown in Table2.

Table2.Max.PD amplitude at different applied Voltages for different solid dielectrics

Applied voltage in KV	Max. PD amplitude in µV		
	Epoxy resin	Rubber	Teflon
5	4.008	3.841	5.545
10	12.55	5.09	11.46
15	3.632	3.14	9.113
20	3.16	4.2	3.272
25	3.492	10.06	4.873
30	13.46	6.029	4.274

For the Table2.The graph of Max. PD amplitude at different applied voltages for different solid dielectrics is shown in Fig10.

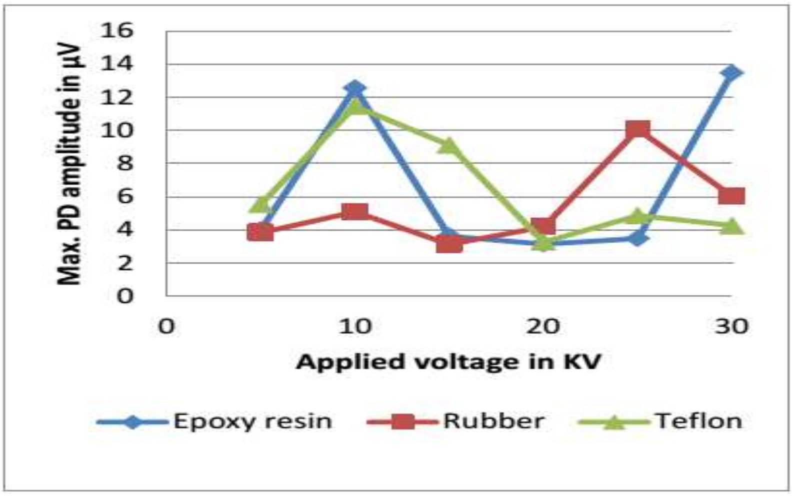

Fig10. Max. PD at different applied voltages for different Solid dielectrics

From the graph of Max.Pd we can that at 30KV the Max. amplitude of Epoxy resin is greater than Rubber and Teflon. The partial discharge pulses are dividing single applied sinusoidal cycle frequency of 50 Hz into eight equal parts. Each part has 45^0 phase angle interval.

The number of PD pulses for every interval is plotted for different applied voltages. Figures (11,12,13) shows graph for number of PD pulses v/s different phase angle for different applied voltages for different solid dielectrics.

Table 3. No. of PD pulse at different applied voltages at different phase angles of Epoxy resin

Phase angle in degree	No.of PD pulses in Epoxy resin		
	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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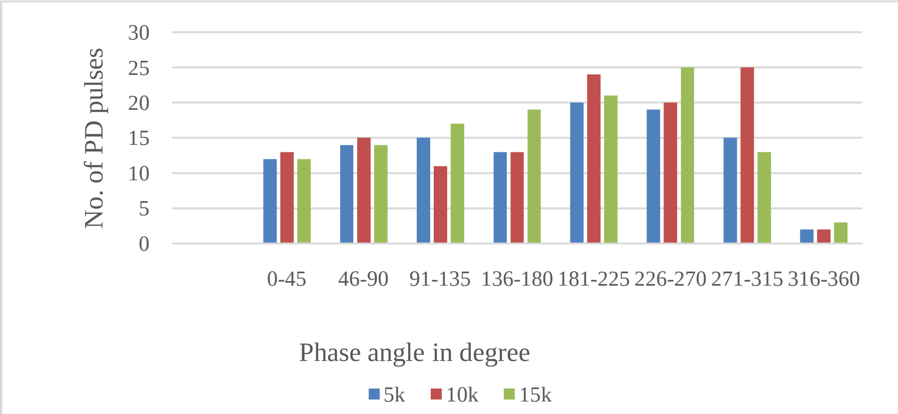

Fig 11. No. of PD pulses at different voltages at Different phase angles ofEpoxy resin

Table4. No of PD pulse at different applied voltages at Different phase angles of Rubber

Phase angle in degree	No. of PD pulses in Rubber		
	5KV	10KV	15KV
0-45	16	9	10
46-90	17	22	12
91-135	10	12	10
136-180	22	31	23
181-225	34	30	23
226-270	20	16	22
271-315	10	17	21
316-360	4	5	8

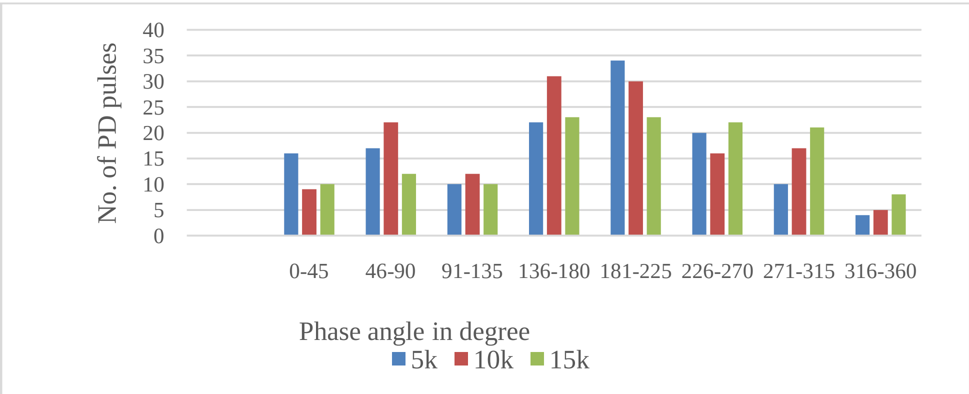

Fig 12. No of PD pulse for different applied voltages at different phase angles of Rubber

Table5. No. of PD pulse at different phase angles at different applied voltages of Teflon

Phase angle in degree	No. of PD pulses in Teflon		
	5KV	10KV	15KV
0-45	11	11	15
46-90	19	16	13
91-145	20	22	13
146-180	14	20	19
181-225	21	22	30
226-270	10	16	17
271-315	17	11	14
316-360	7	9	4

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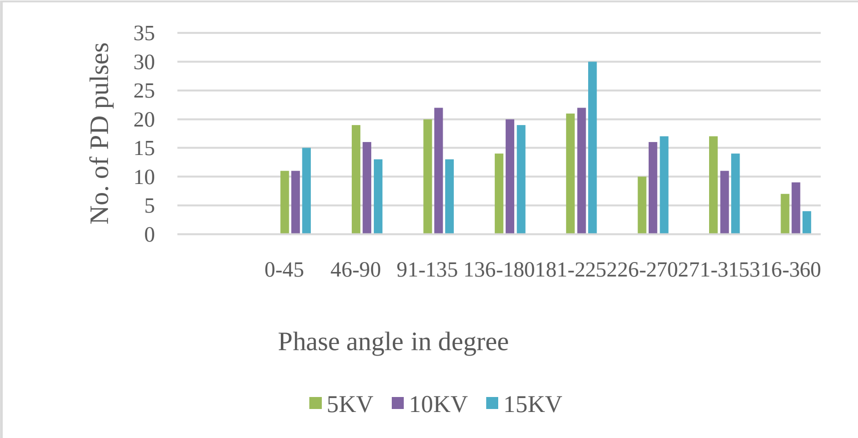

Fig13. No of PD pulse at different phase angles and different applied voltages of Teflon

It is observed that for Rubber the PD pulse are greater at 15KV for the phase angles 226^0 to 360^0. But for phase angles less than 225^0 the no of PD pulse at 10KV is greater.

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 figure9and 10.

Table6. No of PD pulse at different applied voltages at 10KV for epoxy resin, Rubber and Teflon

Phase angle in degree	No.of PD pulses at 10k		
	Epoxy resin	Rubber	Teflon
0-45	13	9	11
46-90	15	22	16
91-135	11	12	22
136-180	13	31	20
181-225	24	30	22
226-270	20	16	16
271-315	25	17	11
316-360	2	5	9

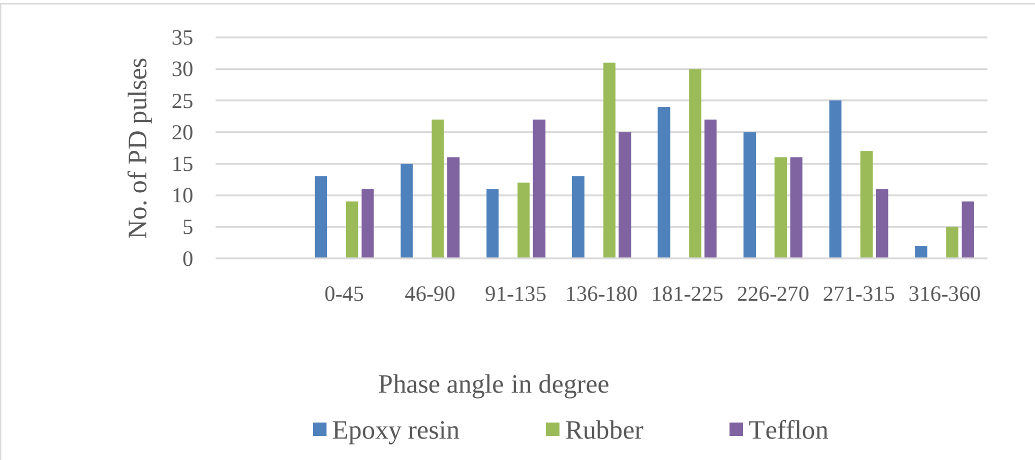

Fig 14.No. of PD pulse at different phase angles at 10KV for different solid dielectrics

At 10KV the no of PD pulse are greater between 46^0 to 225^0 for Rubber is more when compared to other two dielectrics . But for same voltage of 10KV between phase angle more than 226^0 the no. of PD pulse for epoxy resin is more but it reduces after 315^0.

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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

$$Q = V_c * C_a \quad [3]$$

Table7. Apparent charge transfer at different applied Voltage for different dielectrics

	Apparent charge in pC		
Applied voltage in KV	Epoxy resin	Rubber	Teflon
5	0.361	0.309	0.206
10	0.721	0.618	0.412
15	1.08	0.927	0.618
20	1.44	1.236	0.824
25	1.8	1.545	1.03
30	2.16	1.854	1.236

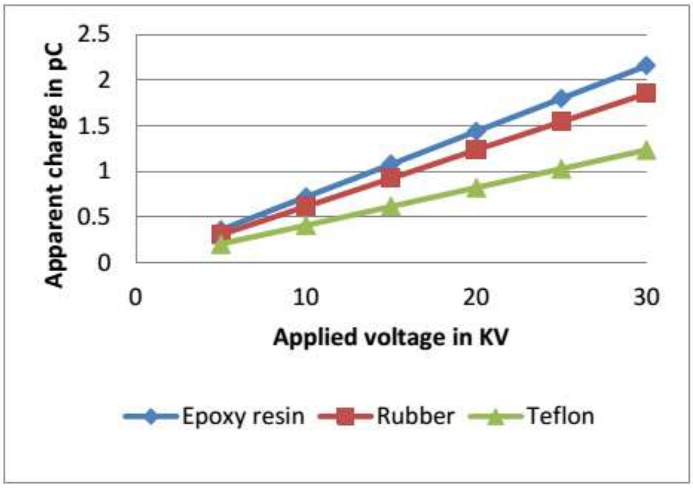

Fig 15.Apparent charge for different applied voltages of different solid dielectrics

We can see that from the graph the no. of apparent charges are more for epoxy resin when compared to other two dielectrics for the same applied voltages of5KV, 10KV,15KV, 20KV, 25KV, 30KV.

We can also that from Fig15. the apparent charge transfer increases linearly as the input voltage increases[7].

CONCLUSION

Insulation is one of the most important parts of highvoltage instruments. Failure of insulation means failure of entire instrument, therefore it is necessary to pay attention to it. Partial discharge is one of the main causes for the insulation failure in HV systems instead of ageing ,progressive deterioration and then ultimate failure[3] .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 materialshave been taken to obtain the partial discharge pattern. All sample considered for the simulation are cuboidal 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 study shows that the permittivity of the insulation material is also an important parameter of partial discharge. It shows that partial discharge is the 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 other parameters on which partial discharge depends and can be made more accurate.

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BIOGRAPHIES

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