



Analysis of Partial Discharge in Rubber a Solid Dielectric Using MATLAB Simulink

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Abstract: Insulators or dielectrics plays an important role in the high voltage power equipment. Various types of insulators are used in high voltage (HV) electrical power systems to protect the power equipments. For the purpose of safety and better efficiency, insulators should be kept in a healthy condition during its operation. As the insulators are not pure due to presence of impurities and cavities inside the insulators, the local electrical breakdown known as partial discharge (PD) takes place due to the High Voltage stresses. It is well evident that most of the insulation failure is caused due to the partial discharge in the insulation material. It gradually degrades the properties of the material which further become the major cause of the failure of the insulation. In this paper, simulation of partial discharge is done using MATLAB for Rubber as insulation material. All the simulation work is done on Rubber which is a solid insulation material. In this study, the dependency of partial discharge on the permittivity of the insulation material is tried to be analyzed with the help of void model made in the very well-known software “MATLAB”.

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

I INTRODUCTION

With the rapid development of technology, electricity has now become a basic necessity, and providing uninterrupted power supply to mankind has become a major priority. Insulation quality plays a important role and one of the major problems in a high voltage power system is the breakdown of insulators or continuous degradation of insulating system. Partial discharge (PD) is one of the major issues which will lead to breakdown of insulators.

Generally, such discharges appear as pulses having duration less than 1 μ s[2]. PD occurs if dielectric strength within a certain region of the insulation of an electric device is locally exceeded, but the surrounding insulation is strong enough to prevent total breakdown. In order to understand the occurrence of PD and the response of electrical network to the excitation by discharge pulses, it is important to model the system. MATLAB SIMULINK has been used to model the PD of a cubical void inside an Rubber cube and the mechanism to measure the maximum charge discharged.

Here we are considering a cubical void inside Rubber which is used as solid dielectric.

II. 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 not occur adjacent to a conductor.[1]

Classification of Partial discharge

(a) External partial discharge :

External partial discharge that occurs outside of the power equipments. Such types of discharges occur in overhead Transmission lines, on armature etc.

(b) Internal partial discharge:

The partial discharge which is takes place inside of a system. The discharge in void is belonging to such type of partial discharge and essential for PD measurement system. PD phenomena include other types of discharge which is surface discharge, cavity discharge, corona discharge, Treeing channel.

Corona discharge: Corona discharge that takes place due to non uniformity of electric field on sharp edges of conductor subjected to high voltage. The insulation supplied for such type of discharge is gas or air or liquid.



Surface discharge: Surface discharges occurs on boundaries of insulating material such as air/solid interface due to over stressed times the stress on the solid material. This may takes place in bushing, end of cable, any point on insulator surface between electrodes.

Treeing channel: High intensity fields are produced in an insulating material at its pointed edges and it degenerates the insulating material .That is responsible for production of continuous partial discharge, called as Treeing channel.

Cavity discharge: The cavities are generally formed in solid or liquid dielectrics. The cavity is generally filled with air or gas. When the gas in the cavity is over stressed such discharges occur.[2]

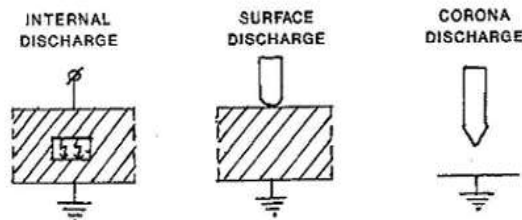


Fig1: Different Discharge Phenomena

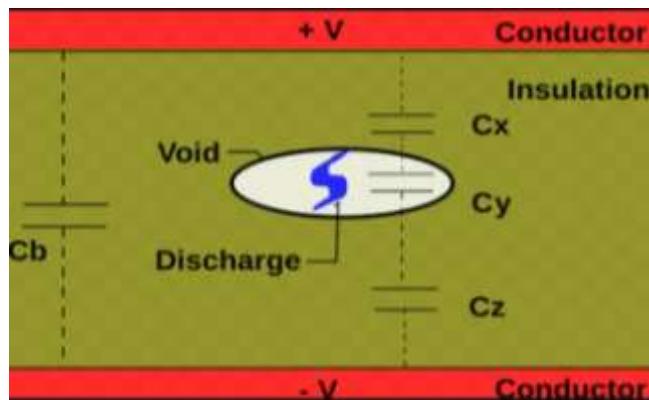


Fig2. Presence of void inside the solid dielectric

Sample preparation:

A Rubber 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.

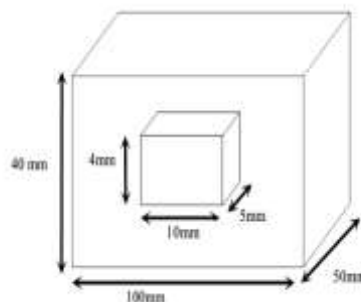


Fig3: void model of Rubber insulator.

The Capacitors model mentioned in the sample preparation Fig4. This is nothing but the equivalent circuit of the test object.

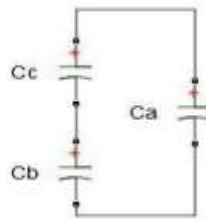


Fig4: equivalent circuit of the test object

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

$$C_a = \frac{\epsilon_0 * \epsilon_r * A}{d}$$

$$C_b = \frac{\epsilon_0 * \epsilon_r * A}{d-t}$$

$$C_c = \frac{\epsilon_0 * A}{t} \quad [5]$$

Where, ϵ_0 = absolute permittivity = $8.854 * 10^{-12}$

ϵ_r = relative permittivity = 3 [8]

$C_a = 3.3202 * 10^{-14}$, $C_b = 3.689 * 10^{-14}$, $C_c = 1.1067 * 10^{-13}$

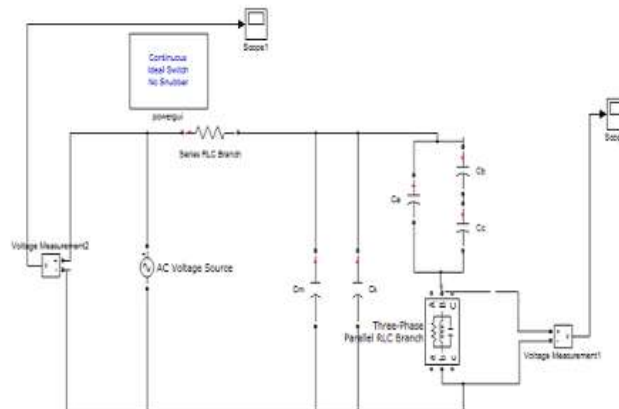


Fig5: Simulink model[4]

The calculated 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 ($C_c \gg C_b \gg C_a$) for a cubical void.

The Simulink model for detecting partial discharge characteristics is shown in figure4. C_a , C_b and C_c together constitutes the test object. C_m refers to the measuring capacitor and C_k refers to the value of coupling capacitor.

The circuit model drawn in Fig.4 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. When V_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].

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. 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
Permittivity	3	ϵ_r	-
Resistance	50	R	Ω
Inductance	0.60	L	mH
Capacitance	0.45	C	μF

III. RESULTS AND DISSCUSSIONS

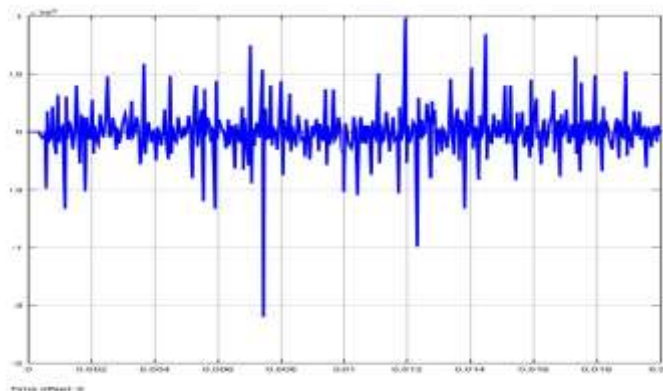


Fig6: Observed Partial discharge pulse at 5KV

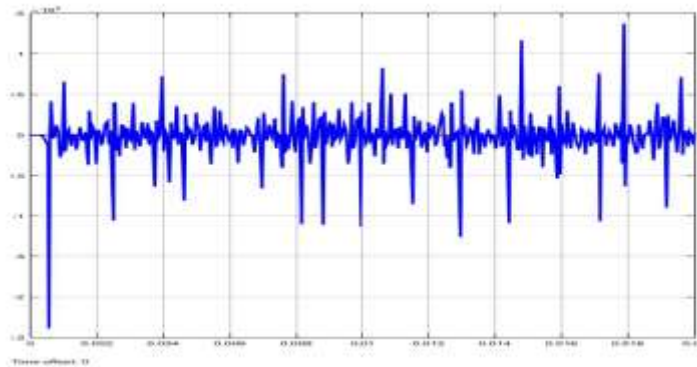


Fig7: Observed Partial discharge pulse at 10KV

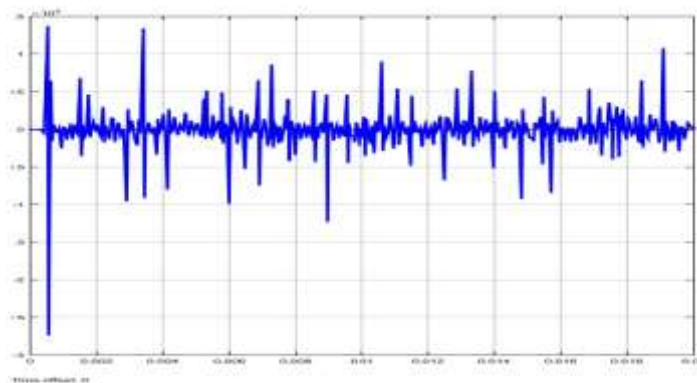


Fig8: Observed Partial discharge pulse at 15KV

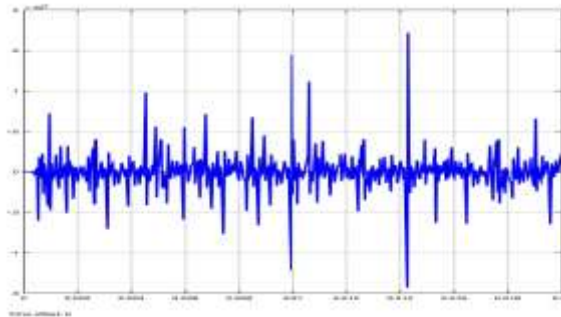


Fig9: Observed Partial discharge pulse at 20KV

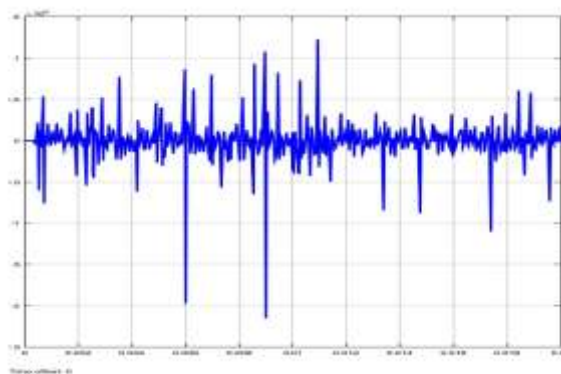


Fig10: Observed Partial discharge pulse at 25KV

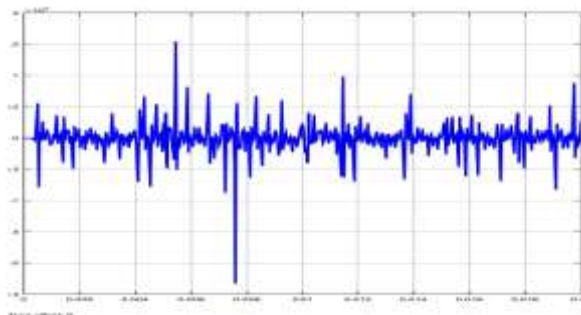


Fig11: Observed Partial discharge pulse at 30KV

Fig6,7,8,9,10,11 shows the PD characteristics of output obtained from scope1 for applied voltages of 5KV, 10KV, 15KV, 20KV, 25KV, 30KV. It is observed that at 5KV the amplitude of PD pulse obtained is $3.84\mu\text{V}$ and at 10KV amplitude is PD pulse is $5.09\mu\text{V}$. The input and output graph of PD characteristics are shown in Fig12,13,14,15 for applied voltages 5KV, 10KV, 15KV,20KV.

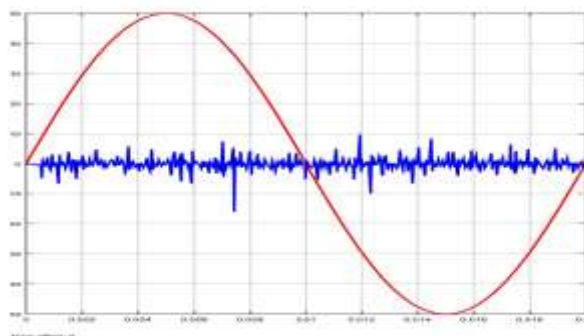


Fig12. PD characteristics along with input at 5KV

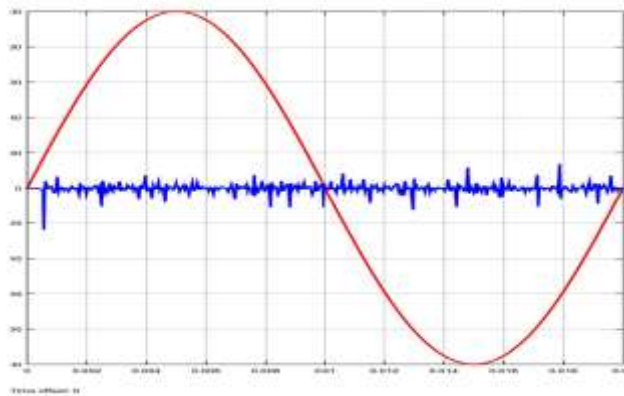


Fig13. PD characteristics along with input at 10KV

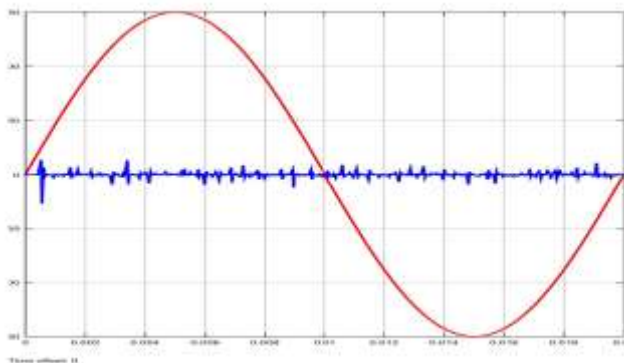


Fig14. PD characteristics along with input at 15KV

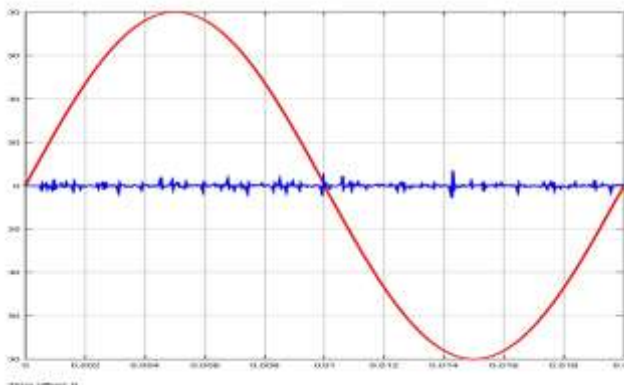


Fig15. PD characteristics along with input at 20KV

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

Table2.Max.PD amplitude at different applied Voltages

Applied voltage inKV	Max. PD amplitude in μV
5	3.841
10	5.09
15	3.14
20	4.2
25	1.006
30	6.029



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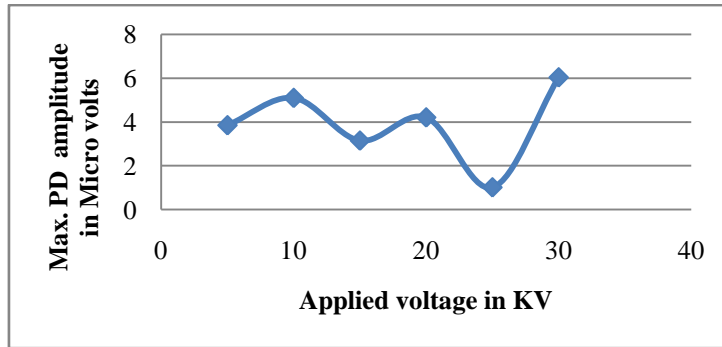


Fig16. Max. PD amplitude at different applied voltages

The partial discharge pulses are examined by dividing single applied sinusoidal cycle of 50 Hz into eight equal parts. Each part has 45° phase angle interval. The number of PD pulses for every interval is plotted for different applied voltages. Figures(17,18,19,20,21,22) shows graph for number of PD pulses v/s different phase angle for different applied voltages. The partial discharge phenomenon is random in nature so the number of PD pulses is not same for every cycle.

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

Sl. no	Phase angle in degree	5 KV	10 KV	15 KV	20 KV	25 KV	30 KV
1	0-45	16	9	10	9	12	14
2	46-90	17	22	12	10	15	16
3	91-135	10	12	10	13	15	15
4	136-180	22	31	23	28	19	23
5	181-225	34	30	23	14	24	23
6	226-270	20	16	22	16	13	17
7	271-315	10	17	21	18	16	17
8	316-360	4	5	8	4	5	10

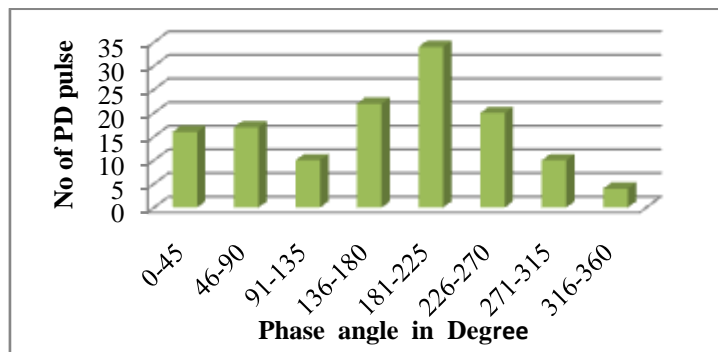


Fig17. No. of PD pulse at 5KV

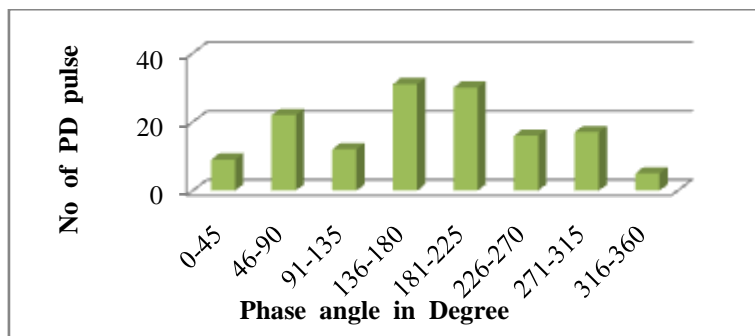


Fig18. No. of PD pulse at 10KV

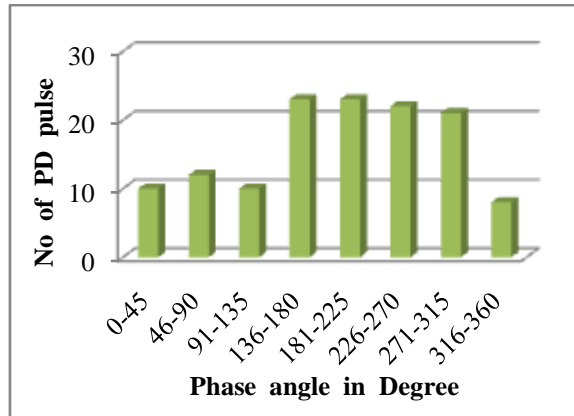


Fig19. No of PD pulse at 15KV

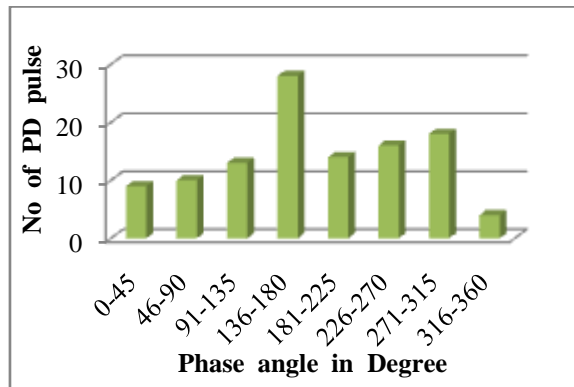


Fig20. No of PD pulse at 20 KV

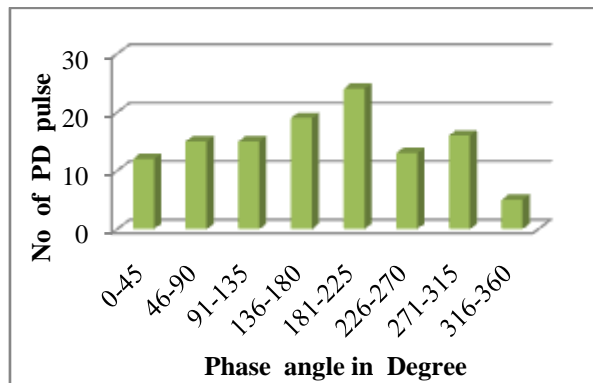


Fig21. No. of PD pulse at 25KV

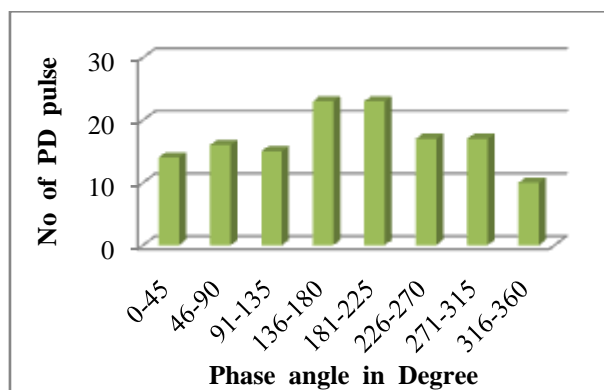


Fig21. No. of PD pulse at 30KV



Fig22 shows the No. of PD pulse together at different phase angles at different applied voltages from Table3.

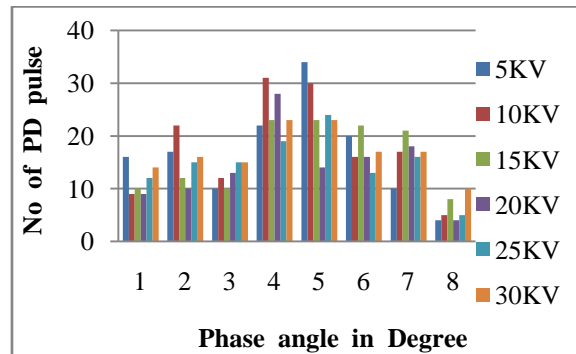


Fig22. No of PD pulse at different phase angles obtained at different applied voltages

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

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

Table4. Apparent charge transfer at different applied Voltage

Applied voltage in KV	Apparent charge in PC
5	0.309
10	0.618
15	0.927
20	1.236
25	1.545
30	1.854

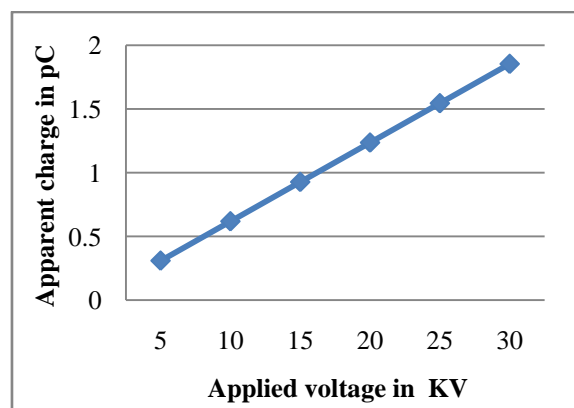


Fig23. Apparent charge transfer at different applied voltages

From Table4 we can see that as the applied voltage increases, the apparent charge transfer also increases. It is shown in the Fig23. We can also that from Fig23,the apparent charge transfer increases linearly as the input voltage increases[7].

IV. CONCLUSION

Insulation is one of the most important parts of high voltage 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]. It is necessary to study



the effect of Partial discharge . Hence, determining and measurement of partial discharge is necessary to keep the equipments in healthy condition during their operation. In this paper Rubber is taken as a solid insulation material and MATLAB Simulink based model has been adopted to observe the partial discharge activity inside the solid insulation. It is found that with increase in applied voltage across the void, partial discharge increases. This study is used 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. Based on the SIMULINK circuit model partial discharge characteristics are found and plotted.

REFERENCES

- [1] High-voltage test techniques - Partial discharge measurements, 3rd ed. Geneva, IEC, 60270: 2000.
- [2] J. R. Lucas, High Voltage Engineering, Sri Lanka ,2001 Revised Edition 2001
- [3] S. Karmakar and A. Sabat, "International Journal On Electrical Engineering an Informatics," Simulation Of Partial Discharge in High Voltage PowerEquipment, vol . 3, Nov. 2, 2011.
- [4] F. H. Kreuger, Partial Discharge Detection in High-Voltage Equipment, London, United Kingdom: Butterworths & co Ltd, 1989.
- [5] E. Kuffel, W. S. Zaengl and J. Kuffel, High voltage engineering: fundamentals, second ed., Eleslever, 2005.
- [6] Sunil kumar, Harisha K S, Gouthami N, HarshithaV, Madhu "Partial Discharge Analysis of a Solid Dielectric Using MATLAB Simulink" International Journal of Innovative Research in Electrical, Electronics, Instrumentation And Control Engineering vol. 4, issue 6, June 2016.
- [7] R. Bartni kas, "Partial Discharge their mechanism, Detection and Measurement ," IEEE Trans. Electr. Insul., vol. 9, pp. 763-808, 2002.
- [8] Deepak Kumar, Dr. Ranjana Singh, "Simulation of Partial Discharge for Different Insulation Material Using MATLAB", IJSRD –International Journal for Scientific Research & Development, Vol. 3, Issue 04, 2015.

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