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# Partial Discharge of a Teflon as a Solid Dielectric using MATLAB Simulink

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**Abstract:** Most serious failure of power equipment is due to the insulation breakdown. Partial Discharge (PD) phenomenon that damages insulation by gradual erosion is major source of insulation failure. In high voltage engineering studies, partial discharge (PD) is an electrical discharge that is localized in nature and partially joins the insulation present in between the conductors and that may or may not happen next to a conductor. So, partial discharge (PD) phenomenon is an important tool for improving the reliability of HV insulation systems. Accurate simulating of PD is more important for insulation study. In this project, partial discharges mechanism in solid dielectric material will be modeled using Simulink in MATLAB® software. In this work, for the analysis of actual PD activity inside the insulator with respect to the application of high voltage using MATLAB Simulink software an electrical circuit model of a Teflon as an insulator with a cubical void as an impurity is taken.

**Keywords:** Partial discharge (PD), void, Highvoltage (HV), $C_a$, $C_b$ and $C_c$.

## I. INTRODUCTION

A partial discharge (PD) is defined as an electrical discharge that is localized in nature and partially present only in a part of the insulation between two separated conductors. The existence of void in an insulation is the real cause for the PD activity, for instance, as shown in Fig 1.When the local electrical field inside the void increase beyond a threshold discharge occurs, it is limited within the void because the surrounding insulation is strong enough due to high dielectric strength than the dielectric strength of the void.

In particular condition due to high electric stress and due to the existence of defects such as void, cracks or inclusions within a solid dielectric, at conductor-dielectric interfaces within solid or liquid dielectrics. Since discharges are restricted to only a part of the insulating material, the discharges only partially bridge the distance between separated conductors.

The appearance of partial discharges in the insulation may degrade the insulation system. PD in a void present inside the insulation are considered to be harmful for insulation material, especially in high-voltage systems from the viewpoint of engineering because they cause energy loss and degradation of the insulation.

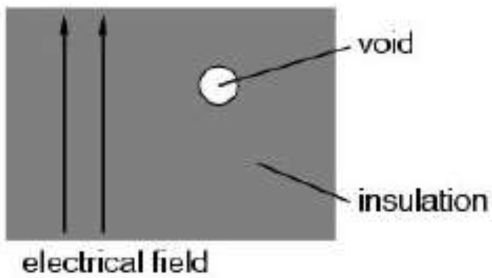


Figure 1.A schematic diagram of partial discharge in a void [1].

## II. TEST OBJECT USED FOR PARTIAL DISCHARGES

The test circuit used for simulation is depicted in Fig. 2. The test object is modelled by the capacitance model developed by Germant&Philippoff in 1932 [3]. In this work, it is consider the Teflon as a dielectric with an internal void is shown schematically in Figure 2(a).

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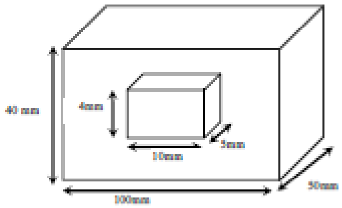
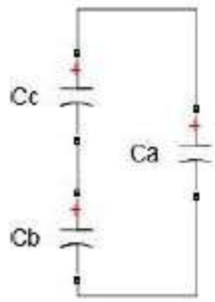



(a)




(b)

Figure 2(a)Void model of Teflon insulator with cubical void,2(b) equivalent circuit of test object.

A Teflon insulator with void inside is considered having dimensions 100mm, 40mm and 50mm. The void having dimensions of 10mm,4mm and 5mm.The electrical circuit model consists of three capacitorand the value of those capacitors can be calculated using [4]

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

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

$C_c=\frac{\varepsilon_0 \times A}{t}$

Where $\varepsilon_0$= absolute permittivity

$\varepsilon_r$= relative permittivity

Assuming that $\varepsilon_0$=8.854X$10^{-12}$ ,$\varepsilon_r$=2. [7]

For the model shown in figure 2.

$C_a = 2.213\times10^{-14}$ F.

$C_b = 2.4594\times10^{-14}$ F.

$C_c = 1.0613\times10^{-13}$ F

## III. ELECTRICAL CIRCUIT FOR PD MEASUREMENT

The equivalent circuit diagram for detection of partial discharge inside the solid insulation is shown in Fig. 3. It consists of high voltage transformer ($V_s$), filter unit (Z), high voltage measuring capacitor ($C_m$), coupling capacitor ($C_k$), void model of solid insulation called as test object ($C_t$), matching impedence circuit for measurement of partial discharge ($Z_m$) and the measurement instrument (MI).

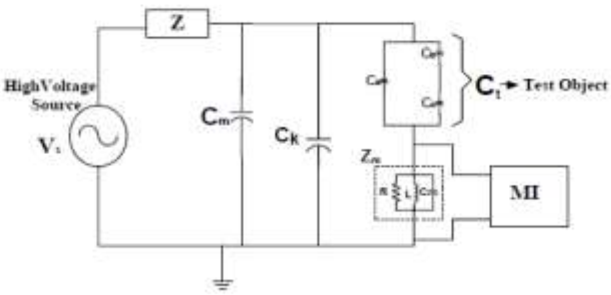



Figure 3. Electrical equivalent circuit model of cubical void (test object) in solid insulation along with high voltage equipment.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The matching impedence circuit for measurement of PD is a parallel combination of the resistor, inductor and the capacitor. The cubical void model (test object) of the insulating material is represented as 'abc' diagrams [5-6]. In the equivalent circuit the test object is represented in the form of small capacitance and the capacitance Cc corresponds to the cubical void present inside the solid insulation, $C_b$ corresponds to the capacitance of the remaining series insulation with cubical void ($C_c$) and $C_a$ corresponds to the capacitance of the remaining discharge-free insulation of the rest of the solid insulator. Such circuit is energized with AC voltage, a recurrent discharge occurs $C_c$ is charged, reaches the breakdown voltage of the cavity, is charged again and breaks down. The voltage across the cavity $C_c$ is

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

where, the $V_a$, $V_b$ and $V_c$ are the voltage across the corresponding capacitance $C_a$, $C_b$ and $C_c$ respectively. The apparent charge q across the test object ($C_t$) is measurable during the PD activity inside the solid insulation which is calculated by the empirical Eqn.

$q = C_b \times V_c$

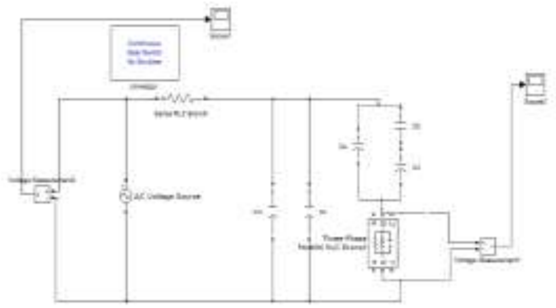

Figure 4.Simulink model

The model drawn in Fig.4 is simulated using MATLAB. When high voltage is applied across the test object ($C_t$), 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. 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.

**Table.1.Parameter Used for Simulation of Partial Discharge**

| Parameter | Symbol | Value | Dimension |
|---|---|---|---|
| HV measuring Capacitor | $C_m$ | 1000 | pF |
| Coupling capacitor | $C_k$ | 1000 | µF |
| Permittivity | $\varepsilon_0$ | $8.854\times10^{-12}$ | F/m |
| Relative permittivity | $\varepsilon_r$ | 2 | - |
| Resistance | R | 50 | Ω |
| Inductance | L | 0.60 | mH |
| Capacitance | C | 0.45 | µF |

## IV.RESULT AND DISCUSSIONS

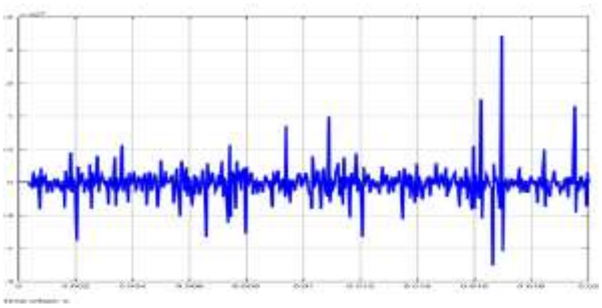

Fig5: observed partial discharge pulse at 5kV

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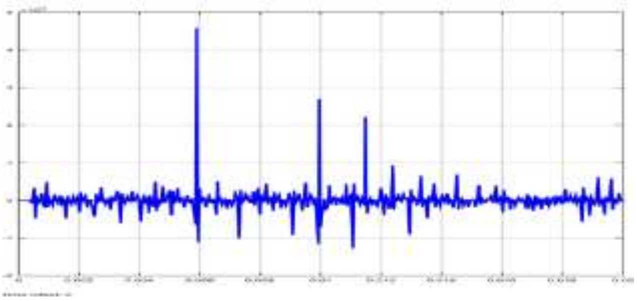

Fig6: observed partial discharge pulse at 10kV

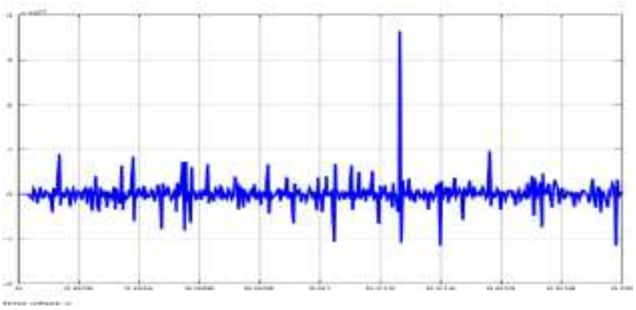

Fig7: observed partial discharge pulse at 15Kv

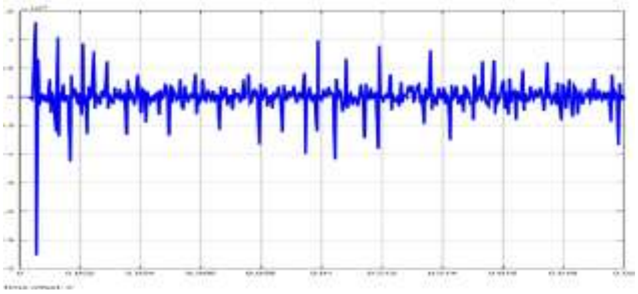

Fig8: observed partial discharge pulse at 20Kv

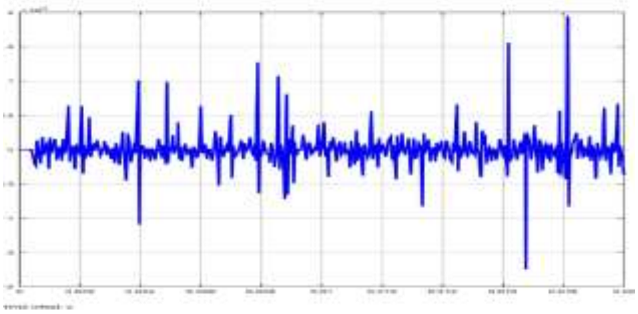

Fig9: observed partial discharge pulse at 25Kv

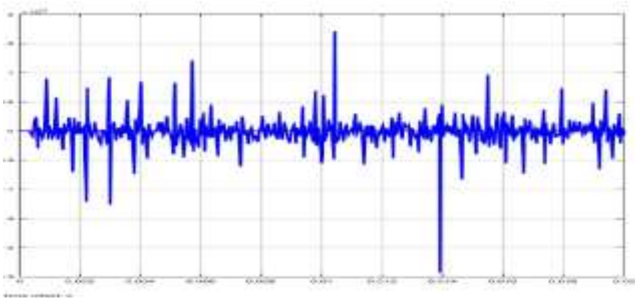

Fig10: observed partial discharge pulse at 30Kv

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Figures 5, 6,7,8,9 and 10 shows the PD characteristics for the applied voltage of 5kV, 10kV,15kV,20kV,25kV and 30kVrespectively. In this work,the wide range of the PD activity inside the solid insulation is observed by increasing the voltage from 0-30 kV between the cubicle void model. It is also observed from the Figure. 11 thatdischarges in every input voltage are different. In AC source, when the source increase the amplitude of waveform increases, so the maximum amplitude of the PD is the function of the applied voltage. The appearance of maximum amplitude of such PD signal is also changes over a cycle of applied voltage due to the random PD phenomenon.

An increasing voltage of 5-30 kV is applied across the solid insulation to observe the maximum amplitude PD pulses. The corresponding data found is depicted in Table 2 and graph has been plotted as shown in figure 11. From the graph it is observed that maximum amplitude of 11.46 µV is obtained at 10 kV of applied voltage. 6

**TABLE2: Max PD values with different applied voltages**

| Sl.no | Applied voltage in KV | Max.PD amplitude in microvolt |
|---|---|---|
| 1 | 5 | 5.54 |
| 2 | 10 | 11.46 |
| 3 | 15 | 9.11 |
| 4 | 20 | 3.27 |
| 5 | 25 | 4.87 |
| 6 | 30 | 4.27 |

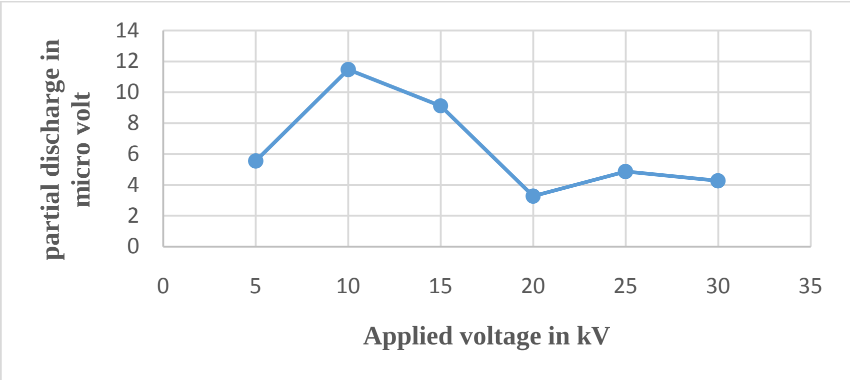


Figure11: Max PD Amplitude with different applied voltage

Commonly, the amplitude of the partial discharge phenomenon is the function of the applied voltage. It is observed during the simulation study that the PD magnitude increases with increase in applied voltage on the test object [1-2]. The max.amplitude of the PD is highly variable with the different applied voltage which is shown in Fig. 11.

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

**TABLE3: Apparent charge transfer at different applied voltage**

| Sl. no | Applied voltage in KV | Apparent charge in (pC) |
|---|---|---|
| 1 | 5 | 0.236 |
| 2 | 10 | 0.473 |
| 3 | 15 | 0.71 |
| 4 | 20 | 0.947 |
| 5 | 25 | 1.184 |
| 6 | 30 | 1.421 |

Further an analysis has been made for presence of PD pulses over a total measuring period under applied voltage of 5-30 kV. In this work the total phase angle is divided into eight section having 45˚ phase angle each. It is observed that, as the PD activity is not constant the number of PD pulse appeared in the each section is not constant. In this Figure.19, the number of PD pulses is appeared in the different phase angle of the applied voltage. In addition, it is also observed that the number of the PD appears in different applied voltage is not fixed because PD phenomenon appears randomly.


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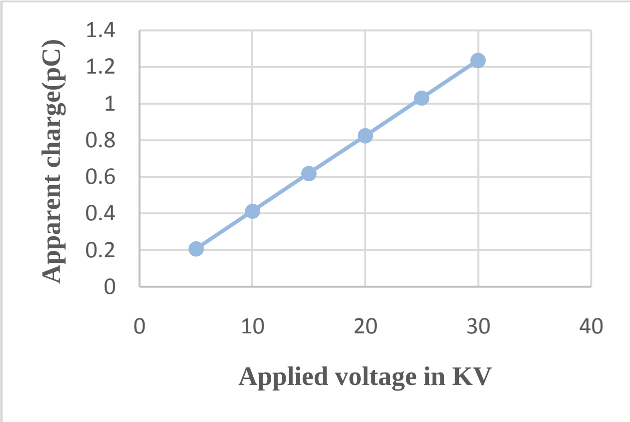


Figure.12.Apparent charge transfer in cubical void at different applied voltages

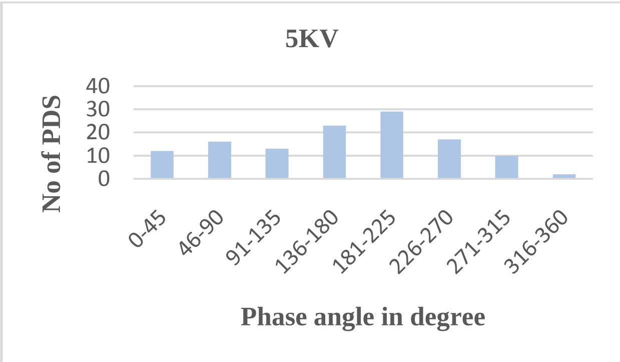


Figure 13: Partial discharges pulses at different phase angle of cubical void at 5kV of applied voltage.

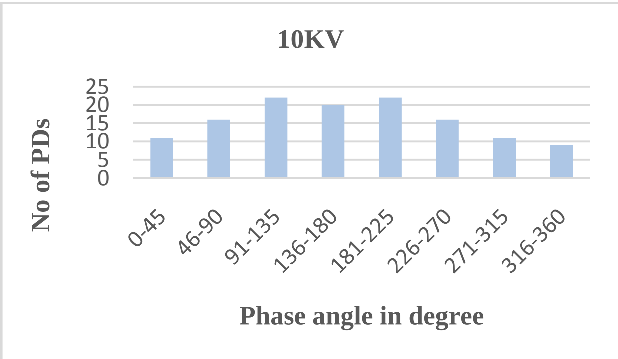


Figure 14: Partial discharges pulses at different phase angle of cubical void at 10kV of applied voltage.

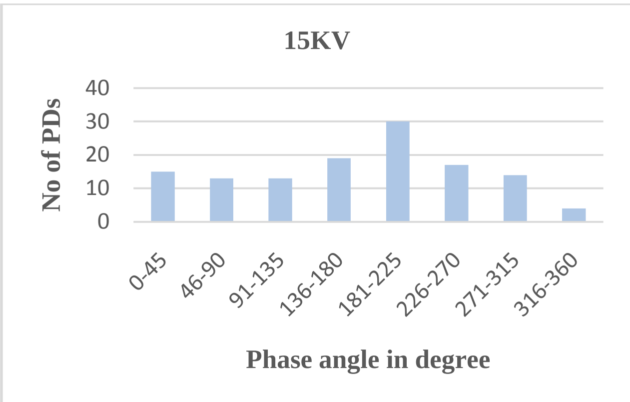


Figure 15: Partial discharges pulses at different phase angle of cubical void at 15kV of applied voltage.

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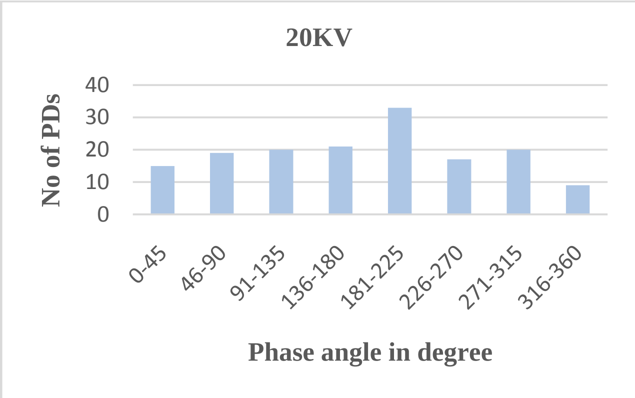


Figure 16: Partial discharges pulses at different phase angle of cubical void at 20kV of applied voltage.

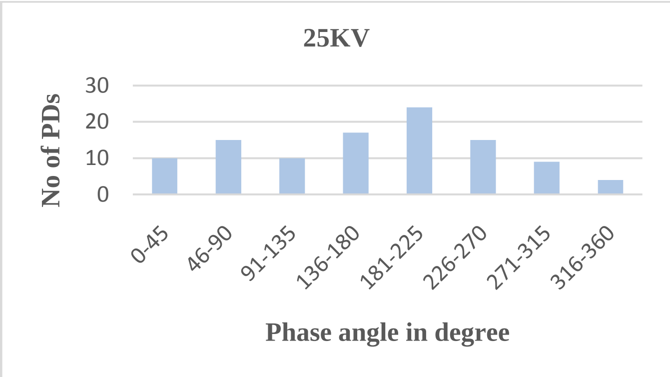


Figure 17: Partial discharges pulses at different phase angle of cubical void at 25kV of applied voltage.

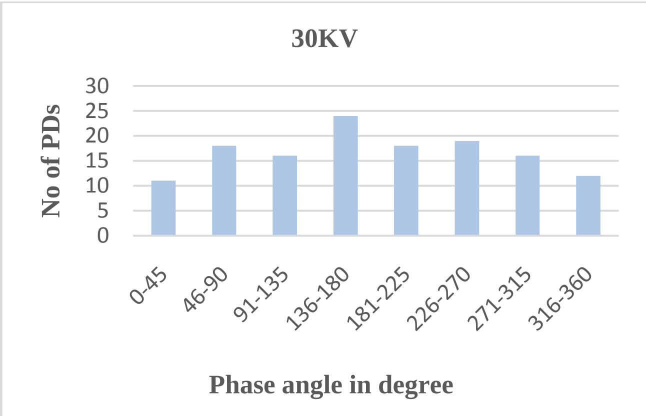


Figure 18: Partial discharges pulses at different phase angle of cubical void at 30kV of applied voltage.

**TABLE.4. Number of partial discharge at different applied voltage at phase angles**

| Sl.no | Phase angle in degree | 5KV | 10KV | 15KV |
|---|---|---|---|---|
| 1 | 0-45 | 12 | 17 | 12 |
| 2 | 46-90 | 16 | 14 | 15 |
| 3 | 91-135 | 13 | 12 | 13 |
| 4 | 136-180 | 23 | 30 | 24 |
| 5 | 181-225 | 29 | 20 | 23 |
| 6 | 226-270 | 17 | 11 | 18 |
| 7 | 271-315 | 10 | 15 | 13 |
| 8 | 316-360 | 2 | 11 | 6 |


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| Sl.no | Phase angle in degree | 20KV | 25KV | 30KV |
|---|---|---|---|---|
| 1 | 0-45 | 15 | 10 | 11 |
| 2 | 46-90 | 19 | 15 | 18 |
| 3 | 91-135 | 20 | 10 | 16 |
| 4 | 136-180 | 21 | 17 | 24 |
| 5 | 181-225 | 33 | 24 | 18 |
| 6 | 226-270 | 17 | 15 | 19 |
| 7 | 271-315 | 20 | 9 | 16 |
| 8 | 316-360 | 9 | 4 | 12 |

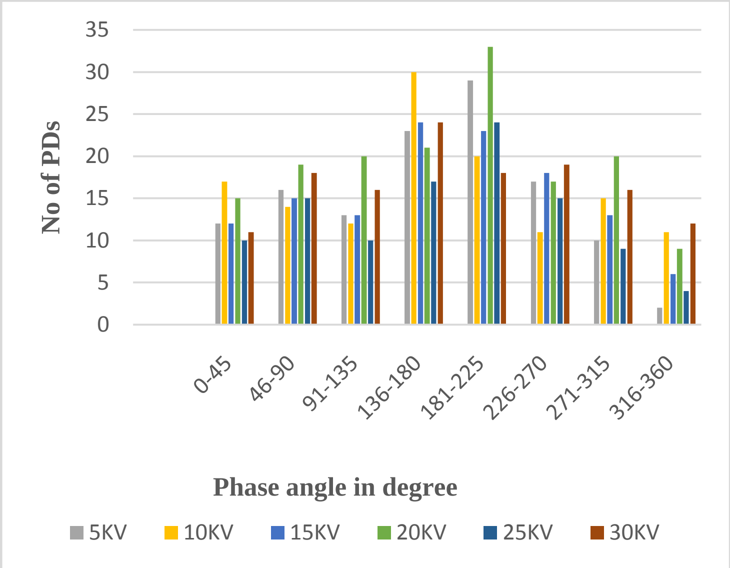


Figure 19.Number of partial discharge at different applied voltage at different phase angles.

## V. CONCLUSION

This research work has been able to successfully study the activities of PD in a solid insulation. Partial discharge (PD) measurements is an important tool for improving the reliability of the insulation. The major cause of insulation failure in high voltage power system is partial discharge which needs to be monitor continuously to avoid the incipient failure in the power system network. A MATLAB based simulink model has been developed to understand the PD activity inside the solid insulation in this work. In this work it is studied that the entire geometry of the void presence inside the solid insulation model plays a major role in the PD activity as the high voltage is applied. In addition, with the increase of applied voltage inside the solid insulationPD is increases. In this study an efforts have been made to investigate the maximum PD magnitude, number of PDs with phase angle and apparent charge transfer with applied voltage.

This study will help the power engineers the way to predict the quality of the insulation used for high voltage power equipment. The present work is to be extended for further studyto monitor the PD activity continuously to avoid the incipient failure in different high voltage power equipment such as current transformer (CT), potential transformer (PT), switch gear and circuit breaker.

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