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Simulation Internal Partial Discharge Activity within Void as Function Frequency Using: COMSL+MATLAB LIVELINK

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Abstract:

The good performance of all power system networks is mainly determined by the health of dielectric material high voltage equipment. In this paper Internal Partial discharges within a disc-shape void in polycarbonate are simulated as function frequency (100-0.01) Hz of voltage applied. The developing combined mathematical solving technique, COMSOL + MATLAB LIVLINK, to ameliorating the FEM analysis. As the solving technique is time and accuracy dependent, the pre-used solving techniques based mainly on one solver, which was -in some cases- of low precision and time consuming. Thus, it is of importance to develop a highly accurate and system responded solving technique that can simultaneously simulate the changes in any (or all) of the system parameters. This development implemented to modelling partial discharge and compare with experimental result of behaviour partial discharge as function a frequency and voltage applied for disc-shape cavity that represent by 2D model. This is work explained effect frequency on behaviour of partial discharge at different voltage applied and cavity size.

Key words: Partial discharge, Simulation, Finite element method analysis, Variable frequency, Disc-shape cavity

1. INTRODUCTION

The partial discharge activity is normally affecting on performance of power system because it is influent on health of insulation system in electrical equipment and might make possible the breakdown and irrecoverable damage to the system. For this reason, many researchers described the partial discharge phenomena to understand behaviour of PD [1-5]. The cumulative effects of partial discharge in solid dielectric materials lead to insulations deterioration and reduce the electrical strength of it. The important factors that affecting on behaviour of partial discharge within cavity are the basic characteristics of the dielectric material, the field intensity, the cavity geometry, the distance between electrodes, the pressure of void, and characteristics of the gas filling a void.

The Physical modelling of partial discharge in dielectric material within cavity Provides significant information into PD mechanisms, in addition to description for several features of the Partial discharge pattern [1,2]. Suitable models depicting the behaviour of partial discharge within void in solid insulation became a subject of increasing interest [3-8]. Gemant & Philippoff in 1932 modelled PD within void and symbolized by sample circuit known as the capacitance model, then developed to Whitehead model of the three capacitors and the Maxwellian approach (Pedersen mostly) [6]. In recent years, by using computer to assist processing technique has facilitated modelling partial discharge, Especially phase resolved partial discharge (PD) measurement systems became very common[9-14].

Forssén in 2005, a finite element analysis model has been developed by using COMSOL software to depict Partial discharge activity to study an effect factors on the behaviour of PD activity [15], then Illias improved the model of PD by using (FEA) software in parallel with a mathematical package to enhance the finite element analysis[16]. The modelling partial discharge using (FEA) is complex analysis due to there is many factors caused numerical convergence problems during simulation. The inception voltage that is one of the necessary conditions to partial discharge occurrence within voids in solid insulation depends upon many factors such as the type of gas in the void, the gas pressure, surface properties of the void, size and shape of the void, and dielectric constant of the surrounding medium [17]. the inception voltage magnitude comes to be equal to various materials that have the same cavity since it is independent of the permittivity of insulation material [18].

The advantage of modelling dynamic partial discharge is that the parameters which may influence on PD activity under diverse conditions can be readily evaluated, for this reason a lot of authors modelling partial discharge. In this work, the simulation of dynamic partial discharge activity has been developed combined two mathematical solving technique COMSOL + MATLAB LIVLINK, to improving the FEM analysis in parallel with a mathematical bundle using MATLAB code and used the development of inception voltage which depend on permittivity of insulation material [17].For different diameter of disc-shape cavity in polycarbonate with various applied voltage and range of frequency have been carried, The simulation data are compared with the experimental results to study behaviour of partial discharge [19].

2 PARAMETERS OF PARTIAL DISCHARGE MODEL

There are two types of parameters that have been introduced in PD modelling and simulation studies are:

a. The parameters related with surface charge deterioration after Partial Discharge occurrence are:-

1. The effective lifetime of De-trappable electron in the void surface (t_{trap}).
2. Conductivity of void surface (σ_{sf}).
3. Electrons injected into the insulation and the void per unit time.

b. The Parameters related with the void size are:-

1. Inception voltage V_I.
2. Extinction voltage V_{ext}.
3. The critical current for an electron avalanche to develop I_{crit}.

A lower trap or higher σ_{sf} may increase the surface charge decay rate through diffusion into deeper traps or conduction along the cavity wall respectively, reducing the number of electrons available for the next PD occurrence and increasing the time waiting for PD initiator electron (t_{stat}) to become available.

3 MODELLING OF PD

A. Field Equations

The electric potential distribution in the dielectric is described by the field model. The basic governing equations of the field model are as follows:

$$\nabla \cdot D = \rho_f \text{……….. (1)}$$

$$\frac{\partial \rho_f}{\partial t} + \nabla \cdot J_f = 0 \text{…….. (2)}$$

Where the D is the electrical displacement field, ρ_f is the free electron density and J_f is the free current density. On the assumption that the insulation is non-dispersive material, linear isotropic with an instantaneous polarization which is exposed to a tardily altering field, can write equ.1 as:

$$\nabla \cdot D = \nabla \cdot (\varepsilon_\circ \varepsilon_r E)$$

Then

$$\nabla \cdot D = -\nabla \cdot (\varepsilon_\circ\, \varepsilon_r \nabla V)$$

Where E is electric field, $\varepsilon_\circ$, ε_r are the permittivity of vacuum and relative respectively and V is the electric potential, then the equ.2 can be written as:

$$\nabla \cdot (-\sigma \nabla V) = \nabla \cdot \varepsilon_\circ\, \varepsilon_r \nabla (\frac{\partial V}{\partial t}) \ldots\ldots\ldots\ldots (3)$$

From equation (3), σ is conductivity of insulation material, the finite element analysis software can solve equation this equation.

B. MODEL GEOMETRY AND MESH

It depends on the test sample of experimental measurement created model geometry as shown in fig 1 [20]. The model is employed using two-dimensional (2D) symmetric FEA analysis using COMSOL and MATLAB LIVLINK depend on a field model that solves electric potentials and interfaces with MATLAB code. The model consists of a homogenous insulation material (ε_r=3), the sample consist of three layer from polycarbonate, each layer has 1.0 mm thickness and 30 mm width, disc-shape cavity of (1.5,4) mm diameter and a void surface of 0.1 mm thickness to allow the modelling of surface charge decay through conduction along the void wall. A sinusoidal AC voltage is applied to the upper electrode while the lower electrode is always grounded. FEA model is used continuously throughout the simulation to calculate the field distribution in the void. This is achieved in FEA modelling by assuming that during a PD event, the whole cavity is affected.

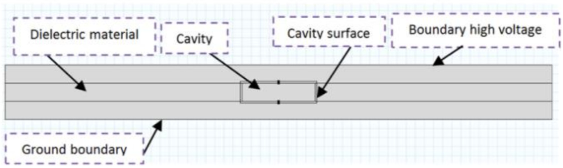


FIG. 1 2D axial-symmetric model geometry contain three of polycarbonate each one 1mm×30mm and cylindrical air void (1.5, 4) mm×1mm.

A mapped mesh with Free Triangular elements is used, the element size parameters are:

1. The maximum element size =0.76mm.
2. The minimum element size =0.0029mm.
3. The maximum element growth rate =1.2
4. Resolution of curvature =0.25
5. Resolution of narrow regions =1

The mapped mesh is chosen instead of an unstructured mesh to make it easier to control the element density in the thin cavity surface as show in fig 2. The number of element depends on size of sample.

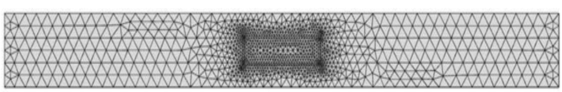


FIG. 2 Generated mesh of model.

C. DISCHARGE

The partial discharge may be occurring when the voltage inside cavity exceeds the inception voltage and there is initial free electron present. The inception voltage (V_I) across cavity for partial discharge has been developed by [17],whereas V_I written as:

$$V_i = \left(\frac{\mathrm{Bp}}{\mathrm{In(pt)+k}}\right)\left(\frac{[\mathrm{t+t\prime(\varepsilon_r-1)}]}{\varepsilon_r}\right) \ldots\ldots (4)$$

Whereas t' is the thickness of void, t is the thickness of insulation, B constant depend on gas inside void where for air is 2737.50 V/kPa-cm [21,22], the pressure of air in gap assumed 77 KPa [18],and k=M $(pt')^N$, M and N are constants as given for air 3.5134and 0.0599 respectively [23].there are three source to generate electron because of surface emission, the electrons of shallow traps (N_{ed}), free surface electrons (N_{es}) and electrons injected from electrode (N_{ei}) ,the electrons generated from shallow traps(N_{ed}) can be written as[16]:

$$N_{ed}(t) = N_{ed0}\, abs(\frac{V_{PD}(t)}{V_I}) \times e^{\left(\frac{-t}{t_{trap}}\right)} \ldots\ldots (5)$$

And

$$N_{edo} = \begin{cases} N_{edoH} & (\ V_{\ cav}\, and\, V_{sf}\ )same\ \ polarity \\ N_{edoL} & (\ V_{\ cav}\, and\, V_{sf}\ )\ different\, polarity \end{cases}$$

From equation (5), N_{ed0} is initial electron of sallow traps, V_{PD} is the voltage inside void of Previous partial discharge happened, t is the time interval between the previous and new PD, t_{trap} is effective age of electrons generated from shallow traps, the initial electrons classified into two magnitude high number of electron (N_{edoH}) and low number of electrons(N_{edoL}),whereas the choose one of them depend on the polarity of cavity voltage and surface voltage ,if the same polarity use high value and vice versa.

The free surface electron can be written as:

$$N_{es}(t) = N_{eso}\ \times abs(\frac{V_{PD}(t)}{V_I}) \times abs(\frac{V_{sf}(t)}{V_{sfPD}(t)}) \ldots\ldots (6)$$

From equation (6),N_{eso} is the initial free cavity surface electron, V_{sf} is the voltage of cavity surface and the cavity surface voltage after partial discharge instantly, Therefore the total electron generated (N_{et}) calculated by equation below:

$$N_{et}(t) = (N_{ed}(t) + N_{es}(t) + N_{ei}) \times \exp\left\{abs\left(\frac{V_{cav}(t)}{V_I}\right)\right\} \ldots\ldots. (7)$$

From equation 7, Nei is the electron injected by electrode; V_{cav} is the voltage inside cavity.

The conductivity of cavity change during partial discharge depend on voltage and current inside cavity, from V_{cav},V_I ,I_{cav} and critical current (I_{cr}), the conductivity of cavity calculate by:

$$\sigma_{cav}(t) = \sigma_{max}\left[1 - exp\left[\!\left[-\left[abs\left(\frac{V_{cav}(t)}{V_I}\right) + \left(\frac{I_{cav}(t)}{I_{cr}}\right)\right]\right]\!\right]\right] \ldots. (8)$$

From equation 8, σ_{max} is the maximum cavity conductivity and I_{cr} is critical current to start electron avalanche[24,25],when the voltage inside cavity exceed the inception voltage, the probability of occur partial discharge calculate by:

$$PD(t) = 1 - \exp(-N_{et}(t) \times dt) \ldots\ldots (9)$$

From equation 8,dt is the time step interval[24,25],then the result from equation 8 compare to random vector the value of vector from 0 to 1 and length of vector is same number of step times multiply by the number of cycles, the partial discharge occur when the PD large than random vector.

The conductivity of surface cavity depend on polarity of cavity voltage and the surface voltage, when the polarity is same the conductivity reset depend on voltage cavity and voltage decay V_{dca} ,can calculate by:

$$\sigma_{sf}(t) = \sigma_{sfo} \times exp\left(abs\left({V_{cav}(t)}/{V_{dca}}\right)\right) \ldots.. (10)$$

From equation 10, σ_{sf} is the initial conductivity of surface cavity; if the polarity is different the conductivity is equal initial value.

4 DISCHARGE PROCESS

Partial discharge simulation demonstrated by flow chart shown in fig 3 ,COMSOL and MATLAB LIVLINK using to solve the electric field by finite element analysis. The discharge in void inside insulation modelled dynamic by change the conductivity of cavity and charge decay. The maximum conductivity of the void during discharge and critical current are chosen to avoid numerical convergence error [26,16] also from literature chosen the value of voltage decay. The extinction voltage and inception voltage are adjusted to get agree with measurement results for each frequency. The maximum surface conductivity depend on the voltage applied , frequency and thickness of sample[18],it is limit to avoid numerical error can calculated by:

$$\sigma_{sfmax} = \alpha \times e^{\left(\frac{\beta V_O}{t}\right)} \times f \ldots\ldots.. (11)$$

Where α and β are constant $5.633 \times 10^{-11}\, S/m$ and 0.4054 m/V respectively.

The electrons generated N_{et} is assumed constant and control by exponential of ratio voltage cavity with inception voltage and the value of N_{et} depend on frequency whereas the generation of electron increase when the frequency increase [26],the initial magnitude of electron generator when the frequency 100Hz and 50Hz is 500 1/s ,300 1/s for frequency 10Hz,1Hz and 0.1Hz and for frequency 0.01Hz the magnitude of electron generation is 150 1/s. the magnitude of initial electron generated by charge de-trapping ,electron generated by surface charge and electrons injection by electrode adjusted to obtain agreement with experimental result. The effective lifetime of electron is constant 2ms[18] .the global parameters used in simulation explained by table 1.

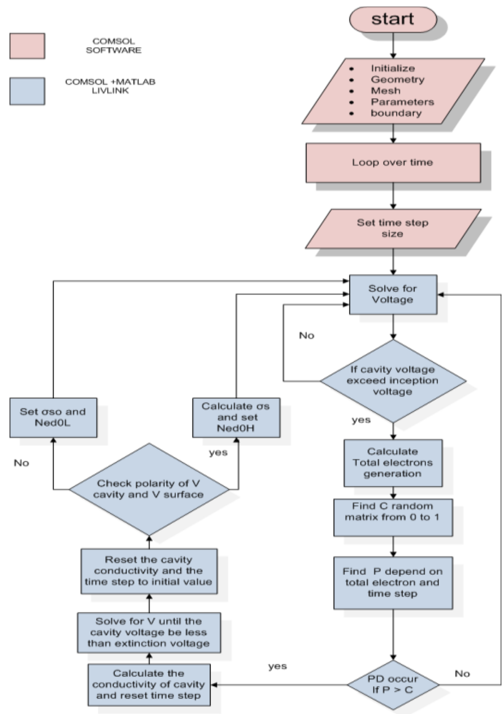


FIG. 3 Flow chart for discharge process.

Table 1 Definition of global parameters used in simulation partial discharge.

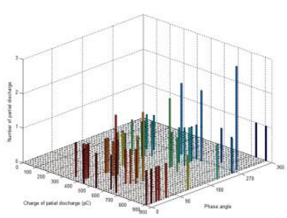
Definition	Symbol	Value	Unit
Time step during no PD	dt_o	$1/2880f$	s
Time step during PD	dt_{pd}	1	ns
Numbers of simulation cycle	Cycle	50	cycle
Material relative permittivity	ε_r	3	-
Cavity surface relative permittivity	ε_{rsf}	3	-
Cavity relative permittivity	ε_{air}	1	-
Material conductivity	σ_{mat}	10^{-15}	S/m
Initial cavity surface conductivity	σ_{sfo}	10^{-15}	S/m
Cavity conductivity during no PD	σ_{air}	0	S/m
Voltage applied on insulation	Vo	8,9,10	KV
Frequency of voltage applied	f	0.01-100	Hz

Diameter of cavity	d	1.5,4	mm
Diameter Surface cavity	ds	0.1	mm
Initial cavity inception voltage	V_{Io}	4900	V
Initial extinction voltage	V_{exto}	1100	V
voltage decay	V_{dca}	100	V
Critical current	I_{cr}	1.5×10^{-6}	A
Conductivity of cavity during PD	σ_{max}	1.5×10^{-4}	S/m

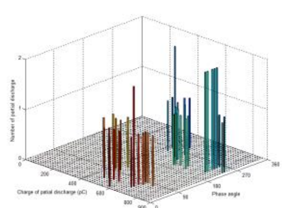
5 RESULT AND DISCUSSION

A. Applied Voltage Amplitude

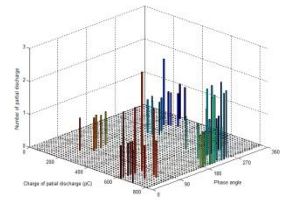
The partial discharge activity of cavity in insulation material with diameter 4 mm at voltage amplitude 8, 9 and 10 KV respectively, and variable frequency of range 0.01Hz to 100Hz is described in this section .The partial discharge patterns simulated at voltage amplitude 8KV and the frequency applied from 0.01Hz to 100Hz, the PD activity in insulation void changes with frequency as show in fig 4. The maximum charge of PD for each frequency clearly changed at 8KV voltage so that the highest maximum charge of PD at 100Hz is 913.2 pC and the lowest maximum charge at 0.1 is 329.05 pC, also the number of PDs per cycle and the position of positive and negative partial discharge altered for different frequencies. Almost positive PD occurred from 0° to 90° and the negative from 180° to 270° and the spread of PDs expanded with increased frequency.



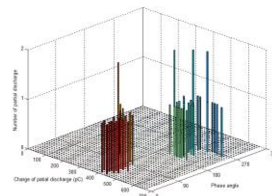
a. (100) Hz



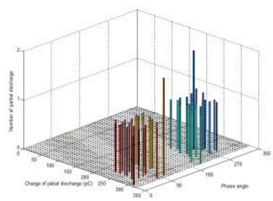
b. (50) Hz



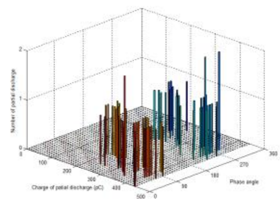
c. (10) Hz



d. (1) Hz



e. (0.1) Hz



f. (0.01) Hz

Fig. 4 simulation result at 8 kV and frequency from 100 Hz (a) to 0.01 Hz (f), at insulation cavity 4 mm.

The effects of frequencies at voltage applied (8KV), described in table 2, obviously the number of PDs per cycle changed with different frequency so that the highest number of PD at 0.01Hz and the lowest value at 50Hz, while the maximum charge of PD increased with the increasing of frequencies, where it's reach up to 913.2pC at 100Hz and drop down to 329.0pC at 0.1Hz, also the lowest mean charge at minimum frequency then increased with the increasing of frequency. However the mean charge depend on frequency of voltage applied and the number of PD per cycle. Table 2 and Table 3 details comparison between the experimental and simulation results for 8KV and 4mm diameter of cavity, the partial discharge patterns are in acceptable agreement [20].

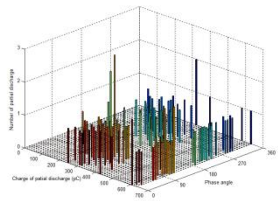
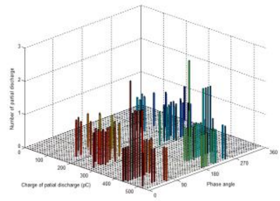
Table 2 simulation results as a function of frequency of 8 KV, 4mm applied voltage.

Frequency (Hz)	100	50	10	1	0.1	0.01
Number of PD per cycle	2.46	2.06	2.54	2.3	2.38	2.62
Maximum charge of PD(pC)	913.2	880.0	810.4	631.4	329.0	433.2
Mean charge of PD	580.9	607.5	562.9	431.3	279.2	233.1
Minimum charge of PD(pC)	243.6	213.4	240.1	270.5	230.6	187.6
Number of PD (positive charge)	61	51	63	57	59	66
Number of PD (negative charge)	62	52	64	58	60	67

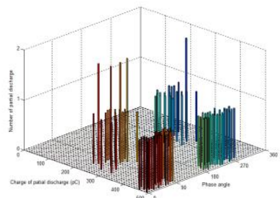
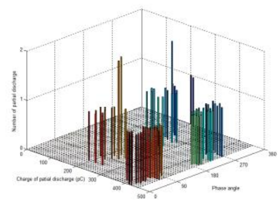
Table 3 The experimental Results as a Function of Frequency of 8 KV, 4mm Applied Voltage[20].

Frequency (Hz)	100	50	10	1	0.1	0.01
Number of PD per cycle	2.5	2.1	2.5	2.3	2.4	2.7
Maximum charge of PD(pC)	reduces from about 900 pC at 100 Hz to about 400 pC at 0.01 Hz.					
Minimum charge of PD(pC)	the minimum PD magnitude is approximately Constant.					

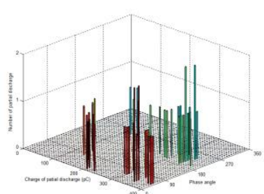
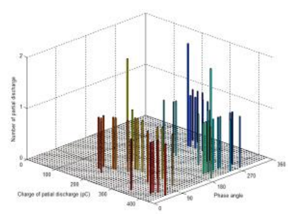
Figure. 5 Show the behaviour of PD within cavity as function of frequency at 9KV voltage applied. obviously the number of PD from 0.1Hz to 50Hz increased with the increasing of the frequency voltage applied, hence the highest value at 50Hz then dropped at 100Hz, and the maximum charge similar behaviour with Number of PD but there were no drops at 100Hz so the highest value happened at frequency 100Hz, while the mean charge rise with the increasing of frequency until 10Hz then drops to lower value at 50Hz.However range of spread PD exceed 90^o for positive PDs and 270^o for negative. The influence of a frequency at 9KV voltage applied on insulation described in table 4.

a. (100) Hz **b. (50) Hz**

c. (10) Hz **d. (1) Hz**

e. (0.1) Hz **f. (0.01) Hz**

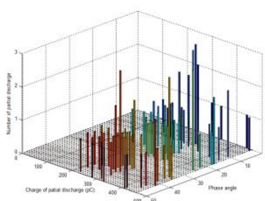
Fig. 5 The simulation result at 9 kV and frequency from 100 Hz (a) to 0.01 Hz (f), at insulation cavity 4 mm.

Table 4 The simulation results as a function of frequency of 9 KV, 4mm applied voltage.

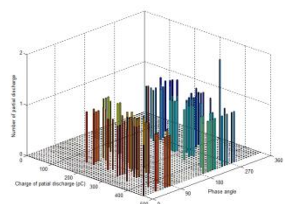
Frequency (Hz)	100	50	10	1	0.1	0.01
Number of PD per cycle	5.54	5.82	4.7	3.82	2.02	2.1
Maximum charge of PD(pC)	640.4	505.8	498.4	428.3	395.4	425.6
Mean charge of PD	243.7	238.7	310.4	292.2	276.5	263.6
Minimum charge of PD(pC)	188.6	189.4	250.6	191.7	155.3	168.3
Number of PD (positive charge)	138	145	117	95	50	52
Number of PD (negative charge)	139	146	118	96	51	53

Figure. 6 Show the effectiveness of the frequency on the partial discharge at voltage applied 10 KV with frequency

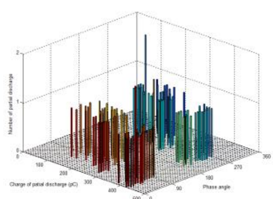
range (0.01-100) Hz. The behaviour of partial discharges affected by frequency of voltage applied, when the frequency increased the number of PDs per cycle increased and mean charge of PD increased. from table 5, the lowest number of PDs per cycle at frequency of 0.1Hz while the highest value at 100Hz, while the maximum magnitude of mean charge of PDs at 1Hz and minimum magnitude at 0.01Hz.The amplitude of mean charge increased with the increasing of frequencies until 1Hz then the magnitude of mean charges decreased with the increasing of frequencies.



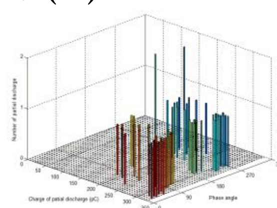
a. (100) Hz



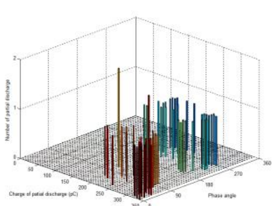
b. (50) Hz



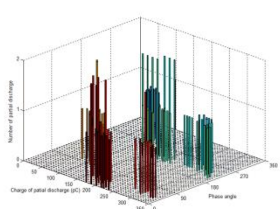
c. (10) Hz



d. (1Hz)



e. (0.1) Hz



f. (0.01) Hz

Fig. 6 The simulation result at 10 kV and frequency from 100 Hz (a) to 0.01 Hz (f), at insulation cavity 4 mm.

Table 5 The simulation Results as a Function of Frequency of 10 KV, 4mm Applied Voltage.

Frequency (Hz)	100	50	10	1	0.1	0.01
Number of PD per cycle	6.7	6.18	5.32	3.2	2.22	2.5
Maximum charge of PD(pC)	445.1	470.4	444.7	402.2	334.3	337.6
Mean charge of PD	231.2	245.6	261.4	269.2	250.2	227.5
Minimum charge of PD(pC)	168.3	145.3	158.2	163.5	175.8	80.8
Number of PD (positive charge)	167	154	133	80	55	62
Number of PD (negative charge)	168	155	133	80	56	63

The behaviour of partial discharge as function of frequency change with different voltage applied for the same size of cavity shown in fig (6, 8). The comparison of the number of Partial Discharges per cycle and the mean PD magnitude for alter applied voltage magnitude shown in fig 6, 7, 8, and 9. The effect of frequency on the behaviour of PD activity alters with the voltage applied. Obviously the number of partial discharge per cycle at 8 KV voltage applied slight change with increased frequency while the mean PD magnitude clearly change, it is increases with increasing frequency. In contrast, at the same range of frequency with increase voltage applied to 9 and 10 kV the effect of frequency on the number of PDs per cycle increase with increase the voltage applied while the effect of frequency on the mean Partial Discharge magnitude decrease with increase voltage applied.

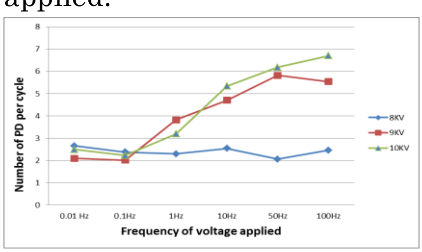


Fig. 6 Shown the simulation result of the behaviour of partial discharge as function of frequency at various voltages applied.

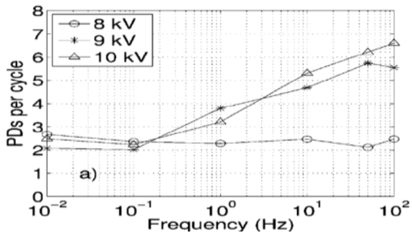


Fig. 7 Showed the experimental result of the behaviour of partial discharge as function of frequency at various voltages applied [20].

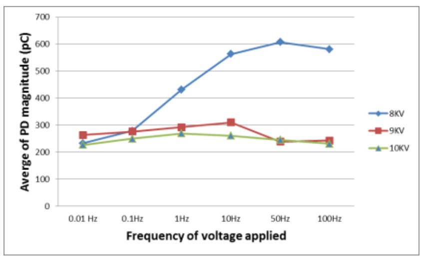


Fig. 8 Shown the simulation result of the behaviour of partial discharge as function of frequency at various voltages applied.

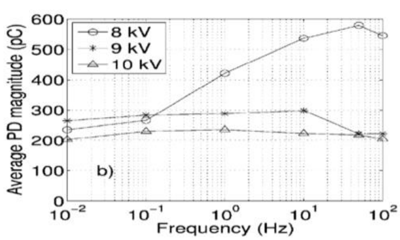


Fig. 9 Shown experimental result of the behaviour of partial discharge as function of frequency at various voltages applied [20].

Fig 10, 11, 12 Shows the charge magnitude of partial discharge against Phase angle for three Voltages throughout the first five cycles showing the pulses of PD distributed in cycle, on other hand The phase arrangement of positives and negatives partial discharges whereas the arrange of PDs more dependent on frequency of voltage applied.at 8KV the spread of PD increasing on y axis (charge magnitude) with increasing of the frequency while at 9KV and 10KV is approximately constant. That means when the voltage applied increased the distributed of PD decreased.in addition the distribution of PD on X axis (Phase angle) also affected by frequency and voltage applied.

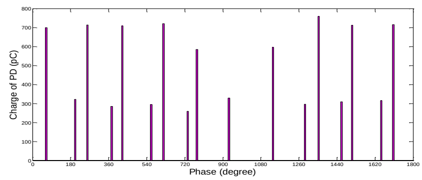


Fig. 10 PD charge magnitude against phase angle of 8KV the applied voltage and at 10Hz.

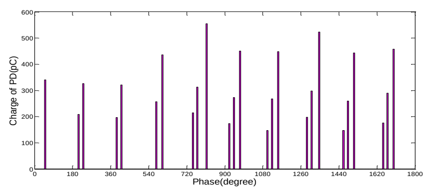


Fig. 11 PD charge magnitude against phase angle of 9KV the applied voltage and at 100Hz.

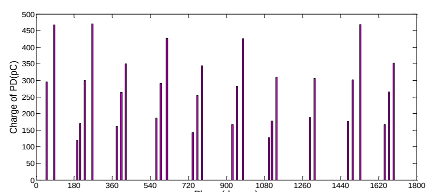
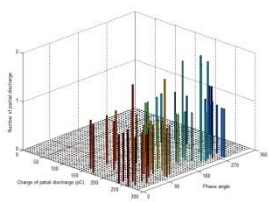


Fig. 12 PD charge magnitude against phase angle of 10KV the applied voltage and at 50Hz.

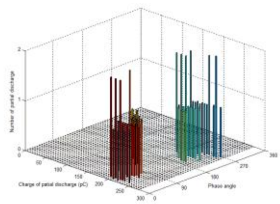
B. Void size

The behaviour of partial discharge depended on diameter of void, in this section the partial discharge simulated at 10KV voltage applied and frequency (100-0.01) Hz within 1.5mm diameter of cavity then compare with 4mm to describe influence of cavity size on partial discharge activity.

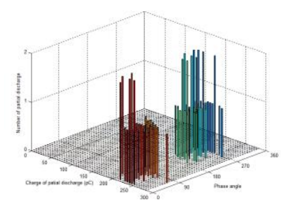
Figure 13 Shown the behaviour of partial discharge at 10KV for 1.5mm cavity diameter. The number of PD per cycle and mean charge of partial discharge is approximately constant when the frequency of voltage applied changed. From table 6, all the number of PDs per cycle for frequency is 2 PD per cycle except at 1Hz the number of PD drop to 1.72, while the mean charge of PD slightly increase with increased frequency.



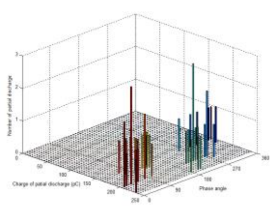
a. (100Hz)



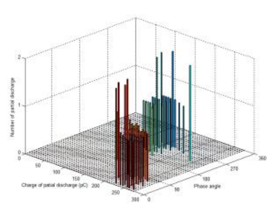
b. (50Hz)



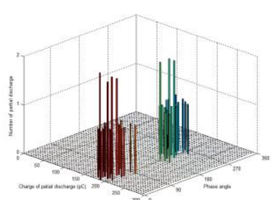
c. (10Hz)



d. (1Hz)



e. (0.1Hz)



f. (0.01Hz)

Fig. 13 The simulation result at 10 kV and frequency from 100 Hz (a) to 0.01 Hz (f), at insulation cavity 1.5 mm.

TABLE 6: The simulation results as a function of frequency of 10 KV, 1.5mm applied voltage.

Frequency (Hz)	100	50	10	1	0.1	0.01
Number of PD per cycle	2.02	2.02	2.06	1.72	2.02	1.94
Maximum charge of PD(pC)	287.6	278.8	269.1	245.4	280.3	225.1
Mean charge of PD	206.2	210.6	201.3	203.4	198.5	185.3
Minimum charge of PD(pC)	160.1	161.8	164.3	165.4	148.9	153.3
Number of PD	50	50	51	43	50	48

(positive charge)						
Number of PD (negative charge)	51	51	52	43	51	49

Figure 14,15 Shown the comparison between 1.5mm and 4mm diameter of void at 10KV for (100-0.01)Hz frequency of voltage applied, Obviously the diameter affected on the partial discharge frequency dependence whereas the number of PDs for model has 1.5mm diameter of cavity is constant with increased frequency while for 4mm the number of PDs mightily increase with frequency. On other hand the mean charge of PDs for both diameters is similar behaviour with increased frequency.in addition the means charges of PDs magnitude of 4mm more than 1.5mm diameter at the same voltage and frequency.

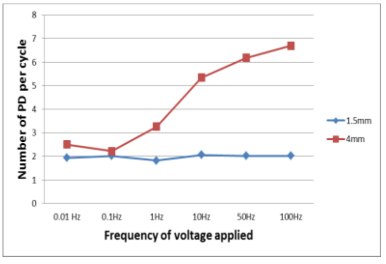


Fig. 14 showed the behaviour of partial discharge as function of frequency at various cavity sizes.

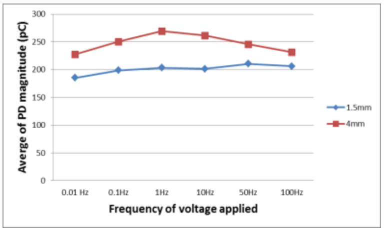


Fig. 15 Shown the behaviour of partial discharge as function of frequency at various cavity sizes.

6 CONCLUSION

The two-dimensional model describes PD action of disc-shaped void in polycarbonate.by using LIVELINK between COMSOL and MATLAB to enhancement finite element analysis to model partial discharge activity. The Partial discharge dynamic behaviour has been simulated as function of frequency for various voltage applied and two cavities size. By comparison between simulation and experimental results, acceptable results have been obtained. The simulations results show behaviour of PD activity in the void relies on the frequency of the applied voltage.

1. The effect of frequency dependence on number of PD per cycle increased when the voltage applied increase, while the mean charge decreased with increasing voltage applied.
2. The behaviors of partial discharge affected by frequency dependence decreased when reduce size of void especially on the number of partial discharge per cycle.
3. The spread of partial discharge at the same voltage applied expanding when the frequency increases and this effect reduced when the voltage increase.
4. The new combination between COMSOL and MATLAB LIVELINK enhanced the finite element analysis to model partial discharge and reduce the tolerance to 0.08% ±.

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