Analysis Study on Partial Discharge Magnitudes to the Parallel and Perpendicular Axis of a Cylindrical Cavity

Srinivasa D M[1], Harish B N[2], Harisha K S[3]

[1,2]*Assistant Professor, E&E Department, PESCE, Mandya, Karnataka, India.*
[3]*UG Student, E&E Department, PESCE, Mandya, Karnataka, India.*

Abstract — *The phenomenon of partial discharges (PDs) gives important information to the reliability of the high voltage power equipment. PDs occur in weaker regions like voids, cracks, and imperfections present inside the insulation. The partial Discharge(PD) is generally accepted as the predominant cause of long term degradation and failure of electrical insulation. Simulation environment is a significant approach towards the study of PD mechanism. In this paper, simulations of partial discharge with the cylindrical void whose axis parallel and perpendicular to the electric field was analysed. The parameters like PD magnitude, partial discharge inception voltage (PDIV)and apparent charge with respect to the geometric parameters of the void and also under different stress conditions. The relationship of PD magnitude with respect to the axes of the cavity in the direction of the electric field has been compared.*

Keyword—Partial Discharges, Solid Insulation, Cylindrical Void, Apparent Charge.

INTRODUCTION

Nowadays electric utilities are facing major problems due to the ageing and deterioration of the high voltage power equipment in their operating service period. There are the several solid materials are used in high voltage power system equipment for insulation purpose. The insulators are used in the high voltage power equipment always have a small amount of impurity inside it. In most cases the impurity in the form of the void which creates a weak zone inside the insulator. This void is the reason for the occurrence of partial discharge in high voltage power equipment while sustaining the high voltage. Deterioration is mainly due to the presence of partial discharge in such insulator used in high voltage power equipment. The presence of partial discharge for a long period of time also causes the insulation failure of high voltage equipment. Therefore, partial discharge detection and measurement is necessary for prediction and reliable operation of insulation in high voltage power equipment. This work aims to study the detection of partial discharge in solid dielectric by simulation and modelling purposes. A solid dielectric with small impurity under high voltage stress creates source of partial discharge. The generated partial discharge is continuously detected and analysed using MATLAB Simulink software. Simulation of real time detection and analysis of partial discharge is proposed which gives the real time visualization of partial discharge produced.

PARTIAL DISCHARGE: *Partial discharge is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor [1].*

III.MEASUREMENT OF PARTIAL DISCHARGES

A cylindrical void within the solid dielectric ie epoxy resin is considered. The void with a 6mm diameter and 6mm height is placed inside the insulation sample of dimension 38mm x 38mm x 7.5mm as represented in the Table I.

DIMENSION OF VOID MODEL WITH SOLID SAMPLE

Insulation Sample (Rectangular Solid)			Cylindrical Void	
Length (a)	Width (b)	Height (c)	Radius (r)	Height (h)
38mm	38mm	7.5mm	3mm	6mm

Table-1

Sample preparation: An insulator of type epoxy resin with void inside is with dimensions 78mm, 78mm and 7.5mm. The cylindrical void having dimensions of 3mm radius and 6mm height as the electrical circuit model consists of three capacitors C_a, C_b and C_c values of these capacitors are calculated by following equations.

$$C_a = \frac{\varepsilon_0 \times \epsilon_r \times (a - 2r) \times b}{c}$$

$$C_b = \frac{\varepsilon_0 \times \epsilon_r \times r^2 \times \pi}{c - h}$$

$$C_c = \frac{\varepsilon_0 \times r^2 \times \pi}{h} \qquad [3]$$

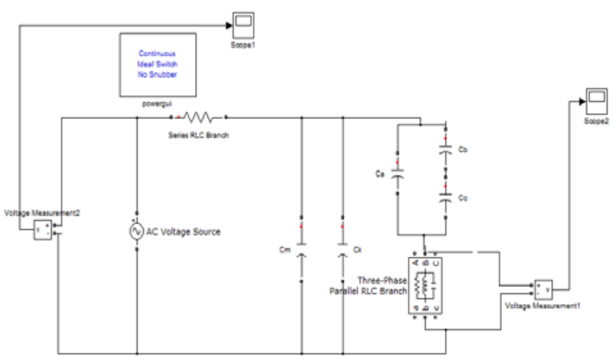

Fig 1: Model of a cylindrical void within a solid insulation shows its axis parallel to the applied electric field

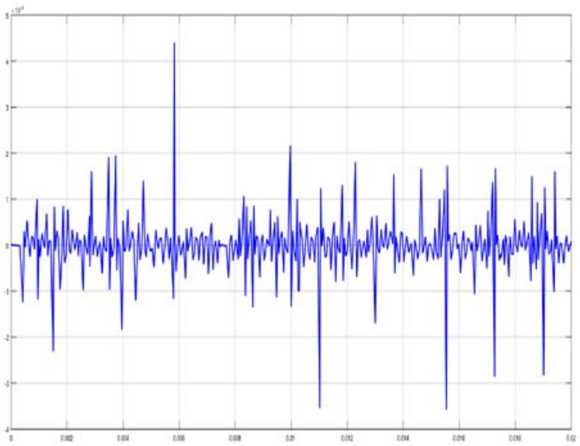

Fig2: Model of a cylindrical void within a solid insulation shows its axis perpendicular to the applied electric field.

Simulation Model of Experimental setup:

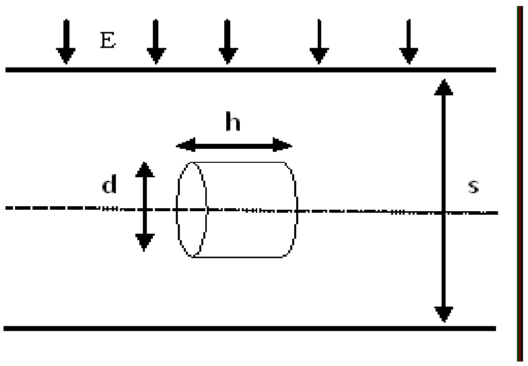

Fig 3: Experimental Simulation Circuit.

These value are required for measurement of partial discharge pulses. Here, an equivalent circuit of solid insulator having a cubical void is taken to evaluate the partial discharge pulses. In this insulator the void is present at the centre of the insulation medium. The value of three capacitors shown in the electrical circuit model is calculated and generally, (Ca>>C_b>>Cc). The figure 3 shows the SIMULINK model which is used for the detection of partial discharge.

In the circuit model the capacitance C_c corresponds to the cylindrical void present inside the solid insulation, C_b corresponds to the capacitance of the remaining series insulation with void (C_c) and C_a corresponds to the capacitance of the remaining discharge-free insulation of the rest of the solid insulator. As the circuit is energized with ac voltage, PD pulses can be observed across the measuring instrument (MI). Capacitance of the void Cc is charged which is responsible for occurrence of PD.

Table2: Parameters used for simulation

Sl No	Parameter	Symbol	Value	D
1	HV measuring capacitor	Cm	1000	pF
2	Coupling capacitor	Ck	1000	pF
3	Permittivity	ε_o	8.85X 10^{-12}	F/m
4	Relative permittivity	ε_r	3.5	-
5	Resistance	R	50	Ω
6	Inductance	L	0.60	mH
7	Capacitance	C	0.45	µF

Table 3: COMPUTED VALUES OF PACITANCES OF THE TEST SAMPLE WITH VOID

Model	$C_a(F/m^2)$	$C_b(F/m^2)$	$C_c(F/m^2)$
Void axis parallel to E	5.02 x 10^{-12}	5.84 x 10-13	4.17 x 10-14
Void axis perpendicular to E	3.77 x 10-12	2.19 x 10-13	

RESULT AND DISCUSSIONS:

Fig 4: Observed PD pulse at 8kV

Above figure shows the observed PD when a high voltage of 8kV is applied across the test object. It is observed that between time period 0.028 to 0.03 sec, the amplitude of PD pulse corresponds to 4.96µv.

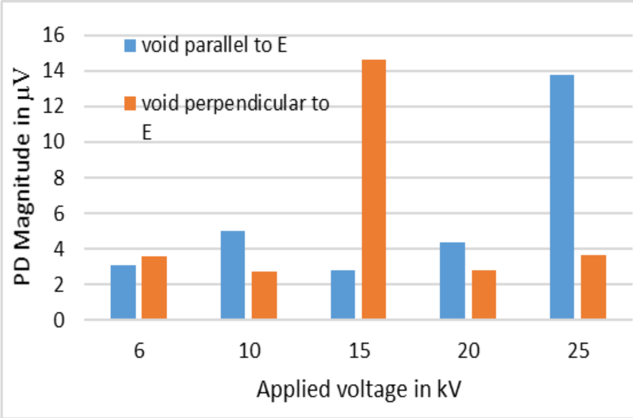

Fig.5: Comparison of PD magnitudes with different applied voltage for the model shown in Fig 1 and Fig 2.

An increasing voltage of 6-25kV is applied across the solid insulation to observe the maximum amplitude PD pulses. A high voltage source between 6 kV and 25 kV has been applied across the sample insulation to learn the PD characteristics. Fig.4. shows the variation of the PD pulse magnitude occurring inside the void of solid insulation for the applied voltage of 8 kV. Maximum PD pulse magnitude has been extracted for the range of applied voltage mentioned. Fig.5. represents the maximum PD magnitude for the various applied voltages for the different void axes. There is an increase in the magnitude of PD pulse with the increase in the applied voltage. The comparison of the PD magnitude for the various applied voltages is depicted in the Fig.5 for the void model represented in the Fig. 1. & Fig. 2.

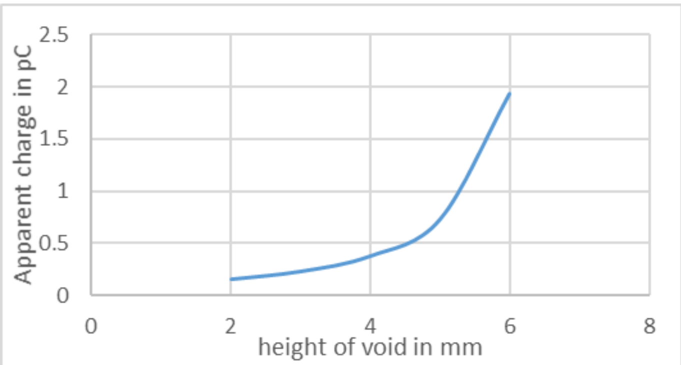

Fig. 6: Variation of apparent charge with height of the void

Fig.6 shows the curve obtained is linear one. Increase in value of thickness of the void will increase the PDIV with a constant pressure value. The apparent charge for an air filled cavity is computed using the equation (4) and its variation with the height and radius of the void was shown in the Fig.6 & 7 respectively. The number of voids with different geometric shapes present within the solid dielectrics cause high stress concentration. 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 cylindrical void Cc is given by $Vc=Va\times CbCa+Cb$ [3] The apparent charge transferred is calculated by $Q=Ca\times Vc$ [3] --------(4)

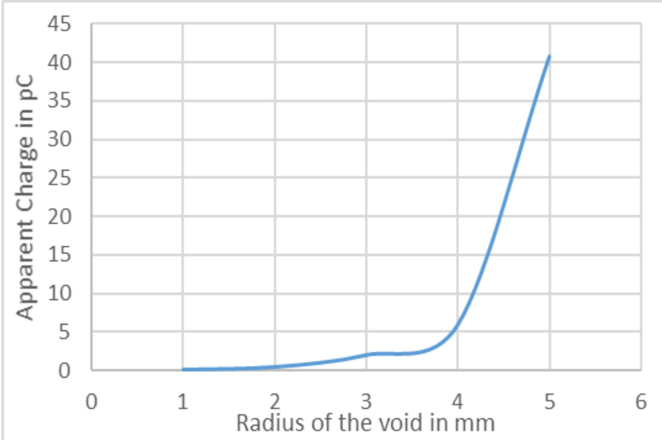

Fig. 7: Variation of apparent charge with radius of the void

It is also observed that as varying the radius of the cylindrical void the apparent charge is also increases as calculated using formula (4).

The partial discharge pulses are analysed by dividing single applied sinusoidal cycle of 50 Hz into eight equal parts. Each part has 45^0 phase angle interval. The number of PD pulses for each interval is plotted for different applied voltages. Figure 8 shows graph for number of PD pulses v/s different phase angle for applied voltage of 8kV and different void axes. It is observed that number of PD's with axis parallel to applied voltage is more as compared to void axis with perpendicular to applied voltage. The partial discharge phenomenon is random in nature so the number of PD pulses is not constant for every cycle.

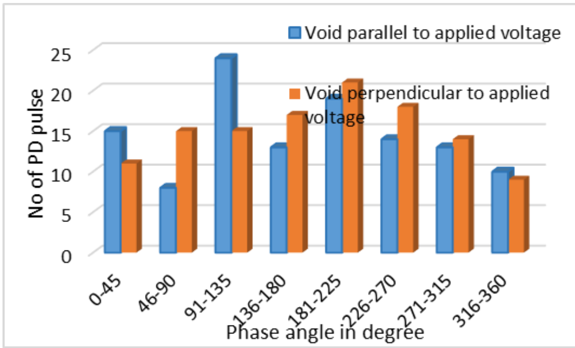

Fig 8: Number of PD pulse for different phase angles

CONCLUSION

PD model and its simulation help to describe the behaviour of PDs inside the solid insulation. The PD model involves various parameters to evaluate the magnitude of discharges. This paper explains the shape of cylindrical void and its behaviour with the variation in the applied voltage. It has understood that the PD magnitude is high for the higher value of the applied voltage for the void axis perpendicular to the applied electric field. This comparison enables the assessment and assurance of the quality of the insulation. This simulated study also depicts the role of void axis with its relationship on PD magnitudes. Better understanding of PD mechanism will avoid the failure and defects of the solid insulation. Hence the life expectancy, reliability and integrity of the high voltage equipment will be ensured.

REFERENCES

[1] E. Kuffel, W. S. Zaengl and J. Kuffel, High Voltage engineering: fundamentals, second ed., Eleslever, 2005.

[2] M. S. Naidu and V. Kamraju, High Voltage Engineering, New Delhi: Tata McGraw- Hill, 2004, pp. 69-85.

[3] S. Karmakar and A. Sabat, "International Journal on Electrical Engineering and Informatics," Simulation of Partial Discharge in High Voltage Power Equipment, vol. 3, nov. 2, 2011.

[4] Gallagher, T.J and Pearmain, A.J, High Voltage Measurement, Testing and Design, John Wiley and Sons, New York. (1983).

[5] F.H.Kreuger, Discharge Detection in High Voltage Equipment, Butterworths, London, 1989.

[6] J. J. Smit, E. Gulski, P. Bauer, P. Cicheki and J. Setyawan, Investigation of Partial Discharge Occurrence and Detectability in High Voltage Power Cable Accessories, Delft, 2009.

BIOGRAPHIES

D. M. Srinivasa completed engineering from BIET, Davangere and Master's degree from MCE, Hassan and presently perusing Ph.D. in university of Mysore, Mysore and working as Assistant professor in PESCE, Mandya, Karnataka, India from 2008

B. N.Harish completed engineering from KVGCE, Sullia and Master's degree from NIE, Mysore and presently perusing Ph.D. in university of Mysore, Mysore and working as Assistant professor in PESCE, Mandya, Karnataka, India from 2008

Harisha K S was born on 5th April, 1993. completed B.E degree in Electrical and Electronics Engineering in PESCE, Mandya, Karnataka, India