Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

EFFECTS OF SUPPLY VOLTAGE FREQUENCY ON PARTIAL DISCHARGE PATTERNS CONSIDERING DISCHARGE AREA

Dr. Prithwiraj Das

Department of Electrical Engineering, Govt. College of Engineering and Textile Technology, Berhampore, Murshidabad, West Bengal, India, pin-742101

Abstract-*Partial Discharge is a high frequency discharge phenomenon having a great deal of importance for electrical engineers, especially to those who are working with high voltages. Since last 20-30 yearsresearchershavebeenworkingonPDsimulation model and consequently different models on PD simulation have been proposed. However, there are areas in which the simulation model could be improved upon. In this paper, a model for Partial Discharge simulation is developed usingFiniteDifferenceMethod(FDM).Thismodeltakesintoaccount not only criticalfieldintensityofPDoccurrence(E_C) andresidualfield intensity(E_r) but also criticalfieldintensityfordischargepropagationalongthevoidsurface(E_S) considering occurrence of partial discharge, extinction of PD and propagation of PD along void surface to be stochastic in nature. In this paper, a Plane-Planeelectrodesystem is considered and the void is chosen asrectangularparallelepiped. The novelty of this paper is to show how discharge areas affect the PD patterns with the change of supply voltage frequency.*

Key words— *Partial Discharge Simulation, Stochastic Parameters, Discharge area, Supply voltage frequency and Phase Resolved plot*

I. INTRODUCTION

Electricaldischargesthatdonotcompletelybridgethedistancebetweentwoelectrodesare knownaspartialdischarges.Animportantreasonforoccurrenceofpartialdischargeswithin solid insulatoris the presence of gaseous voids, which act as weak parts of an insulator and initiatesPartialDischarge (PD). Such discharges deposit free charges on the void surface. Dependingupon thepolarityof theappliedfield,the electric field produced by these free surface charges eitherinhibitorpromotefurtherdischarges. PD causes degradation of insulating material[1,4],whichinturnchangestheconductivityof thevoidsurface.Theeffectof such changesonphaseresolvedplotshavebeenpresented in [11]. PD patterns have been observed to beturtlelike[3]andwing-like(ortriangle-like)forelectricaltrees[5-6].TheshapeofPDpatternsalso changewithmaterialaging[7-8].Theturtle-likepatternwas foundconsideringtheeffectoftimelagofPD[3]. ThePDbehaviorinanartificialsinglechannelwasstudiedin [9]toshowthegrowthoftree along the channel. Partial discharges within voids under square voltages were also reported in [12]. Effect of discharge area on PD patterns was discussed in [13]. Influence of high voltage harmonics on PD patterns were studied by the authors of [15].

TostudyPDmechanism,itisessentialto accuratelycomputetheelectricfielddistribution withinthespecimen,whichisdonebyusingFDMinthiswork.Phaseresolvedplots**(**φ-q**)**havebeenobtainedat different supply frequencies and also for different values of critical field for discharge propagation.The changes in the shape of PD pattern(shapeofphaseresolvedplot)andthe amount of charge released during PD with the change supply frequency considering variable discharge area are studied indetailsinthiswork.Aturtle-likePDpattern with periodicity is obtained in which stochastic variation of the PD magnitude is reflected.

II. CHARGE DISTRIBUTION DUE TO PD AND CONCEPT OF DISCHARGE AREA

As per [13], [16] & [17], charge released during PD depends on electric field intensity acrossthetwooppositevoidsurfaces(E) at the time of discharge,residualfieldintensity(E_r) and dischargearea(A). The part of void surface area where the discharge channel can propagate at the time of partial dischargeoccurrenceiscalleddischargearea.Thesurfacearea of thevoidplays an important role in the determination of dischargearea.Ifthesurfacearea islarge,theprobabilityofdischargeareabeinglargeisalso high.Foraparticularvoidsurfacearea if the magnitudeof $E_S$is low, the dischargechannelcan cover larger area on the void surface. Thus the effective value of A (discharge area) increases causing higher instantaneous charge release during PD.

@IJAERD-2018, All rights Reserved

III. FDM BASED PD MODELING AND SIMULATED MODEL

The model for PD simulation has been developed using FDM. The corresponding equations and boundary conditions are taken from [13-17]. After computing electric potential using those equations, electric field intensity has been calculated across and along the void surface. In this work, a rectangular parallelepipedvoid has been considered to be placed insidearectangularparallelepiped insulator with Plane-Plane electrode arrangement.Fig.1 shows theelectrode-insulator-voidconfigurationused in this simulation. The mesh used in the simulationisathreedimensionaloneofsize(60×60×10) units. The electrode separation is taken as10units.Oneunitinthemeshcorrespondsto0.2 mm.Thevoiddimension is (10×10×2)units.Relativepermittivity(ε_{r1})ofthedielectricistakenas 4.Thepeak value of the power frequency sinusoidal applied voltage is 20kV.

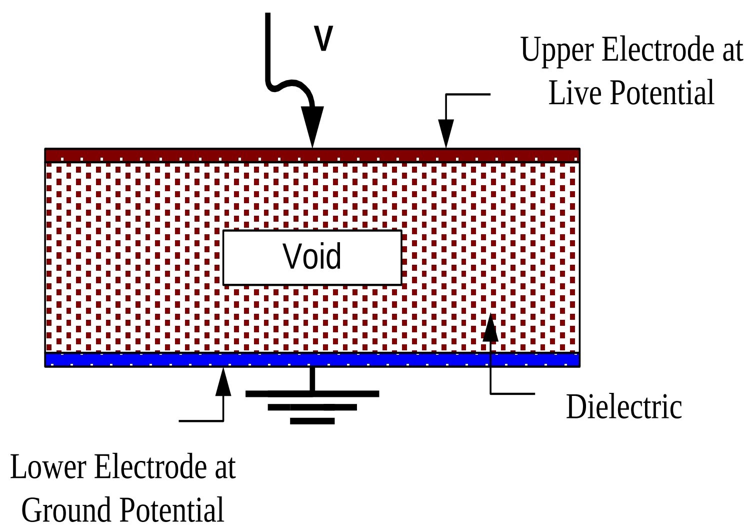

Figure 1. Electrode-insulatorconfigurations consideredforPDsimulation

IV. INTRODUCTION OF STOCHASTIC PROPERTIES TO THE MODEL

The stochastic features of PD occurrence and extinction have been introduced to this model by few equations mentioned in [18], where probability of PD occurrence has been considered to be a sigmoid function of over voltage across the void surface. The nature of the sigmoid function can be controlled by two parameters K_{sig} *and* K. In this work the values of those two parameters have been considered to be 100 and 1.5 respectively. The stochastic nature of discharge propagation along the void surface is introduced in this model by Eqn. 1. Once the conditions for discharge are satisfied, a discharge channel initiates from one surface of the void and moves towards the opposite surface of the void in the direction of the applied field. After reaching the opposite surface of the void, it is assumed that, the discharge channel can propagate along the void surface in any direction according to the field at those directions. This process is assumed to be instantaneous and the propagation of the discharge channel along the void surface is restricted by the parameter E_s (critical field intensity for discharge propagation along the void surface). In this work, E_s is the magnitude of the electric field in the directions normal to the applied field along the void surface, above which discharge can propagate along the void surface. This propagation of the discharge channel along the void surface is also assumed to be probabilistic in nature. The probability of discharge propagation along the void surface between any node (x,y,z) and (x+1,y,z) is given by Eqn.1, where $E_{x+1,y,z}$ is the field between the nodes (x, y, z) and (x+1,y,z), and $p_s(E)$ is the probability of discharge propagation between these two nodes. The value of x and y in this equation varies within the perimeter of the top and bottom surface of the void. This equation is valid only when field intensities in all the four directions are greater than E_s. Fig.2 shows how discretisation of the total dielectric material has been done to develop FDM equations. Apart from the direction in which this probability has to be calculated, if the field intensities in any one or more of the remaining three directions are less than E_s, then those field intensity termsshould be assumed to be zero in the denominator of the Eqn.1. From the expression it is evident that for a particular value of E_s, the probability of discharge to propagate along any direction along the void surface is high when the field in that direction is much higher than E_s compared to that in all other directions. In other words, when the value of E_s is much below the magnitude of field intensity along the void surface then $p_s(E)$ becomes high and therefore majority of the discharges can

@IJAERD-2018, All rights Reserved

propagate far away from the discharge site causing release of charge of comparatively higher amplitude. It is just the opposite when E_s is close to the value of field intensity along the void surface. For any moderate value of E_s, some of the discharge channels can propagate and some are not, therefore during such discharges smaller to moderate amount of charges are released. In other words, larger variation in the released charge magnitudes is possible during such discharges.

$$p_S(E) = \frac{\left(E_{x+1,y,z} - E_S\right)}{\left(E_{x+1,y,z} + E_{x-1,y,z} + E_{x,y+1,z} + E_{x,y-1,z}\right)} \quad (1)$$

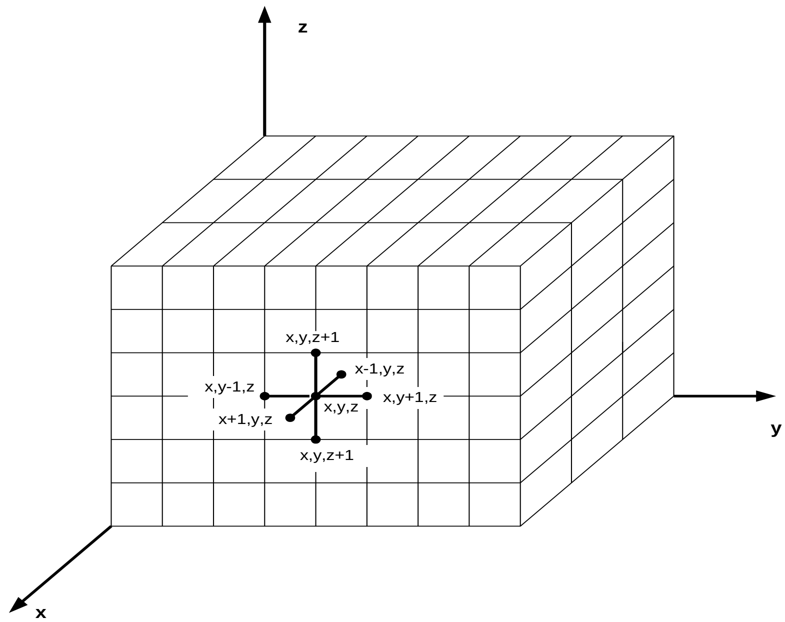

Figure 2. Discretisation of the total dielectric material into three dimensional meshes

IV. ANALYSIS OF SIMULATED RESULTS

The time period corresponding to 50 Hz frequency of the applied sinusoidal voltage is divided into 2000 discretetimeintervals. Resultsin theformofphaseresolvedplots(φ-q)havebeenobtained,whichshowtheeffects ofE_s and supplyfrequencyonPDpatterns.

Theeffectofdifferentvaluesof$E_S$can be observedfrom Fig.3-6. The corresponding variation in the average number of dischargetakingplaceper half cycle is presented in Table 1, where average number ofdischargeperhalfcycleisequaltototalnumberofdischargeinahalfcycledividedby 180degree.WiththedecreaseinthevalueofE_S, dischargecanpropagatefarawayfromthe dischargechannelalongthevoid surface, which would increase the discharge area. Conversely,with theincreaseinthevalueofE_S, theprobabilityofdischargepropagationalongthesurfaceofthe void decreasesand hencethe averagenumber of discharge per half cycle increases. That is why withincreaseofE_S, thedensenessofthephaseresolvedplots increasesand themagnitudeof releasedchargepulsesdecreases,whichcanalsobeobservedfrom thephaseresolvedplotsin Fig.3-6.AllthosephaseresolvedplotsobtainedbyvaryingE_S arealmostliketurtleand closely resemble the experimental results of [3],[8] & [11] in terms of shape of PD pattern. The phaseresolvedplotinFig.5 & 6,whichshow comparativelylesseramountofinstantaneousreleasedcharge magnitudecomparedtothatinFig.3&4, whichisalmostidenticaltothephase resolvedobtained by the authors of [8], which is referred as swarming pulsive micro discharge (SPMD).From the density of the points on the phase resolved plots, itmaybeobserved that fora particularsizeofvoidthenumberofdischargeincreasesand releasedchargemagnitude decreaseswithincreaseofE_S. Consequently,thetimelagbetween two consecutive discharges decreasesandasaresultaveragenumberofdischargeoverhalfcycleincreases,whichmayalso be observed fromTable 1.

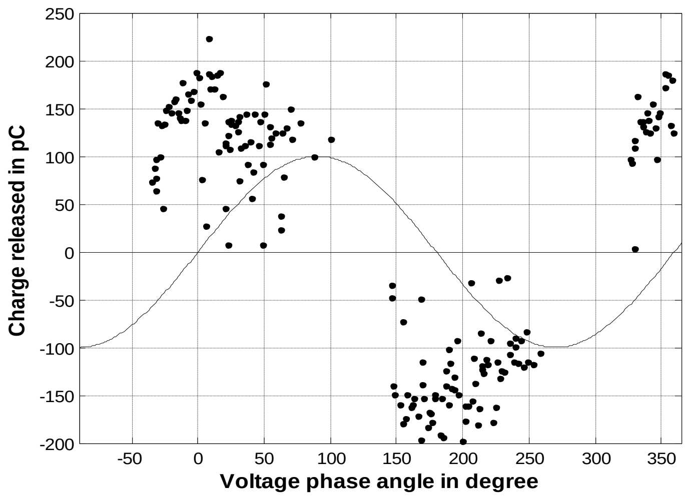

Figure 3. Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=0.1kV/mm andrelative permittivity: ε_{r1}=4andappliedvoltage20kVpeak.

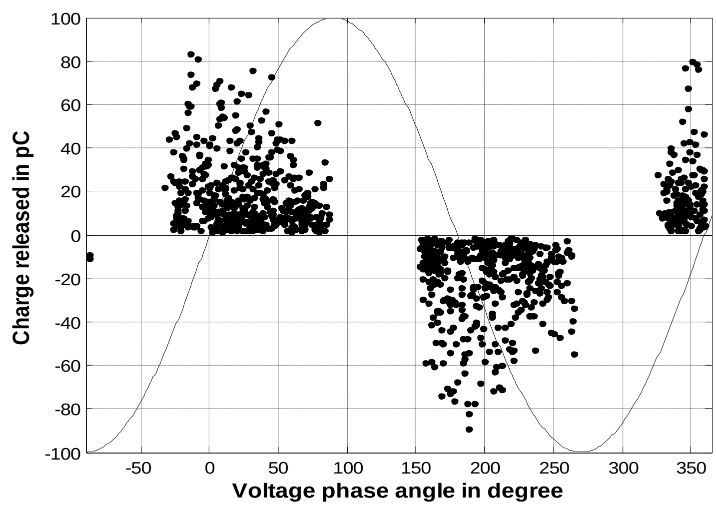

Figure 4. Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=0.5kV/mm andrelative permittivity: ε_{r1}=4andappliedvoltage20kVpeak.

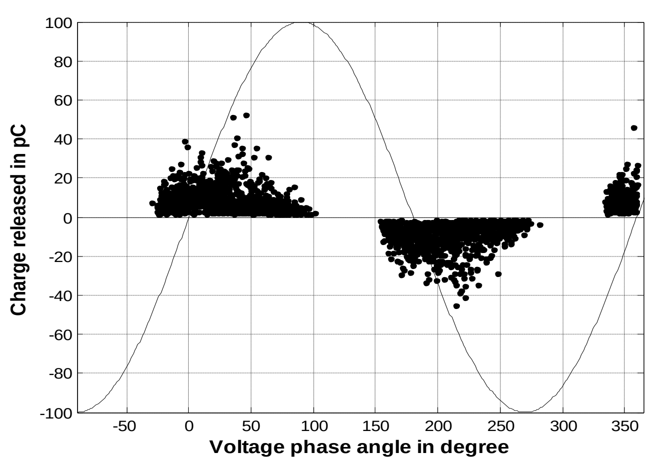

Figure 5.Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=1kV/mm,relative permittivity:

@IJAERD-2018, All rights Reserved

ε_{r1}=4andappliedvoltage20kVpeak.

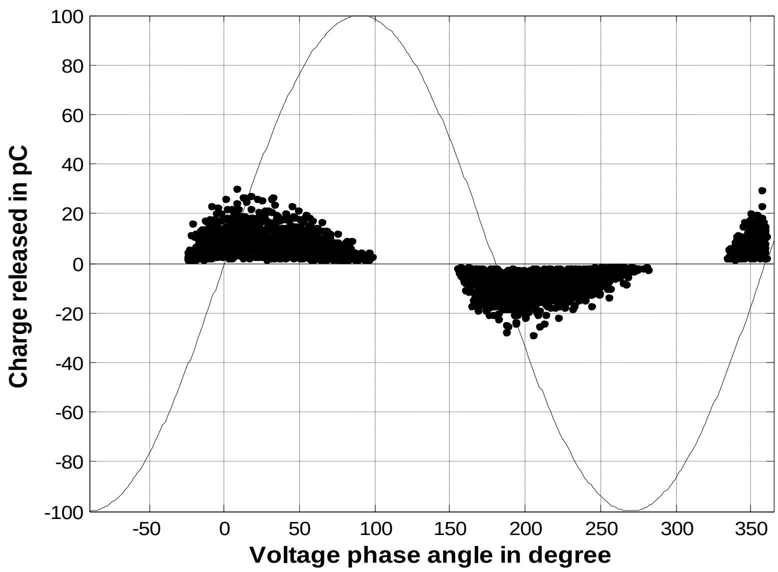

***Figure 6.**Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=2kV/mm,relative permittivity: ε_{r1}=4andappliedvoltage20kVpeak.*

***Table 1.** Averagenumberofdischargevs.critical fieldintensityfordischargepropagationalongthevoid surface(E_S)with relativepermittivity:ε_{r1}=4*

$E_S$in kV/mm	Averagenumber ofdischargeper half cycle
0.5	3.38
0.6	4.46
0.70	4.70
0.80	5.20
0.90	5.41
1.0	5.41

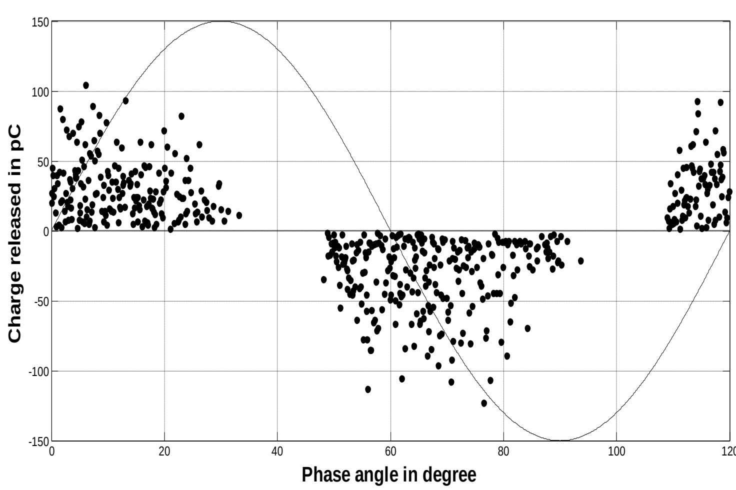

***Figure 7.**Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=0.5 kV/mm,relative permittivity:*

ε_{r1}=4andappliedvoltage20kVpeak, supply frequency 150 Hz.

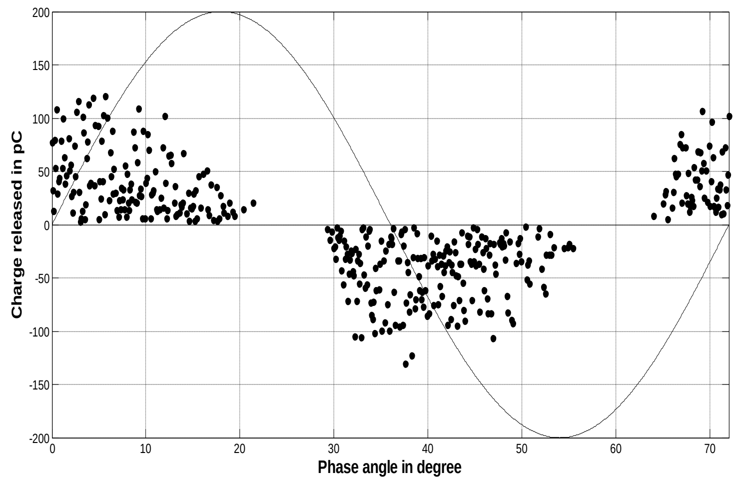

Figure 8.Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=0.5 kV/mm,relative permittivity: ε_{r1}=4andappliedvoltage20kVpeak, supply frequency 250 Hz.

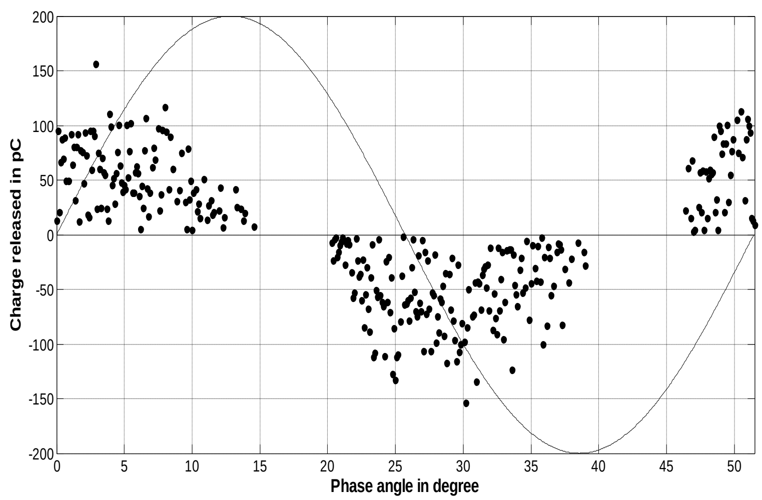

Figure 9.Phaseresolvedplotforvoiddimension(10×10×2)units,E_S=0.5 kV/mm,relative permittivity: ε_{r1}=4andappliedvoltage20kVpeak, supply frequency 350 Hz.

Theeffectsofsupply frequencyonPDpatterns are studied by setting the supply frequency 150,250&350Hz, respectively, keeping thesupplyvoltagemagnitude same.Phase resolved plot at those frequencies are shown in Fig.7-9. Fromthesethree figures,itmaybeobservedthatwiththeincrease in supply frequency, number of pointson the phase resolved plot with higher magnitude increases and lower magnitude decreases with the increase in the supply frequency. With the increase in the supply frequency the slope of the voltage waveform increases, as a result, the probability of discharge at higher field intensity also increases. In other words, the difference between E_c and the actual field intensity at which discharge take place increases, which in turn increases the instantaneous magnitude of released charge.Apartfromthis,forhighfrequencysupply the field along the surface of the voidalsobecomeshighduringdischarge,whichenhances the magnitude of the discharge areaandasaresult,thereleasedchargemagnitudegetsincreased.As a consequence, the timelagbetweentwoconsecutivedischargesincreases,whichinturn reducesthedenseness ofthechargepulses. The simulation results presented in this paper for different supply frequencies tally with the results obtained by the previous researchers [12].

TheresultsofthepresentworkclearlyindicatetheeffectofdischargeareaonPDpatterns.Inthecaseofhighersupplyfrequencyasthe

@IJAERD-2018, All rights Reserved

dischargestakeplaceatacomparativelyhigherelectric field, the probability of those discharges tocovermoreareaonthevoidsurfaceisalso high,whichinturncausesreleaseofhigher magnitudes of charge during PD.

VI. CONCLUSIONS

ThisproposedFDM-basedmodeliscapableof simulatinginception,extinctionandshapeofPD patternsfordifferentsizesofvoidembeddedin dielectricmaterial. The effects of varying discharge area with supply frequency have been shown in this work.This work is restrictedtostreamerlikedischargeswiththeassumptionthattheconductivityofthevoid surfaceisnegligible.Thestochasticnatureof PD for streamer likedischargeis reflectedin simulationresults,whichtallycloselywiththeexperimentalresults of previous researchers.Futureaim is to develop this model to study the PD patterns for different types of voltage waveform considering the conductivity of the dielectric material of the void surface.

REFERENCES

[1] J. H. Mason "Discharges",IEEE Trans. on EI, Vol.13, pp.211- 238, 1978.

[2] R.J.Vanbrant,"StochasticPropertiesof PartialDischargePhenomena", IEEE Trans. On EI, Vol. 26, pp.902- 948, 1991.

[3] M.Hikita,K.Yamanda,A.NakamuraandT.Mizutani,"Measurementof PartialDischarges byComputerandAnalysisofPartialDischarge Distribution by Monte Carlo Method",IEEE Trans. on EI, Vol.25, No.3, pp.453- 468, 1990.

[4] F.GutfleischandL.Niemeyer,"MeasurementandSimulationofPDinEpoxyVoids", IEEETrans. Dielectr. & EI, Vol.2, No.5, pp.729-743, 1995.

[5] Suwarno,H.Ichikawa,Y.Suzuoki,T.Mizutani and K.Uchida, "A Model for Electrical TreeingDischargePolyethelene", International Symposium on Electrical Insulating Materials, Tokyo, Japan, pp.443-446, 1995.

[6] Suwarno, Y. Suzuoki,F. Komori and T. Mizutani, "Partial Discharge due to Electrical TreeinginPolymers:phase-resolvedandtime-sequenceobservationandanalysis", J. Phys. D: Appl. Phys. Vol.29, pp.2922-2931,1996.

[7] K.Wu,H.K.Xie,Y.SuzuokiandT.Mizutani,"TheEffectsofConductivityDistributionin Tree Channel on the Behavior of PD in Electrical Tree", ISEIM'98, pp.701-704, 1998.

[8]T. Ishida, M. Nagao, Y. Mizuno and K.Kosaki, "Swarming Pulsive Microdischarge CharacteristicsofInternalVoidSpecimen and Factors Affecting its Occurrence", Trans. IEE Japan, Vol.113-A, No.1, pp.43-51, 1993.

[9] K.Wu,H.K.Xie,Y.SuzuokiandT.Mizutani"A Novel PhysicalModelforPartial Discharge in Narrow chanels",IEEE Trans. On Dielectr. & EI, Vol.6, No.2, pp.181-190, 1999.

[10] KaiWu,TatsukiOkamotoandYasuoSuzuoki,"ASimulationModelforPDPatternsinVoidswith consideration of PD Discharge Areas", IEEE Conference on EI and Dielectric Phenomena, pp.649-652, 2000.

[11] KaiWu,YasuoSuzuoky,FumitakaKomori,TatsukiOkamoto,"ContributionofSurface conductivitytotheCurrentFormsofPartialDischargesinVoids",IEEETrans.onDielectr.& EI, Vol.12, No.6, pp.1116-1123, 2005.

[12]KaiWu,TatsukiOkamoto,YasuoSuzuoky, "Effects of Discharge Area and Surface ConductivityonPartialDischargeBehaviorinVoidsunderSquareVoltages", IEEETrans.on Dielectr. & EI, Vol.14, No.2, pp.461- 70, 2007.

[13].K. Wu and Y.Suzuoki, "Effects of Discharge Area on PD Patterns in Voids", IEEE Conference on EI and Dielectric Phenomena, pp.227-230, 1999.

[14] Kai Wu, Tatsuki Okamoto and Yasuo Suzuoki, "A Simulation Model for PD Patterns in Voids with consideration of PD Discharge Areas", IEEE Conference on EI and Dielectric Phenomena, pp.649-652,2000.

[15] P.Das and S. Chakravorti, "FDM Based Simulation of PD Patterns Due to Narrow Void Considering Stochastic Parameters",Proceedings of IEEE Power India Conference, New Delhi, India, 2006.

[16] P.Das, "Partial Discharge Simulation for Different Sizes of Void with Stochastic Parameters", Proceedings of MS-2007, Kolkata, India, 2007.

[17] M. Florkowski, "Influence of High Voltage Harmonics on Partial Discharge Patterns", Proceedings of the 5thInternational Conference on Properties and Applications of Dielectric Materials, pp.303-306, May25-27,1997.

[18]P.Das and S. Chakravorti, "Simulation of PD Patterns Due to a Narrow Void in Different E-Field distribution" Journal of Electrostatics, Vol. 68, issue 3, pp.218-226, 2010.