# Detection of Partial Discharge in High Voltage Power Equipment under Sinusoidal Applied Voltage

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*A thesis submitted in partial fulfillment of the requirements for the award of the degree of*

## Bachelor of Technology

by

**NEERAJ SETHI**

**(Roll No: 111EE0615)**

May-2015


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**Under the Guidance of**

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# National Institute Of Technology
# Rourkela

## CERTIFICATE

This is to certify that the thesis entitled, **"Detection of Partial Discharge in High Voltage Power Equipment under Sinusoidal Applied Voltage"** submitted by **Mr. Neeraj Sethi** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Electrical Engineering with specialization at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by her under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

**Prof. S. Karmakar**
Department of Electrical Engineering
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Date:
Place: **(Neeraj Sethi)**

# CONTENTS

# ABSTRACT

In high voltage (HV) electrical power system, for the protection of high voltage power equipment to protect incipient failure one require proper insulation. For the insulation solid, liquid and gaseous form materials are used. There is no ideal insulating Material in real life that is flawless, in actually, and contains impurities. The biggest affecting impurities in the insulating materials is the presence of air bubble and deeply undesirable for such type of bad insulation which makes a local weak zone inside the insulator. The High Voltage equipment insulation gradually degrades due to cumulative effect of electrical, chemical and thermal stress inside the insulator. Due to the degradation a high voltage stress creates which causes the weak zone inside the insulator. The partial discharge is the result of cumulative collection of all these phenomena. Finally the insulation properties of these materials is excessively degrades its quality. In this work a simulation model investigation of insulating material transformer oil has been finished. Transformer oil as a liquid insulator are taken for acknowledgement of real Pd action inside the insulators with the use of high voltage utilizing the point-plane electrode arrangement. Electrical equipment model of the insulation has been done using MATLAB SIMULINK with a cylindrical void which is impurity. In addition, the relationship between the induced charge and void parameter is discussed for cylindrical void.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| IEC standard | International Electro Techno Commission |
| PD | Partial Discharge |
| HV | High Voltage |
| MI | Measuring Instrument |
| PRPD | Phase Resolved Partial Discharge |
| DGA | Dissolve Gas Analysis |

# LIST OF SYMBOLS

| Symbols | Symbols Name |
|---|---|
| R | Radius related to void |
| D | Distance between the electrodes |
| H | Height related to void |
| $\varepsilon_0$ | Permittivity of free space |
| $\varepsilon_r$ | Relative permittivity of dielectric |
| $E_i$ | Inception voltage |
| $E_l$ | Limiting field related to ionization |
| V | Volume of cylindrical void |
| Q | Apparent charge |
| $C_k$ | Coupling capacitor |
| $C_t$ | Capacitance related to object to test propose |
| $C_c$ | Capacitance of void |
| $C_b$ | capacitance of the remaining series connected insulation with void ($C_c$) |
| $C_a$ | capacitance of the remaining discharge-free insulation of the rest of the Insulator |
| $R_m$ | Resistance of measuring system |

# LIST OF FIGURES

# CHAPTER-1

## INTRODUCTION

Introduction

Literature analysis

Motivation and objective

Organization

# Chapter-1

## INTRODUCTION

### 1.1. INTRODUCTION

The quality of insulation has a great deal in high voltage power engineering. Various types of materials are utilized and formed together for making insulation useful in HV devices. Insulation gets worse due to electro-mechanical stresses and strains by partial discharge. Some impure insulation forms causes a lot of ill effects. Cause of these unrequired substances air bubbles get formed and placed in the insulation region and this makes partial discharge visible. Insulation breakdown is manipulated responsibly by different engineers. In high voltage device partial discharge generally takes place in gaps that makes material good to worse conductors. Due to these problems partial discharge calculation and handling is necessary for foreseeing of insulation breakdown to get a long period performance of high voltage power equipment.

### 1.2 LITERATURE REVIEW

In the start of the previous era, where these high voltage devices or revolutions took place for power production supply system. Partial discharge have been known or understood as a danger for insulation [1-25]. In this present era a lot of experiments took place for further understanding and knowledge of various scientists gave different presentation about tacking it. [1-2]. One Author Van Brunt showed his thesis on the emphasis of memory effects in partial discharge in 1994 [2]. Paithankar and Mokashi founded a method for anomaly detection on mathematics in 1997 [4].

In the knowledge of various authors partial discharge is a haphazard process. It is a nonlinear and random system. Partial discharge identification and analysis method is for preventing high voltage devices from insulation failure and availability of partial discharge is the solo reason for insulation dielectric damage ad failure. They have showed their patents and created a small module of partial discharge of combined analysis mode with the help of common test programs like PSPICE, MATLAB SIMULINK. Some scientists designed a visible virtual design and showed a study of epoxy resin envelop only one ad two pits [6].

Numerous strategies have been proposed in the writing to gauge the amount of pollutants stored on an insulator surface, for example, estimation of proportionate salt deposit density, determination of nonsalable deposit thickness, and estimation of surface resistance [7 - 16]. Some tells that analysis and calculation of partial discharge on regard of the synthesis of partial discharges. Some showed virtual nonlinear analysis in real time design of transformer and PRPD analysis. Using a software called PDGold for identification of the $\varphi$-$q$-$n$ design. An author has created a real time control strategy by using ICT facilities enabled ORMPD [17 - 25].

## 1.3. MOTIVATION AND OBJECTIVE

The visibility of partial discharge is a danger sigh for the insulation breakdown in high voltage devices. As we know that the insulation devices management is a careful strategy, so the standard of insulation devices are crucial play in high voltage devices. We have understood that these are made without caring about about the soupcon of impurity in the core of insulators. The distance of insulator are of various types and structure in the production process only it known that generally hard insulator casings are less pure like air circular balloons which are created in the interior side of insulators in tiny places. The destruction of protection places is due to the availability of partial discharges. It is basically controlled and handled by easily placing though high power engineering works. Basically in the high voltage devices the protection casing hard insulator breakdown or damage place due to availability of some partial discharge in the deep core of pit samples. Due to its presence PD analysis and calculation is very important for successful handling and longevity of insulation in those devices.

The main objective of the thesis is

- To get relationship between the void which are the causes of appearance of PDs activities.
- To get the partial discharge functioning in the pit executed with the Transformer oil
- To get the detection of PD activity inside the Transformer oil in high voltage power Equipment

.

## 1.4 ORGANISATION

The whole work Chapter in five different domains including introduction are

**Chapter 1**: Basic understanding of the idea of the concerned work, it undertake all the things works ad review on partial discharge characteristics as well as manipulation of the Thesis.

**Chapter 2**: This defines some normal understanding of partial discharge like the importance ad identification of partial discharge in HV devices, its differentiation, and its management different factors responsible for the hard casing and its significance for PD calculation.

**Chapter 3**: This describes the mathematical representation of partial discharge in the core of hard insulating casing. We represent it by equivalent circuit representation of partial discharge by MATLAB/SIMULINK representation partial discharge calculation.

**Chapter 4**: In this chapter calculated analytical record of the PD and various representation developed by SIMULINK. This includes identification of partial discharge pulses, cyclic ratios of the calculated output found from the PD pulses, characteristics study on changing height and radius of void.

**Chapter 5**: Summary of the whole thesis chart, its future aspect and all the assembled works references.

# CHAPTER-2

## OVERVIEW OF PARTIAL DISCHARGE (PD)

Partial discharge (PD)

Requirement of detection of PD

Classification of PD

Effect of PD in insulating system

PD detection methods

Factors influencing the dielectric strength of insulator

Role of apparent charge

# Chapter-2

## Overview of Partial Discharge (PD)

### 2.1 PARTIAL DISCHARGE

According to IEC (International Electrotechnical Commission) Standard 60270, *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* [13]. As a rule partial discharges are the result of nearby electrical stress focus in protection or on the surface of insulation protection. Such electrical discharges are showed up as impulses i.e., different types of voltage drive and current impulse having spam of significantly less than 1sec [13].

### 2.2 REQUIREMENT OF DETECTION (PD)

Generally insulator are not in the true form or in totally pure form. Because of the availability of air particles, bubbles impurities are made inside the insulating case, this then makes the so called void region weak and the partial discharge got created. The main thing responsible for this is the dielectric constant which is less than its neighbor. It breaks down insulation casing in high voltage devices. Partial discharge queerly takes places voids. These discharge are also the reason for breakdown. Because of these, finally breakdown happens in the main insulation body. So partial discharge identification and analysis is very crucial for high voltage power supply.

Partial discharge begins with the pits or the pits encasing the hard insulation casing. The basic and most important element is the pit for partial discharge. These discharge shorten the path between them. It is also visible on the top of the various insulation substances. The visibility of PD inside the insulating substance is generally started inside the air occupies pits inside the dielectric. The sole objective for all of this is the stresses and strains of the various pits which is minimum and generally low than its neighbor. For these problems the electrical pressure across the pits is generally greater along its longitudinal path of dielectric. We have found that when voltage exceed inception voltage of the gas inside the pit, the partial discharge actually occurs than.

## 2.3. CLASSIFICATION OF PARTIAL DISCHARGE

One can divide Partial discharge into two parts

### (a) EXTERNAL PARTIAL DISCHARGE

External partial discharge happens in the exterior of the high voltage power components. Examples are overhead lines etc.

### (b) INTERNAL PARTIAL DISCHARGE

Inner PD happens in the inside of the entire body. The Partial discharge in the pit respects to different classes of partial discharge and essential in computing PD. PD can be figured by different routines as per the sorts. The basic standard of computation of PD is creation or use of distinctive manifestations of vitality like light and so forth framework .The discharge in void is having a place with such sort of partial discharge and fundamental for PD estimation framework .PD estimation framework gives the data about the properties of protecting material utilized as a part of high voltage power types of gear.

This specimen thing likewise includes diverse types of discharge, some of them are surface release, corona, cavity release [2, 13].

(i) ***Corona discharge****:* Corona discharge happens because of non-consistency of electric field on sharp sides of conductor related to HV. The insulation supplied for such sort of release is gas or air or liquid [2]. Such kind of discharge shows up for a long length of time around the bare conductor. They are not assaulting specifically to the insulating framework like inner and surface discharge. Just by the circuitous activity of ozone shaped by corona decays insulating materials utilized.

(ii) ***Surface discharge****:* Surface discharge happens on reaction of dielectric material, for example, gas/strong interface as ends over focused times the stress on material

.

This may happen in bushing, end of link, any point on insulator surface between terminals. The presence of such discharge relies on upon different variables, for example, as

- ✓ Permittivity of the dielectric material
- ✓ Voltage difference between conductors
- ✓ Properties of the insulation

(iii)**Treeing channel***:* High power fields are delivered in an insulating material at its sharp edges and it disintegrates the insulating material .That is in charge of generation of persistent partial discharge.

(iv)**Cavity discharge**: The cavities are by and large framed in solid or liquid insulating materials. The cavity is by and large loaded with gas or air. At the point when the gas in the pit is over focused on such discharges are occurring.

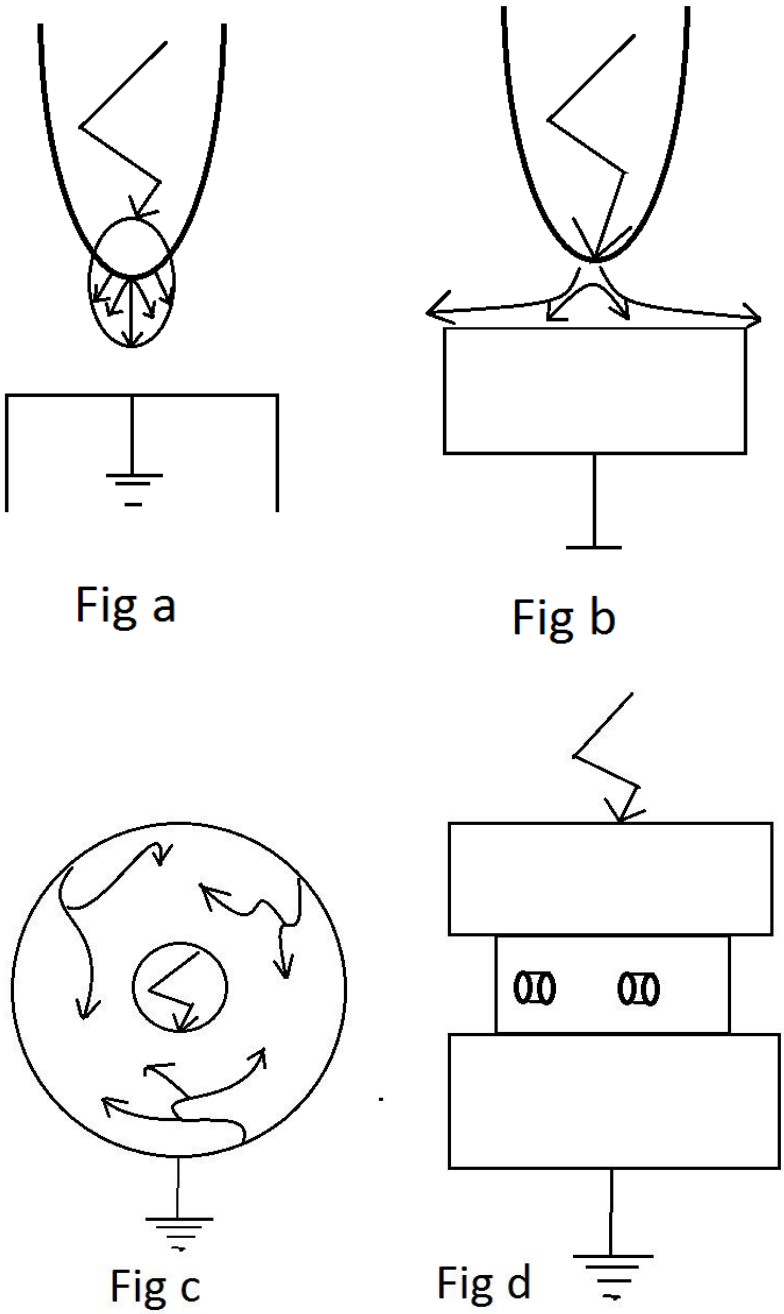



Figure 2.1. Types of partial Discharges (a) Corona Discharge (b) Surface Discharge (c) Treeing Channel (d) Cavity Discharge

## 2.4. EFFECT OF PD IN INSULATING SYSTEM

Presence of PD is the fundamental purpose behind debasement of insulating material and in charge of happening of electrical breakdown. The event of reiteration rate of discharge is the explanation behind mechanical degradation of the insulating material. The impact of release on high voltage power equipment is serious to the insulation framework. Insulation harm happens because of appearance of PD. The conductivity property of the insulation ascents because of substance changes in the dielectric. By and large insusceptibility of inorganic dielectrics is more. Porcelain, glass, mica are having a place with such dielectric. Polymer dielectrics are having a place with natural dielectrics.

By and large, PD creates vitality as warmth. Heat vitality is the fundamental purpose degradation of the protection. This impact is known as thermal impact on insulating materials utilized. For high voltage power supplies, the decay of the protection can be known by checking the PD exercises. PD movement ought to be checked time to time by the power engineer or power manager at the season of assembling.

## 2.5. PD DETECTION METHODS

There are different systems are investigated for the PD estimation in view of both electrical and non-electrical phenomena. The strategies which have been prominently known for PD measurement are,

(i) Optical detection method
(ii) Acoustic detection method
(iii) Chemical detection method
(iv) Electrical detection method

### 2.4.1. OPTICAL DETECTION METHOD

In optical detection system light is scattered as ionization, excitation process amid the presence of discharge. The outflow of light is subject to the insulating medium utilized and different parameters like temperature, pressure kind of insulating material is appropriate for this detection strategy. So some trouble emerges in the event of execution in high voltage transformers because of opaque nature of mineral oil.

### 2.4.2. ACOUSTIC DETECTION METHOD

In acoustic detection strategy, acoustic sensors are set outside of the HV hardware for discovery of PDs [10, 11]. The acoustic system is successful for seeing and encoding the acoustic Signal created amid a partial discharge occasion. Acoustic routines have numerous points of interest over different systems. Acoustic system is unaffected to electromagnetic interference (EMI), which can diminish the affectability of electrical strategies [11]. The constraint of this identification technique is the way of acoustic wave spread is confused because of the utilization of non-homogeneous gadget like high voltage transformer. This technique is broadly relevant for discovery of the different sorts of PD, discovering the area of insulation disappointment. The trouble emerges behind this strategy is necessity of sensitivity.

### 2.4.3. CHEMICAL DETECTION METHOD

In the chemical detection strategy, PDs are distinguished by watching the chemical changes in the arrangement of protecting material utilized as a part of HV force hardware. In this system, the dissolve gas analysis (DGA) and high performance liquid chromatography (HPLC) are broadly utilized for PD determination. DGA gives the data of discharge regarding the volume of gas created and HPLC measures the by items, for example, glucose and corrupted types of glucose delivered [10, 11]. Some downside emerges in this substance identification technique, for example, it doesn't give the data about the attributes of PDs and area of PDs.

.

### 2.4.4. ELECTRICAL DETECTION METHOD

Electrical recognition strategy is a standout amongst the most famous strategies in HV power system for PD estimation. In this work, electrical detection strategy has been utilized to reenact the estimation of PDs in the model using transformer oil as an insulator. It concentrates on appearance of the current and voltage pulse made by the current streamer in the impurities [10]. The beats are under one second and variety of recurrence segments in the scope of KHz, The state of the pulse and event of phase location inside the ac cycle gives the data about kind of PD and data about insulation failure. Time area recording gadget is utilized for perception of partial discharge driving forces in this process of detection. This strategy is insulating material for online electrical PD identification. Both broadband and narrow band electrical noise could be found amid the operation of HV equipment. It is not simple to independent those electrical noises and PDs. The defection which are gotten in this recognition technique rely on upon the geometry of high voltage transformer. This technique has a few downsides however has wide application in power plant which helps the power engineer by giving fundamental and critical data with respect to the characteristic, appearance of changed sorts of PD and about the event of insulation in high voltage power gear like transformer, link and so on.

## 2.6. FACTORS INFLUENCING THE DIELECTRIC STRENGTH OF INSULATING MATERIAL

The fundamental properties of the insulating materials utilized for high voltage power types of equipment are:

1. Insulation resistance ought to be high.
2. Dielectric strength ought to be high.
3. Should have effective mechanical properties.
4. Materials ought to be unaffected by other chemicals.

It is studied over that a few components or conditions make impact on dielectric quality of insulation. The dielectric quality of insulating material relies on temperature, impurities, and so forth and some different variables are likewise in charge of it.

### *A. TEMPERATURE*

The capacity of the insulation is reliant on the working temperature. Higher the temperature, the level of degradation ought to be high and lesser will be its life. The temperature has an impact on the dielectric quality of insulating material. It relies on the sorts of materials utilized as a part of the high voltage power supplies. One sample is desiring it is the impact of temperature in the dielectric quality of dielectric material utilized as a part of force supplies. The utilized dielectric medium utilized is transformer oil which is inhumane to the temperature. As the oil has lower BP, the dielectric quality of the material utilized abatements because of formation of vapor air bubbles. The temperature at which the force supplies work is in charge of degradation of insulating material utilized. The attributes of quality of the material utilized and temperature at which supplies work is inversely corresponding.

### *B. ELECTRODE AND GAP CONDITIONS*

Effective distance between electrodes makes high impact on partial discharge and thus influences material properties. The breakdown quality of oil relies on its width, terminal shape and material utilized for protection. The size and state of anodes are in charge of determination of the volume of medium related to high electric anxiety. Increment in volume builds the debasement content particles. More debasement particles substance brings down the breakdown voltage of the space between terminals.

### *C. IMPURITIES*

The vicinity of polluting influence will make an impact on insulating material which is utilized as a part of force supplies. The quality of dielectric liquid utilized as a part of high voltage transformer reductions to 70 % in view of the polluting influence substance like metal particle.

### *D .OTHER FACTORS*

The dielectric quality of protecting material which is utilized as a part of power supplies is influenced by different variables likewise i.e. thickness of the example and mugginess.

Thickness of the example is specifically relative to the dielectric quality of the insulating material and surface condition like dampness is contrarily corresponding to the dielectric quality of the material. It has been watched that

- Dielectric quality increments with the increment in thickness of the example.
- Dielectric quality reductions with the increment in moisture.

## 2.7. ROLE OF APPARENT CHARGE

Partial discharge is the sequences of dielectric breakdown of a little partition of a solid or a liquid electrical insulation framework which is due to high voltage stress. Partial discharge inside an insulating framework might possibly uncover any obvious releases as the release occasions have a tendency to have a more sporadic character. The impacts of discharge inside links and other high voltage hardware ought not to be dealt with gently as it can even prompt complete failure. PD is an electrical release that can conceivably bring about major issues amongst HV equipment. As the PD is not quantifiable specifically with the assistance of the apparent charge technique PDs are identified and measured in high voltage power hardware. The apparent charge is the vital amount of all PD estimation. The word clear was presented on the grounds that this charge is not equivalent to the measure of charge by regional standards included at the site of release or void [13]. As indicated by IEC standard 60270 (International electro techno Commission), the definition of Apparent charge is given by "Apparent charge q of a PD pulse is that unipolar charge which, if injected within a very short time between the terminals of the test object in a specified test circuit, would give the same reading on the measuring instrument as the PD current pulse itself. The apparent charge is usually expressed in Picocoulombs". The apparent charge can't be measured straightforwardly. To quantify apparent charge the measuring instrument obliges some adjustment. As the partial discharge is profoundly relies on upon the geometrical setup of the void vicinity. As the PD inside the power equipment is not specifically quantifiable due to the PD sources are not open. To conquer the above issue an apparent charge strategy is utilized for estimation of the PD movement.

# CHAPTER-3

## MATHEMATICAL MODELLING OF PARTIAL DISCHARGE

Analyzing of void parameter

Circuit model for PD measurement

Partial Discharge measurement system

Electrical circuit illustration for PD measurement

Simulink model description for detection for partial discharge

# Chapter-3

## Mathematical modeling of partial discharge

### 3.1. ANALYZING OF VOID PARAMETER

Void parameters are the important parameters for PD estimation. PD estimation furthermore rely on upon sorts of void used. Motivation of parameters are void height, void distance across over, and void volume. As showed by the [7], parameters are determined for reveal the relationship of void related parameter with power (apparent) concern of model base. Distance differentiating is taken 0.02 mt., height of the void varies from 0.002 - 0.008 mt. besides, scope of the void contrasts from 0.005-0.04 mt. Exchange tenets used for generation is represented as a piece of Table 1. All the estimations are shown in meter unit.

TABLE-1

**Void Model Parameters Consider for Partial Discharge Test**

| SL.No. | Parameter | Symbol | Value (Default) | Dimension |
|---|---|---|---|---|
| 1. | AC applied Voltage | V | 5 | kV |
| 2. | Relative dielectric permittivity | $\varepsilon_r$ | 2.2 | |
| 3. | Permittivity of free space | $\varepsilon_0$ | $8.854\times10^{-12}$ | F/m |
| 4. | Gap distance between electrode | D | 0.02 | M |
| 5. | Constant characteristic of Gas | B | 8.6 | $Pa^{0.5}\ m^{0.5}$ |
| 6. | Pressure | P | $10^5$ | $N/m^2$ |

## 3.2. CIRCUIT MODEL FOR PD MEASUREMENT

The behavior of internal releases at AC voltage can be deciphered using the most likely comprehended a-b-c structure which is exhibited in Fig. 3.1. Unmistakable models are used for partial discharge wonder which is differentiated data .The Pedersen model is manufactured to enhance Precision.

### A. Circuit Model

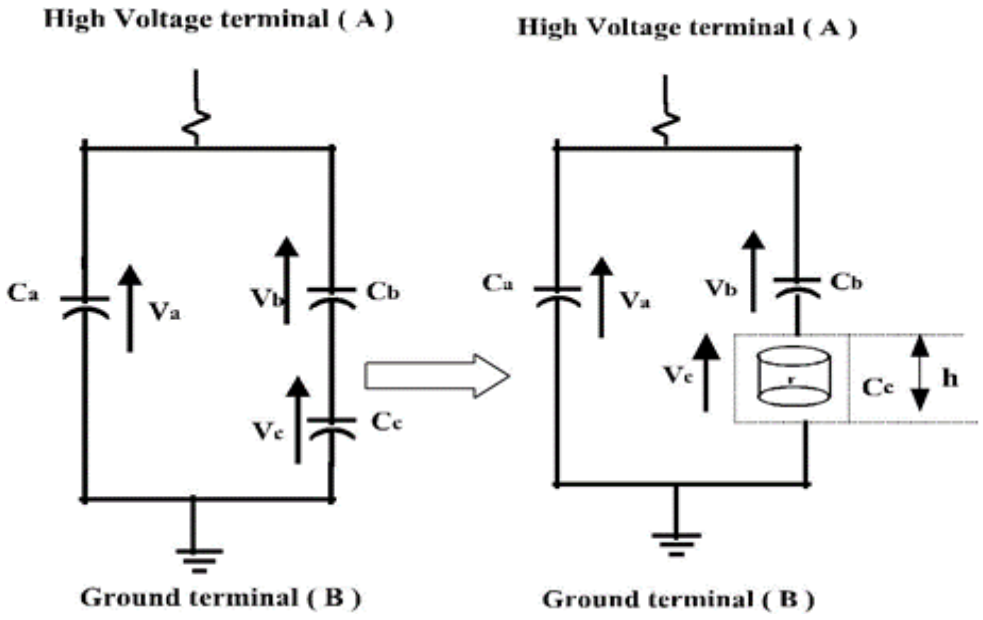


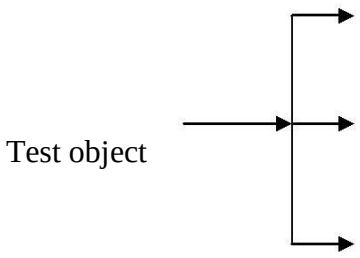

Figure 3.1. Cylindrical Void model inside dielectric

## 3.3. PARTIAL DISCHARGE MEASUREMENT SYSTEM

The basic components required for measurement of PD are

- A coupling capacitor –Coupling capacitor ought to have low inductance. It holds up low level partial discharge at a specific connected voltage for estimation of discharge

- Magnitude when coupling capacitor is joined in arrangement with the measuring framework. A larger amount of PD is measured when coupling capacitor and measuring Framework is joined independently. This happens when measuring framework is associated in Arrangement with the test object.
- A high voltage supply –High voltage supply is having low degree of background Noise to pass the discharge magnitude which is to be measured for a particular Applied voltage.
- High voltage connection having sufficiently lower degree of background noise.
- Input impedance for measuring system consisting of $R_m$, L, and C. Input impedance is the most determinant factor for the wave shape of the PD impulse.
- A high voltage filter- It is used for reduction of background noise from the power
- Supply. Such filters are also used for improvement of voltage stability.
- A test object- Consists of three capacitors. One capacitor is connected in parallel with the two series capacitors




$C_c$ corresponds to the cylindrical void present inside the solid insulation

$C_b$ corresponding to the capacitance of the remaining series insulation with void($C_c$)

$C_a$ corresponds to the capacitance of the remaining discharge-free insulation of the rest of the solid insulator

- Measuring instrument -The measuring framework is utilized to recognize the watched Electrical discharge from the test item.
- Display unit and PC programming utilized for trademark study and its examinant.

## 3.4. ELECTRICAL CIRCUIT FOR ILLUSTRATION OF PD MEASUREMENT

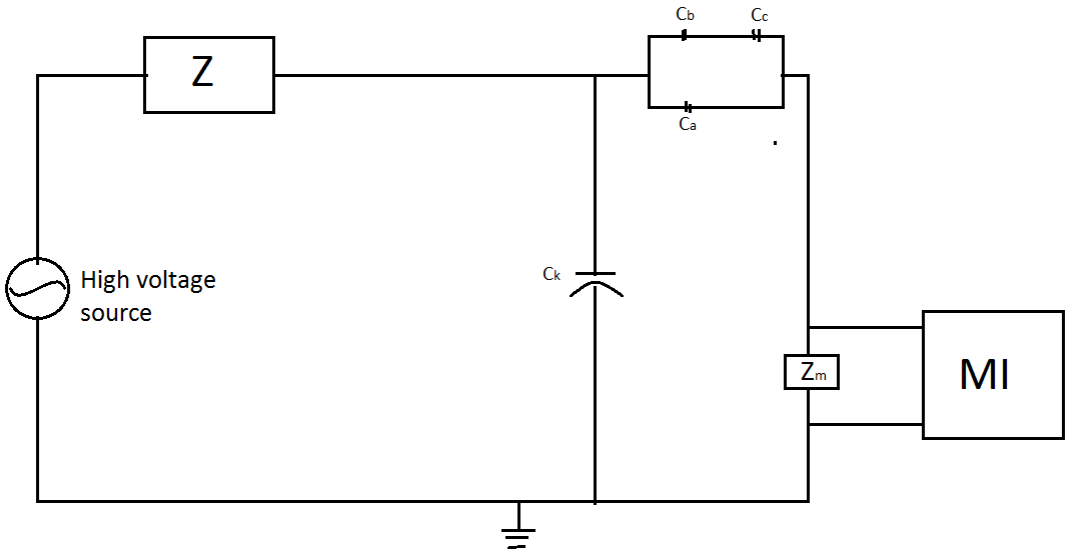



Figure 3.2. Electrical identical circuit model of cylindrical void alongside high voltage hardware

In the equal circuit display the capacitance $C_c$ relates to the tube shaped void present inside the strong protection, $C_b$ compares to the capacitance of the remaining arrangement protection with void ($C_c$) and $C_a$ relates to the capacitance of the remaining discharge free protection of whatever remains of the strong insulator. Such circuit is stimulated with air conditioning voltage source, an intermittent release happens. Capacitance of the void Cc is charged which is in charge of event of break down.

Voltage across the cylindrical void $C_c$ is given by

$$V_C = V_a \times C_b/(C_a+C_b) \quad \text{..... (3.1)}$$

Apparent charge which is measurable at the high voltage terminal A and ground terminal B can be calculated from [3]

$$Q = C_b \times V_c \quad \text{..... (3.2)}$$

Pedersen has suggested a model [3] which is based on induced charge. According to this model, apparent charge will be given by [1] for cylindrical void

$$Q = S \times V \times \varepsilon_0 \times \varepsilon_r \times (E_i - E_l) \times \Delta Z \quad \text{..... (3.3)}$$

where, S is void geometric factor, V is volume of cylindrical void and is given by $\pi r^2 h$, (where, r = radius of void, h = height of void), $\varepsilon_0$ is permittivity of free space, $\varepsilon_r$ is relative permittivity of dielectric, $E_i$ is inception voltage for streamer inception, $E_l$ is limiting field for ionization and z is reciprocal of distance between two electrodes is (1/d).

The value of ($E_i$-$E_l$) can be calculated by equation [3.1, 3.5]

$$\frac{Ei}{p} = \frac{El}{p} \cdot \left(1 + \frac{B}{\sqrt{2ap}}\right)$$

Where, B is constant characteristic of gas in void, a is radius of void, p is pressure of gas in void, of gas in void,

$$E_l/p \text{ (for air)} = 24.2/\text{pa.m.} \quad \text{..... (3.5)}$$

Apparent charge is calculated by using above parameter values by putting in this Eqn. 3.3. It has been studied that, PD phenomena is investigated from different electrical model. A SIMULINK model has been developed to study the discharge characteristic in a single void which is shown in Fig. 3.2.

## 3.5. SIMULINK MODEL DESCRIPTIONS FOR DETECTION OF PARTIAL DISCHARGE

Partial discharges are electrical discharges confined to a localized region of the insulating medium in high voltage (HV) power equipment. The PD phenomenon usually commences

Inside the void, breaks, in void rises inside liquid dielectrics or consideration inside the strong insulating medium. Also, PDs likewise happen at the limits between the distinctive insulating materials, tainting, poor conveyor profiles and gliding metal-work in the HV gear [3-8]. The electrical PD discovery system are in view of the presence of the PD current or voltage beat over the test article for essential examination, which may be either a basic dielectric test item or extensive HV power mechanical assembly. To assess the crucial amounts of PD pulse, a basic proportionate capacitor circuit of strong insulator having barrel shaped void is thought seriously about for this work.

The capacitance value of sample is calculated by using the formula:

$$Ca = \frac{\varepsilon o * \varepsilon r * (a - 2b) * b}{c} \quad \text{..... (3.6)}$$

$$Cb = \frac{\varepsilon o * \varepsilon r * r^2 * \pi}{c - a} \quad \text{..... (3.7)}$$

$$Cc = \frac{\varepsilon o * r^2 * \pi}{h} \quad \text{..... (3.5)}$$

A MATLAB SIMULINK has been shown in Figure 3.3.

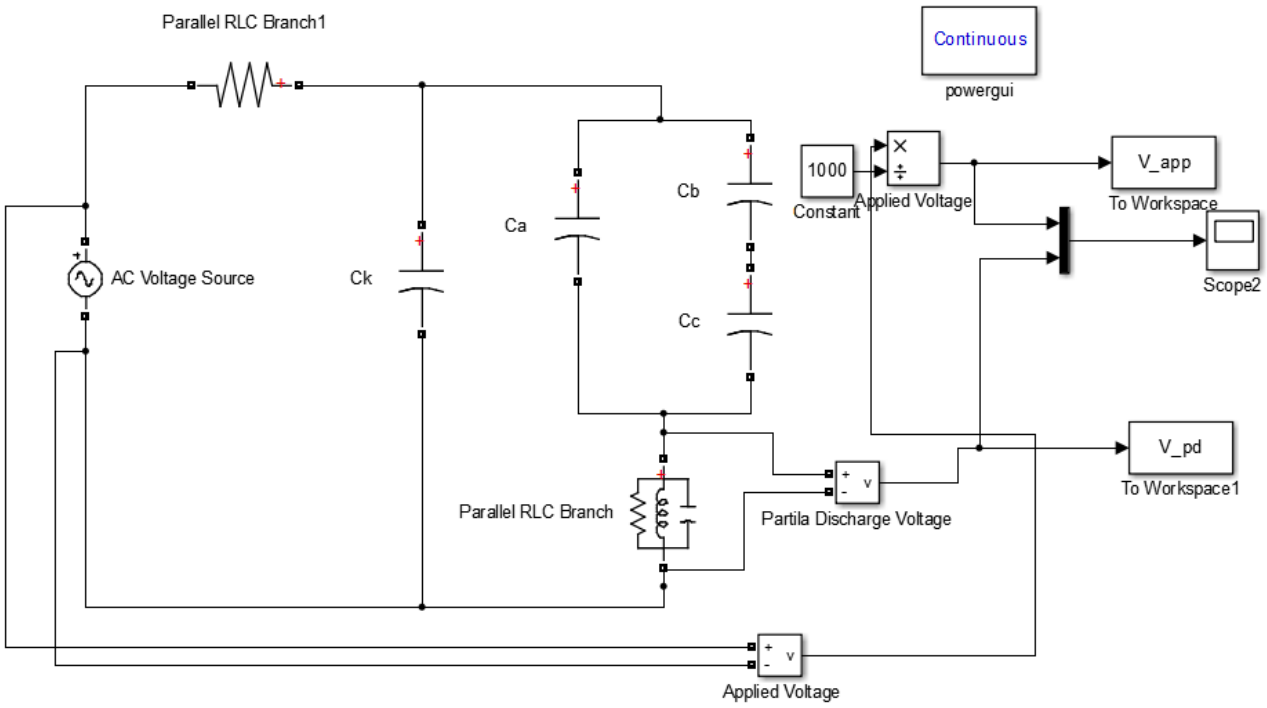



Figure 3.3. Simulink Diagram for PD measurement with 5 kV between object

The connected voltage to the protection test is 5 kV and frequency of 50 Hz. The capacitance estimation of test is computed as $C_a = 4.82\times10^{-12}$ F, $C_b = 3.85\times10^{-13}$ F, $C_c = 2.67\times10^{-14}$ F. In this study the estimation of the void model and the other high voltage hardware for estimation of Partial Discharge has been consider.

# CHAPTER-4

## SIMULATION RESULTS AND DISCUSSION

# Chapter-4

## Results and Discussions

## 4. RESULTS AND DISCUSSIONS

To watch the PD movement because of vicinity of void inside the created strong protection demonstrate a high voltage of 0-30 kV is connected in the middle of the anode. As the event of the PD inside the force hardware is not straightforwardly quantifiable due to the PD sources are not open a clear charge system is utilized. As indicated by IEC 60270 apparent charge „*q*" of a PD pulse is that charge which if injected in a short time between the terminals of a test object in a specified test circuit, would give the same reading on the measuring instruments as the PD current pulse itself.

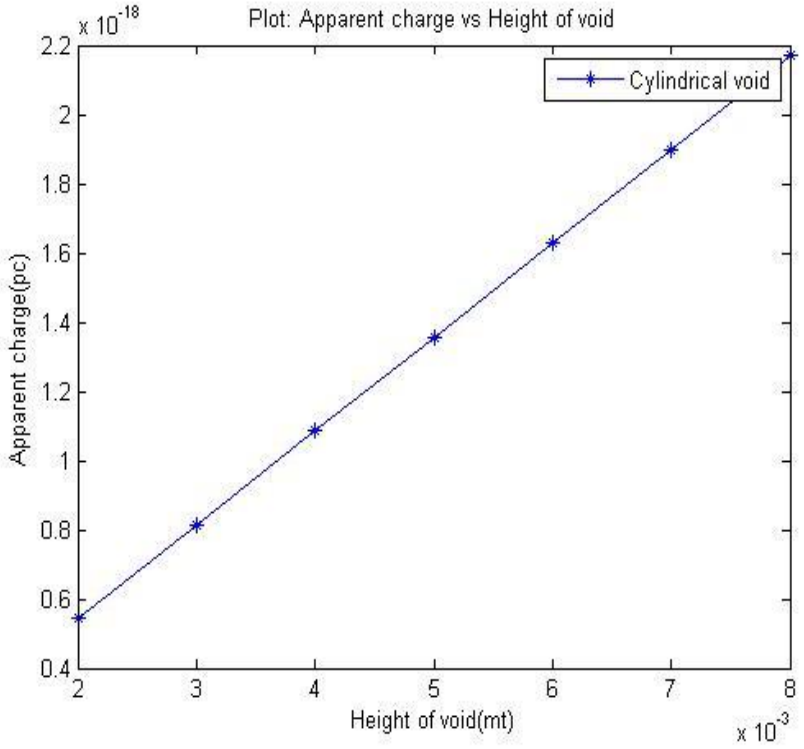



Figure 4.1.The relation between apparent charge and height of the void

It additionally mulled over that, clear charge is an essential element for PD estimation in the high voltage power hardware. As the PD is very relies on upon the geometrical setup of the void vicinity in the strong protection the connection between apparent charge and height of the void, volume of the void and measurement of the void is considered in this study.

The connection between the apparent charge and the tallness of the void is indicated in Fig. 4.1. It is seen from the Fig. 4.1 that with increment of the round and hollow void range from 0.002 to 0.008 mt, the obvious charge will increment from 0.0034×10-18 to 0.8695×10-18 pC. It is seen from simulation come about that the connection between height of void and obvious charge bend is a linear curve.

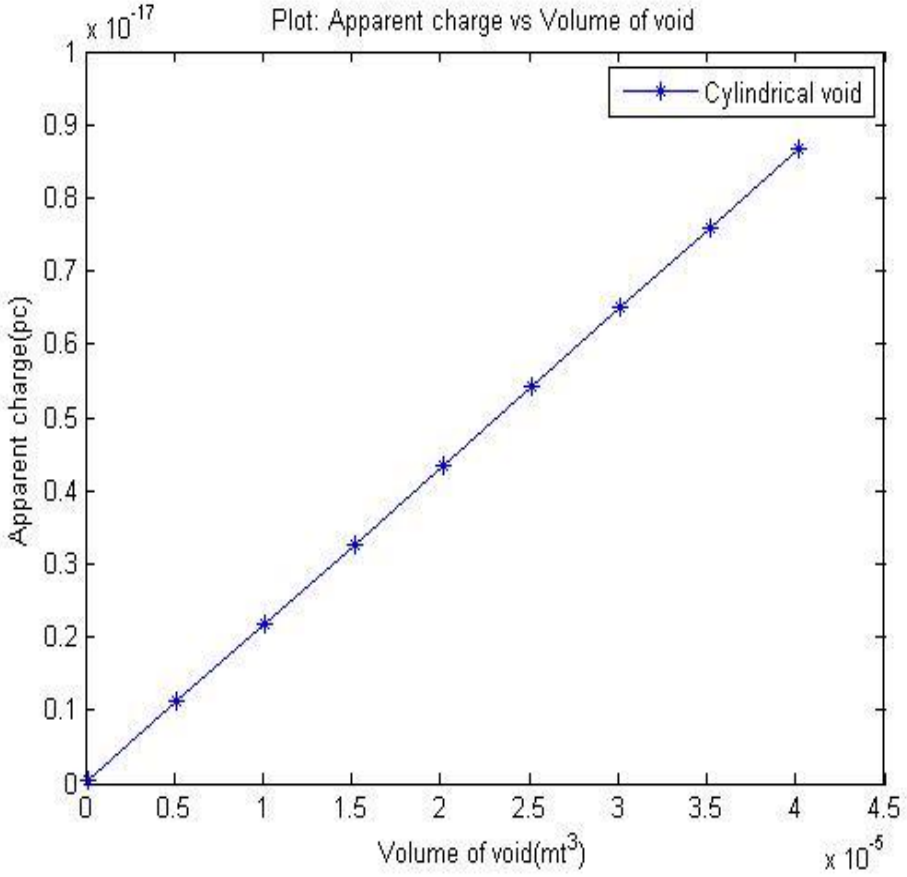



Figure 4.2**.** A linear relationship of volume of void with apparent charge

Another study has been done in this work which is the connection between the apparent charge and the volume of the void. It is watched that the apparent charge is likewise a component of volume geometry of the void structure. It is likewise watched that, the volume is straightforwardly identified with obvious charge which is indicated in Fig. 4.2. It is seen from simulation come about that the connection between void volume and apparent charge bend is a straight one.

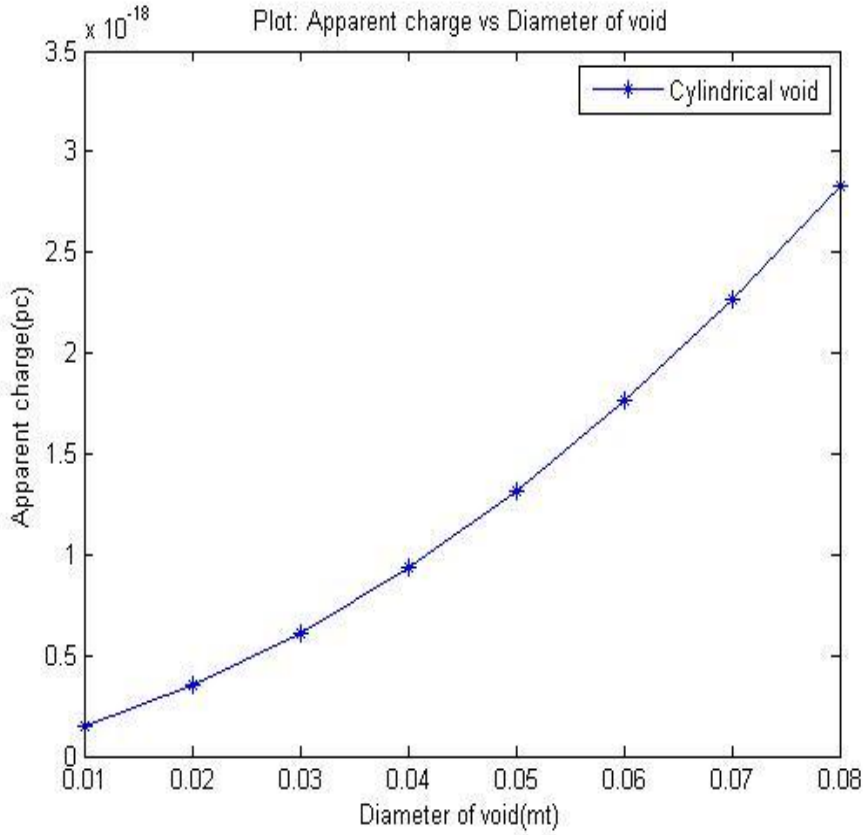



Figure 4.3.The relationship of diameter of void with apparent charge

To study the PD movement because of vicinity of void inside the strong protection, apparent charge and size of the void is additionally considered in this work. In Fig. 4.3 it is watched that with the increment of the diameter of the void evident charge is expansion. It is seen from the

Fig. 4.3 the diameter of the cylindrical void changes from 0.01 mt.-0.08 mt. and comparing estimation of the clear charge is changes from $0.034\times10^{-18}$ to $0.8695\times10^{-18}$ pC.

It is comprehend from the above result that the mean of the PD is likewise differ as the apparent charge is shifting of changing the void distance across and void volume.

Apparent charge is figured by utilizing above parameter esteem by putting in the Eqn.4.1. The dimensional setup of void parameter influence the adjustments in the PD plentifulness while 5kV connected voltage is given between the two cathodes.

The amplitude value of the PD pulse can be determined by this equation

$$V = \frac{q}{Ca + C\left(1 + \frac{Ca}{Ck}\right)} * \left(e^{-\frac{t}{2Rm}}\right) * \cos(\omega t) \qquad \text{.....(4.1)}$$

Where, V represents the result of PD amplitude, q is apparent charge, $C_k$ coupling capacitance,

And w is

$w = \sqrt{\left(\frac{1}{Lm} - \frac{1}{4R^2m^2}\right)}$ $m = \frac{Ca*Ck}{Ca+Ck} + C$ .Therefore by increasing the height of the void the PD pulse sufficiency is additionally increments as due to the apparent charge of the same void is changes. Because of the change of the void height the void capacitance is likewise changes which are delineated.

Further an examination has been made for vicinity of PD pulse over an aggregate measuring period under applied voltage of 5 kV. Partial Discharge top worth changes with the sinusoidal connected voltage. PD voltage goes Maximum to Minimum and can obtain values with the variety in source voltage.

# CHAPTER-5

## CONCLUSION

## AND

## SCOPE FOR FUTURE WORK

# Chapter-5

## Conclusions and Scope for Future work

### 5.1. CONCLUSION

Partial discharges are a significant wellspring of protection failure in High Voltage Power framework which needs to be observed constantly to evade the early disappointment in the force framework system. The PD movement inside the liquid protection is profoundly relies on upon the whole geometry of the void vicinity inside the liquid protection structure. Furthermore, PD increments with the increment of connected voltage inside the Liquid protection. Detachment of air bubble particles are exceedingly basic extensive protest because of its impact which lessen the nature of protection and the estimation of Partial Discharge Inception Voltage (PDIV).

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## 5.2. SCOPE FOR FUTURE WORK

- A diverse kind of void structure has to be created to research the execution normal for PD inside the distinctive dielectric medium.
- Detection of the PD movement inside the HV power hardware with various detection technique which helps the early determination of such high voltage power hardware for their increments of lifetime and additionally the solid operation.
- Frequency examination of PD utilizing the created structure.
- On-line checking of the HV hardware utilizing defferent structure.

# REFERENCES

**REFERENCE**

[1] G. C. Crichton, P. W. Karlsson and A. Pedersen, "Partial Discharges in Ellipsoidal and Spherical Voids", *IEEE Trans. on Dielectric and Electrical Insulation*, Vol. 24, No. 2, pp. 335-342, April 1989.

[2] R. J. Van Brunt, "Physics and Chemistry of partial discharges and corona", *IEEE Trans. On dielectric and Electrical Insulation*, Vol. 1, No. 5, pp. 761-784, October 1994.

[3] M. G. Danikas, "Some New Relationships and a Scaling Law Regarding Partial Discharges in Spherical Cavities Enclosed in Solid Insulation", *Acta Electrotechnica Napocensis*, Vol. 39, No. 1, pp. 5-9, 1998.

[4] A. A. Paithankar, A. D. Mokashi, "Can PD Phenomena be Analysed by Deterministic Chaos?*" EIC'97, Chicago, (IEEE) Conference proceedings*, pp. 283-290, 1997.

[5] N. Kolev, P. Darjanov, E. Gadjeva and D. Darjanova, "Partial Discharge Phenomena Simulation using General-purpose Analysis Program*", Proc of 6th IEEE International Conference on Conduction and Breakdown in solid Dielectrics-ICSD 98*, pp. 149-152, June 22-25, Vasteras, Sweden, 1998.

[6] C. Y. Ren, Y. H. Cheng, P. Yan, Y. H. Sun, T. Shao, "Simulation of Partial Discharges in Single and Double voids Using SIMULINK*", Journal of Xi'an Jiatong University*, Vol. 38, No. 10, pp. 120-122, 2004.

[7] N. Kolev, P. Darjanov, E. Gadjeva and D. Darjanova, "An approach to develop a partial discharge investigation*", Proc. of the IEEE Electrical Insulation Conference and Electrical Manufacturing and Coil Windings conference*, pp. 507-510, Chicago, 1997.

[8] L. Satish, and W. S. Zaengl, "Artificial Neural Networks for recognition of 3D Partial Discharge patterns*", IEEE Trans. on Dielectrics and Electrical Insulation*, Vol. 1, No. 2, pp. 265-275, April 1994.

[9] F. Gutleisch and L. Niemeyer, "Measurement and Simulation of PD in Epoxy Voids", *IEEE Transaction on Dielectrics and Electrical insulation*, Vol. 2, No. 5, pp. 729-743, 1995.

[10] R. Bartnikas, "Partial Discharge their mechanism, Detection and Measurement", *IEEE Trans. Electr. Insul.* Vol. 9, pp. 763-808, 2002.

[11] L. E. Lundgaard, "Partial discharge. XIII. Acoustic partial discharge detection-fundamental Considerations," IEEE Electrical Insulation Magazine, 1992, 8(4): 25–31

[12] .S. Karmakar, N. K. Roy, P. Kumbhakar, "Partial Discharge Measurement of Transformer with ICT Facilities", *Third International Conference on Power Systems, Kharagpur, India,* December 27 -29, 2009.

[13] S. Karmakar, N. K. Roy and P. Kumbhakar "Monitoring of high voltage power transformer using direct Optical Partial Discharges detection technique", *journal of Optics,* Vol. 38, No. 4, pp.207-215, 2009.

[14] E. Kuffel, W. S. Zaengl, J.Kuffel, *High voltage engineering: fundamentals*, Published by Eleslever, ISBN 0-7506-3634-3, second edition, 2005.

[15] F. H. Krueger, *Partial Discharge Detection in High Voltage Equipment*, London, Boston, 1989.

[16] M. S. Naidu and V. Kamaraju, *High Voltage Engineering,* New Delhi, Tata McGraw-Hill, pp. 69-85, 2004.

[17] Mu-Kuen Chen and C. Y. Cheng, "*Proceedings of 2008 International Symposium on Electrical Insulating Materials*", September 7-11, Yokkaichi, Mie, Japan, 2008.

[18] T. Krüger and R. Patsch**,** "Active Noise Reduction for Partial Discharge Measurement in the Frequency Domain", *IEEE Bologna Power Tech Conference,* Bologna, Italy, June 23th 26th, 2003.

[19] G. Chen and F. Baharudin, "Partial Discharge Modeling Based on a Cylindrical Model in Solid Dielectrics", *International Conference on Condition Monitoring and Diagnosis,* China, April 21-24, 2008.

[20] C. Forssén and H. Edin**,** "Partial Discharges in a Cavity at Variable Applied Frequency Part 1 Measurements", *IEEE Transactions on Dielectrics and Electrical Insulation,* Vol. 15, No. 6, December 2008.

[20] R. E. James and B. T. Phung, "Development of Computer-based Measurements and their Application to PD Pattern Analysis", *IEEE Transactions on Dielectrics and Electrical Insulation,* Vol. 2, No. 5**,** October 1995.

[21] K. Wu1, T. Ijichi, T. Kato, Y. Suzuoki, F. Komori, T. Okamoto, "Contribution of Surface Conductivity to the Current forms of Partial Discharges in Voids", *IEEE Transactions on Dielectrics and Electrical Insulation,* Vol. 12, No. 6, pp .1116-1124, December 2005.

[22] Q. Shaozhen and S. Birlasekaran, "The Study of PD Propagation Phenomenon in Power Network", *IEEE Transactions on power delivery,* Vol. 21, No. 3, pp.1083-1091, July 2006.

[23] Suwarno School of Electrical Engineering and Informatics, Institute Teknologi Bandung, Indonesia, "Role of Applied Voltage Waveforms on Partial Discharge Patterns of Electrical Treeing in Low Density Polyethylene", *International Journal of Electrical and Power Engineering 3*(3)*:184190,* ISSN:1990-7958, Medwell Journal, 2009.

[24] W. Deng, Z. Zheng, L. Ruan, Y. Shen, Q. Xie, H. Wang, "Power Apparatus Insulation Diagnosis through Partial Discharge in a Smarter Grid", Supported by National Basic Research Program of China.

[25] N. P. Kolev, Michael G, Danikas, E. D. Gadjeva, N. R. Gourov, **"**Development of Partial Discharge Model, Simulation and Measurement", *Conference on Electrical Insulation and Dielectric Phenomena*, pp.214-217, 2009.