Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 5, May -2015

Partial Discharge Detection and Localization in High Voltage Transformers Using an Acoustic Emission Technique

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***ABSTRACT*: -** *In this paper Optical acoustic (OA) sensor is use to study the partial discharge detection and location in high voltage transformer. This paper present a fiber optic acoustic sensing system design that can be used to detect and locate the PD source within transformer. This system is based on optical acoustic sensor that is capable of surviving good environment of transformer interior without changing transformer functionality. It also present positioning system design using TDOA (time difference of arrival) of acoustic pulse with respect to four sensor that is capable of detecting 3D positioning of PD within ±2 cm on any axis*

Keywords: *Partial discharge detection, Acoustic method, Acoustic path Propagation, Positioning system, TDOA (Time Difference of Arrival).*

I. INTRODUCTION

A partial discharge (PD) is short release of current caused by the buildup of electric field intensity in a finite region. In high voltage devices, PDs can be symptomatic of problems within the device such as floating components and insulation flaws.PD detection can be used as a tool to judge the state of the device and the quality of its manufacture.. In a modern high voltage power system, PD detection is used to monitor the state of health of a transformer in service and helps plant managers schedule device maintenance.

The basic methods of PD detection are based on the observable electric and acoustic characteristics of the phenomenon. Acoustic PD detection systems are more favorable than electric systems in transformer monitoring because it can be detection, measurement of the observed PD signal by acoustic sensors allows for PD location [1].Position information can then be used by plant monitors to analyze the cause of the PD.The location of the source of the PD within the transformer tank is determined by measuring the time difference of arrival (TDOA) of the acoustic signal between each of several sensor positions within the tank, which can then be used to solve a system of non-linear equations.

In this paper presents an optical based sensor system that has both acoustic detection and source location capabilities.The sensor, a fiber optic acoustic sensor based on extrinsic Fabry- Perot interferometry (EFPI), is made of silica so that it is both chemically and electrically inert without compromising or altering the functionality of the device.The system also has positioning capabilities because it consists of four sensors, which provide three TDOA measurements and can provide the source position in 3D.

II. PARTIAL DISCHARGE AND DETECTION METHODS

Partial Discharge (PD) detection is an important tool for monitoring insulation conditions in high voltage (HV) devices in power systems. As the HV device ages, the insulation can breakdown due to mechanical, thermal and electrical stress, resulting in the catastrophic failure of the device. Partial discharge (PD) is the dissipation of energy caused by the buildup of localized electric field intensity.PD can be divided into three categories: Floating Points, Corona, Voids. Apartialdischargecanthenoccurwhentheelectricfielddifferenceacrossthevoidexceeds minimumbreakdownfield strength.

AN insulation within an HVT begins to breakdown due to mechanical, thermal and electrical stress. PD detection is used to evaluate the condition of and diagnose problems with the HVT insulation. Over the past forty years, several methods have been developed to detect PDs within HVTs. These can be grouped into four categories, based on the PD manifestation that they measure: chemical, electrical, acoustic and optical detection [2].

In this paper I worked on acoustic method .Acoustic detection is like electrical Detection, it focus on data acquisition and recording of signal generated by partial discharge.PD signal is created within the void, the material around the hot streamer is vaporized. This vaporization causes an explosion of mechanical energy, which then propagates through the transformer tank in the form of a pressure field. Acoustic Detection is widely used in GIS (GAS insulated substation)> Acoustic method can be categories into two categories: External And Internal systems. The primary advantage of acoustic method over chemical and electrical method is position information can be found using acoustic system sensor at multiple locations.IT can be help to identify type of PD as well as location also. Acoustic method is immune to Electromagnetic Interference so it makes ideal for online detection.

Mechanisms of propagation are different for acoustic waves and electromagnetic waves, the mathematics that describes both conditions is very similar. To find the pressure field created by an acoustic wave, one must solve a second order differential equation of the form

$$\nabla^2 p = \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2}$$

Where p is the pressure field, ∇2 is the scalar Laplacian operator, and c is the speed of sound in medium of interest.

This equation is of the same form as the scalar wave equation in electromagnetics if the scalar quantity p is replaced by either e for the electric field or h for the magnetic field [3][4].

III. SENSOR SYSTEM DESIGN

The two main objectives are to detect partial discharges in HVT and to locate the source of that discharge using an optical acoustic sensor. This system is used for to meet first objective by sensing and recording data. In this part describe signal processing to locate PD source.

The Basic structure of any general PD detection system, its contain four parts: the sensor, the filter, the preamp, the data acquisition system.

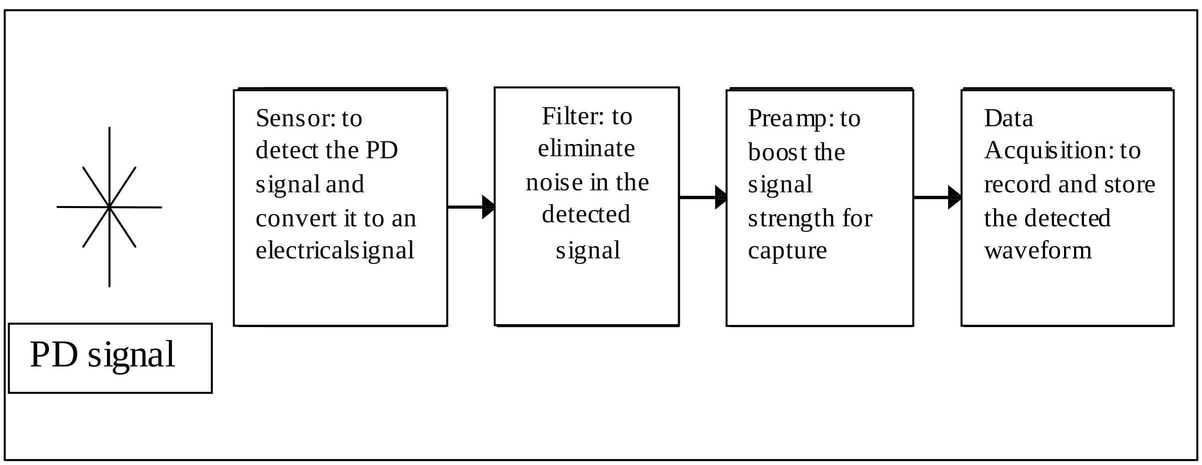


Fig 1: basic sensor system block diagram

Now I worked for sensor placement inside high voltage transformer for acoustic wave detection shown in below figure. Here sensor can be directly captured signal from transformer oil so avoiding multipath problem. Thus optical fiber connects internal sensor to external OE signal processing unit and converted into electrical signal that is recorded using digital oscilloscope. Here filtering and pre- amplification are worked in signal processing unit and A/D conversion and data storage are performed by digital oscilloscope[5][6].

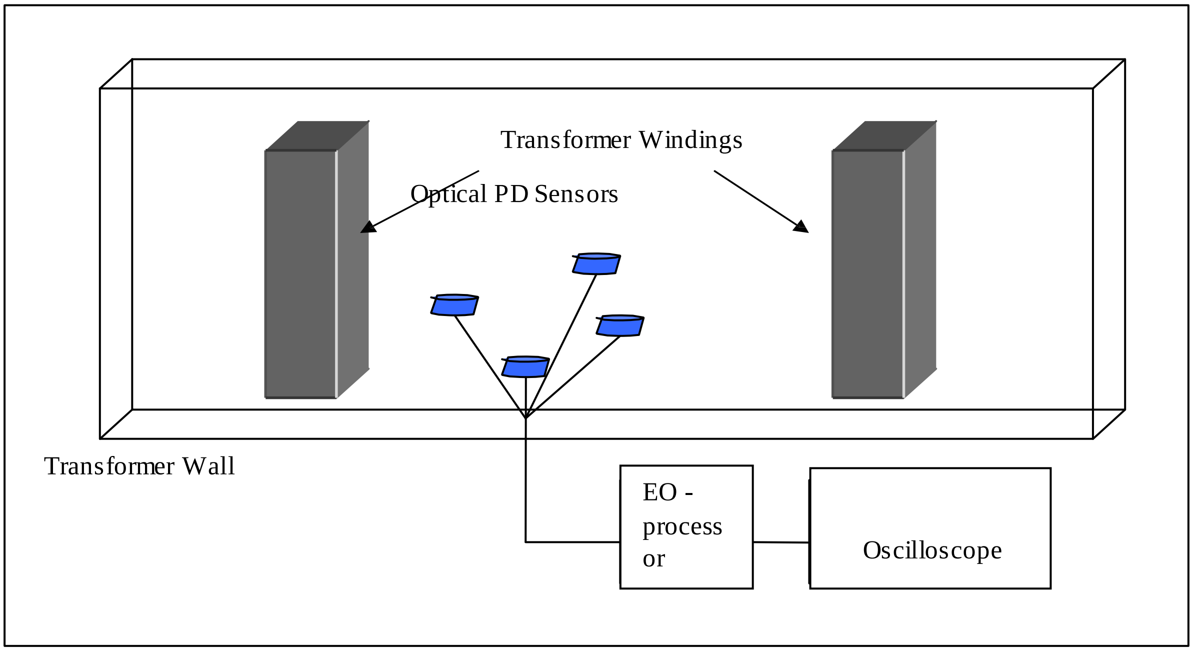


Fig 2 : Illustration of sensor implementation in HVT transformer

IV. ACOUSTIC PATH ANALYSIS

The shape of the detected signal depends on the source, the propagation media, the detection equipment, and the AE sensors.For detection and location of PD in oil-filled power transformers the acoustical location method has been used. First it was introduced in 1964. The main problem with the location of PD defects is due to the ability of acoustic waves to propagate equally in all directions. Wave propagation path divided in to two parts: direct and indirect[8].

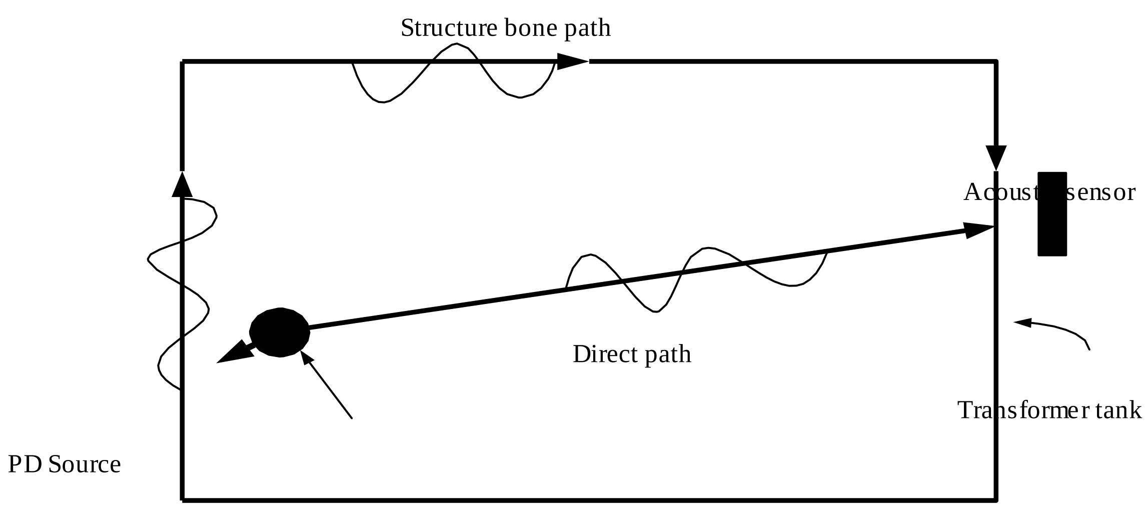


Fig 3: Illustration of typical propagation paths for the acoustic PD signals

In this paper worked for direct path so consider direct path only. If the coordinates of the sensor are (x_S, y_S, z_S) and the coordinates of the PD source are (x_1, y_1, z_1) then the direct path distance between the sensor and the source of PD is given by:

Direct path distance: $dd = ((x_S - x_1)^2 + (y_S - y_1)^2 + (z_S - z_1)^2)^{1/2}$

The time taken by the shortest path AE signals is given by:
Time taken: $T_{direct} = dd / 150000$

Where the velocity of the wave in oil is 150000cm/s.

V. POSITIONING SYSTEM DESIGN

The second objective of paper was to determine the position of PD event based on signal from sensor array within transformer tank. There are 3 main task of this system.1) Define the parameter of the system; 2) Select the positioning algorithm that is capable of providing specific accuracy; 3) Implement the algorithm using computer program and test the algorithm's ability to meet specification.

Now for this purpose it is important to design for position accuracy that is useful to plant monitoring. Based on information we was taken position accuracy of ±2cm on any axis for this PD detection system. The designed system must be calculate a position within set of error bound in one reading of PD event.

The positioning algorithm used to find the acoustic signal in transformer is based on distance equation from known point to unknown point to position of source .Distance equation is based on Pythagoras theorem.

$r_1 = ((x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2)^{½}$ where the coordinates of the sensor are (x, y, z) and the coordinates of the PD source are (x_1, y_1, z_1).

For each sensor in array, one of this spherical equation can be written and nonlinear equation is created. Many method have been developed to solve system of nonlinear equations. As example N-R method but it computationally expensive. An alternative of this is to form a differential equation using distance equation from two sources

If we take distance in form of speed of sound then the difference equation can be written in terms of time difference between two sensors. This leads to system of linear equation that relates source coordinates to unknown range from reference sensor to source.

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = -\begin{bmatrix} x_{21} & y_{21} & z_{21} \\ x_{31} & y_{31} & z_{31} \\ x_{41} & y_{41} & z_{41} \end{bmatrix}^{-1} \times \left\{ \begin{bmatrix} r_{21} \\ r_{31} \\ r_{41} \end{bmatrix} r_1 + 1/2 \begin{bmatrix} r_{21}^2 - K_2 + K_1 \\ r_{31}^2 - K_3 + K_1 \\ r_{41}^2 - K_4 + K_1 \end{bmatrix} \right\}$$

Where (x_{i1}, y_{i1}, z_{i1})= Difference between the coordination of i^{th} sensor and 1^{st} sensor

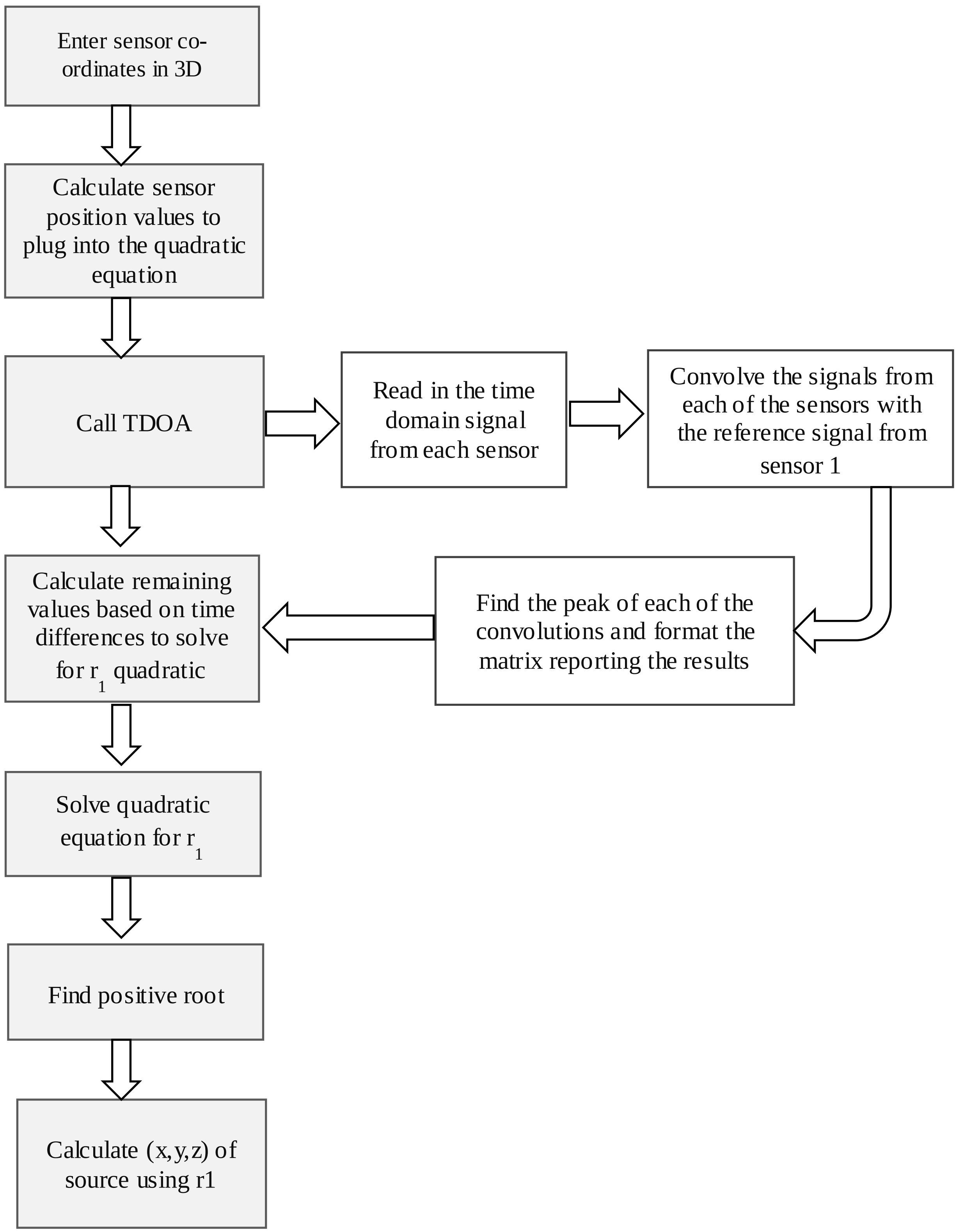
$K_i = x_i^2 + y_i^2 + z_i^2$

r_1 = Range from sensor 1 to source

r_{i1} = Speed of Sound in the medium times the times difference found between 1^{st} and i^{th} sensor

If each of the source coordinates (x,y,z) are solved in terms of r1, the resulting expressions can be inserted in the range equation for sensor 1 in order to solve for r1. Once the positive root of the quadratic equation is determined, the value of r1 can be used in above equation to determine the source coordinates.to understand that possible error in TDOA calculation could impact on accuracy of positioning algorithm[7][9].

FLOWCHART OF THIS ACOUSTIC PD DETECTION SYSTEM



VI. SIMULATION RESULT

Geometry for simulation position test

	x-coordinate (mm)	y-coordinate (mm)	z-coordinate (mm)
Sensor1	4.5	4.5	80
Sensor2	-15.5	15.5	70
Sensor3	-7	-12.5	50
Sensor4	14	-15	20
Source	-11	14	110

Table lists the sensor and source locations for the simulation. Given this geometry, the time differences between the sensor signals are 8, 24, and 48µs. The simulated signal parameters were fixed at the following values.

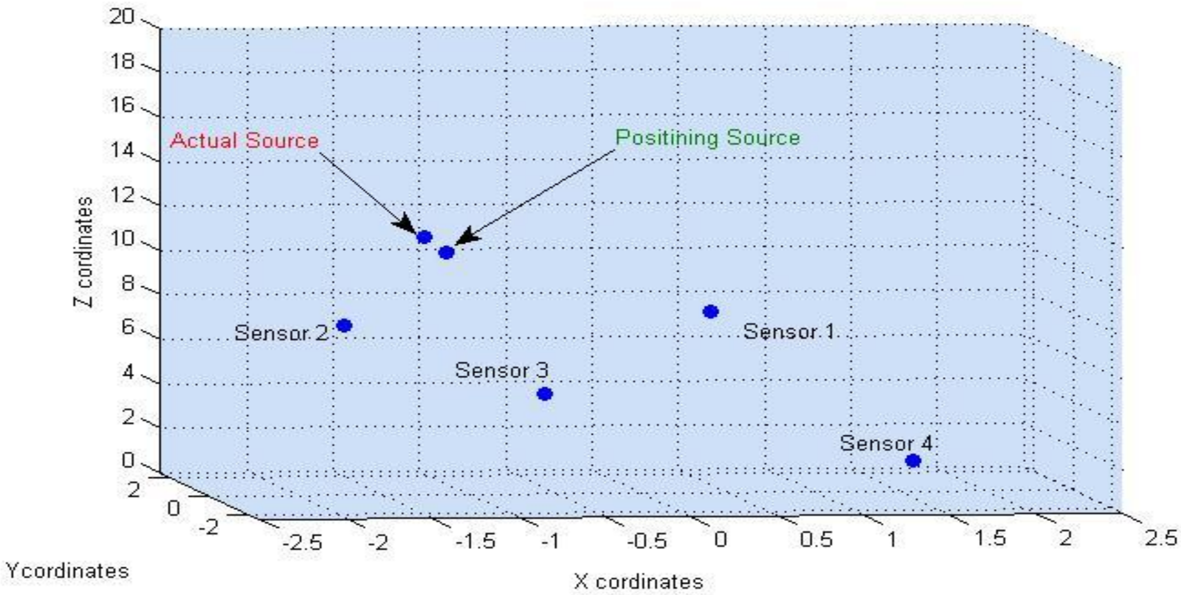


Fig 4: The plots representative of the calculated sensor locations, the source location and the location found by the position code.

Figure shows theresultsof test,whichwasrunwithnonoiseineitherofthe simulatedsignalstoconfirmthatthepositioningsoftwarefunctionsasexpectedandthatthereis noinherenterrorinthealgorithmwhenaconstantacousticvelocityisassumed. The accuracy of the calculated position is determined by the uncertainty of the time difference of arrival found for each pair of sensors and the accuracy of the known sensor positions. And its Accuracy will be within ± 2 cm in 20cm X 10cm X 10cm cube.

VII. CONCLUSION

In this paper simulation result were presented to find out PD detection ans Location system in High voltage transformerusing acoustic sensor within specified parameter. It also describe that sensor are small in size and chemically and electrically inert are capable of operatingwithin tank of transformer without changing functionality of transformer. This paper also present algorithm for find PD location and detection using four sensors within ± 2 cm in 20cm X

10cm X 10cm cube.The new approach of sensor positioning as proposed in this paper is found to have a greater efficiency in locating the source of the partial discharge than the conventional method of placing the sensors in the tank.

VIII. REFERENCES

[1] IEEE guide for the detection and location of acoustic emissions from partial discharges in oil-immersed power transformers and reactors, IEEE Std C57.127-2007.

[2]R. Bartnikas, “Partial Discharge their mechanism, Detection and Measurement”, IEEE Trans. Electrical Insulation, Vol. 9, pp. 763-808, 2002

[3]G. C. Stone, "Partial Discharge - Part VII: Practical Techniques for Measuring PD in Operating Equipment," in IEEE Electrical Insulation Magazine, vol. 7, 1991, pp. 9-19.

[4]L. E. Lundgaard, "Partial Discharge - Part XIII: Acoustic Partial Discharge Detection - Fundamental Considerations," in IEEE Electrical Insulation Magazine, vol. 8, 1992, pp. 25-31.

[5] P. M.Eleftherion, "Partial Discharge XXI: Acoustic Emission-Based PD Source Location in Transformers," in *IEEE Electrical Insulation Magazine*, vol. 11, pp. 22-26, 1995.

[6] Linhai Zhang, Gang Liu, Cheng Li , Yanming Li, Longjun Zhang and Guojun Lu, Study on Location of Acoustic Emission Partial Discharge Detection in Power Transformers”, International Conference on Solid Dielectrics, Winchester, UK, July 8-13,2007.

[7] M.M. de A. Olivieri, W. A.Mannheimer, A.P.Ripper-Neto , “On the Use of Acoustic Signals for Detection and Location of Partial Discharges in Power Transformers, IEEE Electrical Insulation Magazine, April 2-5, 2000.

[8] Prathamesh Dhole, Tanmoy Sinha, Sumeet Nayak, Prasanta Kundu .N.K.Kishore, “Analysis of Propagation Paths of Partial Discharge Acoustic Emission Signals”, Proceedings of NPSC 2008 , Mumbai, India, Dec 2008, pp. 345 to 350

[9] Prathamesh Dhole, Tanmoy Sinha, Sumeet Nayak, Prasanta Kundu, N K Kishore,’’ New Approach of Sensor Positioning for Optimizing Source Location of Partial Discharge’’IEEE Electrical Insulation Magazine pp.28-31, 2011