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Partial Discharge Detection & Localization in High Voltage Transformer Using An Optical Acoustic Sensor

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***Abstract* - A partial discharge is the dissipation of energy caused by the build up of localized electric field intensity. In high voltage devices such as transformers, this build of charge and its release can be symptomatic of problems associated with aging, such as floating components and insulation breakdown. This is why PD detection is used in power systems to monitor the state of health of high voltage transformers. If such problems are not detected and repaired the strength and frequency of PDs increases and eventually leads to the catastrophic failure of the transformer, which can cause external equipment damage, fires and loss of revenue due to an scheduled outage. Reliable online PD detection is critical need for power companies to improve personnel safety and decrease the potential for loss of service.**

I. Introduction

The PD phenomenon is manifested in a variety of physically observable signals including electric and acoustic pulses and is currently detected using host of exterior measurement techniques. These techniques include electrical lead tapping and piezoelectric transducer (PZT) based acoustic detection. Many modern systems use a combination of these techniques because electrical detection is an older and proven technology and acoustic detection allows for the source to be located when several sensors are mounted to the exterior of the tank. However, if an acoustic sensor could be placed inside the tank, not only acoustic detection be easier due to the increased signal amplitude and elimination of multipath interference, but positioning could also be performed with more accuracy in a shorter time.

This thesis presents a fiber optic acoustic sensing system design that can be used to detect and locate PD sources within a high voltage transformer. The system is based on an optical acoustic (OA) sensor that is capable of surviving the harsh environment of the transformer interior while not compromising the transformer's functionality, which allows for online detection positioning. This thesis presents the theoretical functionality and experimental validation of a band limited OA sensor with a usable range of 100-300 kHz, which is consistent with the frequency content of an acoustic pulse caused by a PD event. It also presents a positioning system using the time difference of arrival (TODA) of the acoustic pulse with respect to four sensors that is capable of reporting the three- dimensional position of a PD to within ±5cm on any axis.

Acoustic Detection

Acoustic detection like electrical detection focuses on the acquisition and recording of a signal generated by a partial discharge. However, instead of capturing an electrical signal, acoustic PD detection endeavors to sense and record the acoustic signal created during a PD event. This signal is created because when the current streamer is formed 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 pressure field. This phenomenon is analogous to the formation of thunder after a lightening strike.

II. Experimental Analysis

Insulation materials used on power facilities may have such production defects aspires, foreign substances, voids or cracks. The deterioration of insulation materials also causes defects during operation. Partial discharge is generated by electric field concentration on spots where the insulation material has defects. In particular, it is necessary to steadily monitor PD as which PD in insulation oil gradually decline the performance of insulation system.

We assembled electrode system of the needle-plane, the plane and the void in equivalent models to simulate partial discharge generated in oil insulated transformers. The plane electrode was made of a tungsten-copper alloy disc of 1.5 mm thick and 60 mm in diameter to avoid electric field concentration. A 1.6 mm thick pressed board was inserted between the electrodes to provide a condition that is similar to that of oil insulated transformers.

The experimental apparatus for the simulation of oil insulated transformers was built using a metallic enclosure. We could generate PD by increasing the AC voltage from 0 to 50 kV while placing the electrode system in insulation oil. The PD in oil was detected by the AE sensor installed on the outer surface of the tank and transmitted to an oscilloscope 400 MHz.

Amplifier

The low-noise amplifier was designed and fabricated to have wideband characteristics to acquire 40 dB gains using the low noise, wide-band operational amplifier whose gain-bandwidth is 70 MHz. The frequency response of amplifier is analyzed by the ratio of output voltage to sine-wave input voltage from 1 kHz to 2 MHz using a signal generator as shown in fig.
The amplifier has a high cutoff frequency of 1.8 kHz and a low cutoff frequency of 1.6 kHz at – 3 dB as shown.

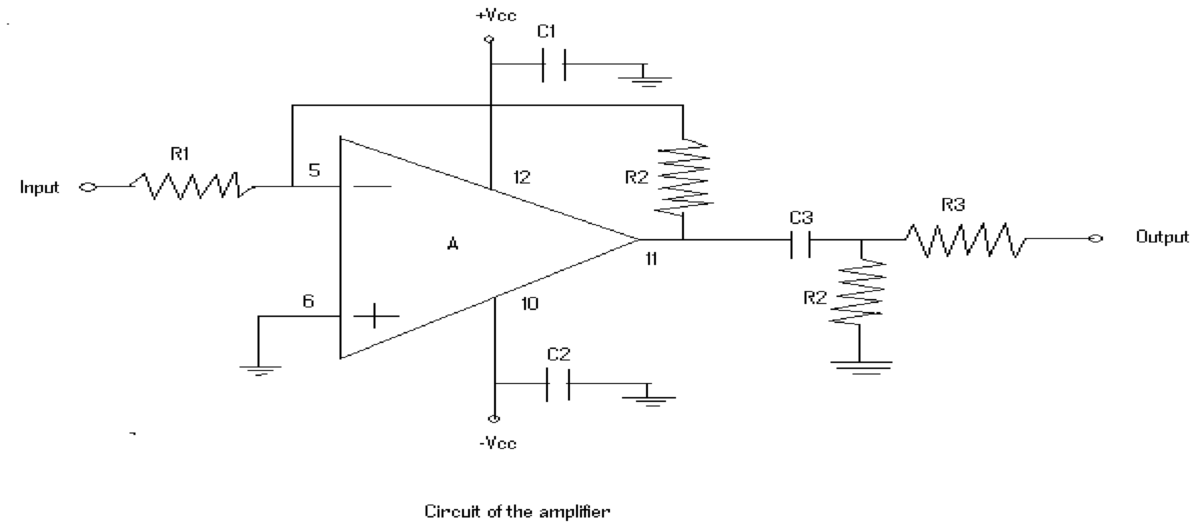

Fig 1 frequency response of amplifier

Measurement System

In this paper, AE sensor (R151-AST, PAC) with the operating frequency range of 50 kHz-200 kHz and resonant frequency range of 150 kHz were used to detect acoustic signal generated by partial discharge. We need a filtering decoupler to separate acoustic signal from the power source as the sensor do not provide separate cables for power and signal lines.

Also we need a wideband amplifier that includes functions to cover the frequency characteristics of the sensor to measure acoustic signal with high sensitivity through they are equipped with an embedded preamplifier. Figure shows the circuit of decoupler designed to separate the acoustic signals while supplying DC voltage. Explained as:

1. The high frequency component of DC voltage is blocked at L 1.
2. Only DC voltage is supplied to AE sensor.
3. The acoustic signal detected by AE sensor is passed to the amplifier via C 4 and
4. Can not pass to DC source by L 1 and C 3.
5. The prototype decoupler designed in this study has frequency responses shown in figure.
6. Any acoustic signal of 10 kHz or higher from the power source is attenuated to 145 dB but is transmitted to amplifier input terminal, R2 without attenuation.

Application of Acoustic Sensing and Signal Processing for PD Detection n GIS

Development of Partial Discharge Detection Unit

Constructional Details

To detect partial discharge one squares shaped size box using MS sheet constructed at fabrication workshop. The dimension and view is as shown in the figure of the partial discharge detection unit.

Also in the front view of the box one window is created where an acrylic transparent is used to see the inside activity. The designing of window is as such that there is seal proof of acrylic sheet placing at the window

Since the box is filled with transformer oil so that precaution of leakages has been under consideration. At the top view three identical holes provided as shown in the figure. The holes located at the center are provided for an electrodes arrangement and one hole for oil filling or for other operational work.

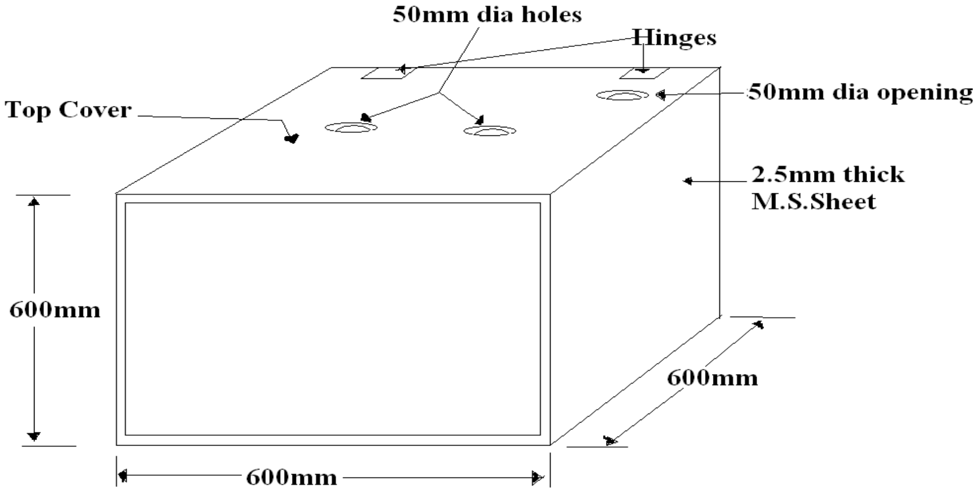

Fig 2

PD Localization Techniques using the electric and acoustic measuring method results

The transformer is energized from the electric power network. The acquisition control is made practically at the same time both for the MPD system and for the acoustic one. Data processing is made off-line[3].

In a first stage there are removed the disturbances generated by corona effect identifying the signals having the same amplitude and are identically positioned on the time axis of the three phases with the same nominal voltage.

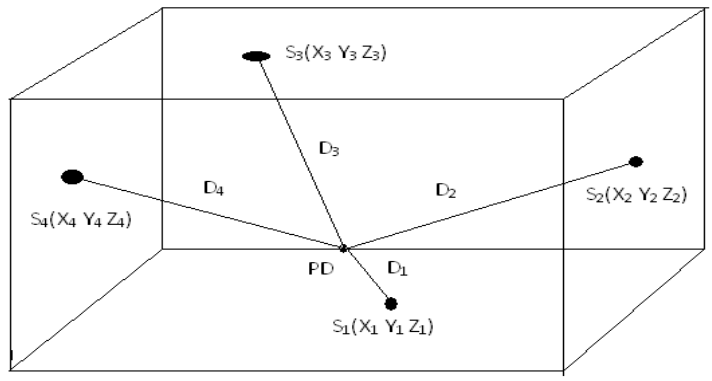

Fig 3

Noting $T = T_1 - \Delta t^*$ and representing relations $T_2 - \Delta t^*$, $T_3 - \Delta t^*$ and $T_4 - \Delta t^*$ depending on T and on the propagation time difference between the signals from the transducers 2,3,4 and the signal from transducer 1there are obtained 4 equations with 4 unknowns: x, y, z and T. Knowing T and T_1 it is obtained Δt^*. This time (Δt^*) is compared with the one obtained by the electric measurement (Δt).If the said quantities are quite close it follows that the geometric position of the PD source is correct but if the differences are great the acoustic transducers are re-positioned and the acoustic measurement is repeated until the best closeness between the two times is obtained.

III. CONCLUSIONS

When a transformer fault is noticed the first questions are : "Where the fault is localized and what is its nature?" Using the electric methods for PD measurement, the winding with the highest PD level can be determined. The PD area localization is performed by the acoustic measurement of the propagation times and then the PD impulse position toward the zero passing of the high voltage is determined. It is considered that a good approximation of the PD source was obtained when the positioning of the electrically measured impulse is the same or almost the same with one calculated from the acoustic measurement.

In order to establish the error margin for PD source localization it is necessary to continue the measurement program and checks of the faults localization by un-tanking.

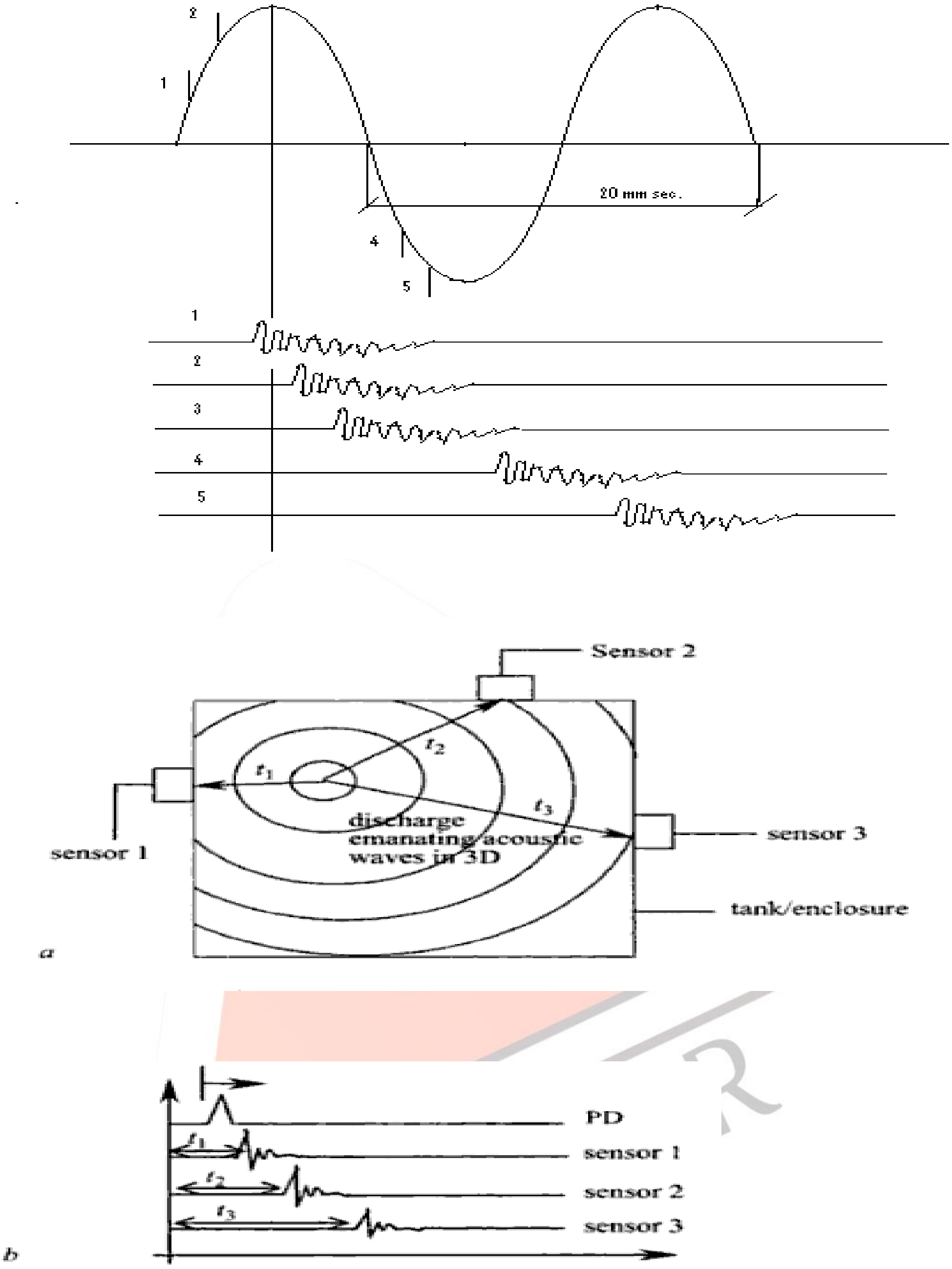

Fig 5

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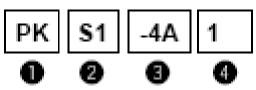
[7] Received through Internet: **Part Numbering Shock Sensors (Lead Type)** (Part Number)
1. Product ID
2. Series
3. Characteristics



4. Individual Specification Code
* "(Part Number)" shows only an example which might be different from actual part number.
* Any other definitions than "Product ID" might have different digit number from actual part .