THERMAL ANALYSIS OF H.V INSULATION OIL DURING PARTIAL DISCHARGE DETECTION

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To my God, Allah ‘azza wa jalla

Then to my beloved mother, family, and all my friends

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ABSTRACT

Historically, the arc discharge analyzing technique was one of the first methods to determine the status of the insulation oil. Due to the harsh environment and the continue usage of the high voltage transformers, many problems of insulation can be produced leading to the failure of the transformer. The problem of the thesis is to find the best available solution to conduct real time analyzing of insulation oil of high voltage transformers, so that the high voltage transformer can be safeguarded from failure in the most effective and economic manner. In this work, the temperature of the insulation oil will be captured and calculated with and without partial discharge occurring. The simulated arc discharge is generated using 7.5 kV power source in two round shape steel electrodes having 5 mm gap. This distance (between the sensor and arc discharge source) is set at 5 cm. The infrared thermometer (laser gun) was used to capture the insulation oil temperature by sending a laser light toward the insulation oil and that light will be reflected beck and received by the device and then the temperature of the oil will be captured and measured. This study will help to predict the insulation oil age of high voltage transformers, which reduce the maintenance cost of high voltage transformer.

ABSTRAK

Menurut sejarah, teknik menganalisis pelepasan arka adalah satu daripada kaedah pertama untuk menentukan status minyak penebat. Oleh kerana persekitaran yang sukar dan penggunaan yang berterusan daripada transformer voltan kuasa tinggi, banyak masalah penebat boleh dihasil membawa kepada kegagalan transformer. Masalah kajian adalah untuk mencari penyelesaian terbaik untuk menjalankan analisis masa sebenar minyak penebat transformer voltan kuasa tinggi supaya transformer voltan kuasa tinggi dapat dilindungi daripada kegagalan dengan cara yang paling berkesan dan ekonomi. Dalam kajian ini, suhu minyak penebat akan diambil dan dikira dengan dan tanpa pelepasan separa yang berlaku. Discaj arka simulasi dihasilkan menggunakan sumber kuasa 7.5 kV dalam dua elektrod keluli bentuk bulat yang mempunyai jurang 5 mm. Jarak (antara sensor dan pelepasan arka sumber) ditetapkan pada 5 cm. Termometer infra merah (pistol laser) telah digunakan untuk menangkap suhu minyak penebat dengan menghantar cahaya laser ke arah minyak penebat dan cahaya tersebut akan dipantulkan semula dan diterima oleh peranti dan kemudian suhu minyak itu akan ditangkap dan diukur. Kajian ini akan membantu untuk meramalkan umur minyak penebat bagi transformer voltan kuasa tinggi, yang mengurangkan kos penyelenggaraan transformer voltan kuasa tinggi.

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LIST OF SYMBOLS

Λ	-	Wavelength
P(λ)	-	Spectral power distribution of optical signal
R(λ)	-	Output response of optical signal
SF_6	-	Sulfur hexafluoride
C a	-	Capacitance of the test object which is not affected by any PD
C b	-	Stray capacitance of the PD source
C c	-	Internal capacitance of PD source
∂n	-	Change in refractive index
Pe	-	Effective photoelastic constant
P	-	Applied pressure
E	-	Young’s Modulus
I	-	Interaction length
$\partial\Phi$	-	Phase change

LIST OF ABBREVIATIONS

PD	-	Partial discharge
µm	-	Micro meter
µS	-	Micro second
AC	-	Alternative voltage
AE	-	Acoustic emissions
B	-	Blue
CH	-	Channel
CIE	-	International commission on illumination
Cm	-	Centimeter
CPT	-	Center for photonics technology
D	-	Dominant wavelet
dB	-	Decibel
DC	-	Direct current
DGA	-	Dissolve gas analysis
DWT	-	Discreet wavelet transform
EHV	-	Extra high-voltage
EMI	-	Electro-magnetic interference
EPIR	-	Electrical power research institute
F	-	Frequency
FFT	-	Fast Fourier transform
FOS	-	Fiber optical sensors
G	-	Green
GHz	-	Giga hertz
GI	-	Graded index

CHAPTER 1

INTRODUCTION

1.1 Overview

The strong electric field has some hidden mysteries that appear as electrochemical and plasma-chemical reactions around the high voltage appliances like cables and transformers. One of the mysterious phenomenon is small electrical sparks that are present in an insulation medium which deteriorates the material as a result insulation becomes weak to sustain that high voltage and causes electrical breakdown. In case of cables, the entrapped gas condition in void spaces of the medium is the root cause of this phenomenon which changes the electro-physical nature of the medium. In case of power transformers, high non-uniform electric field is present near the vicinity of devices which produce degradation and aging effect for insulators. This micro discharge activity near the high voltage devices is called partial discharge (PD) phenomenon which generates energy that can be measured and used for the diagnostic and monitoring study of power transformer before complete failure [1]. The PD emitted energy as electromagnetic emission, acoustic emission and ozone and nitrous oxide gases. We can use this emitted energy to detected PD signal [2]. High Voltage equipment and High Voltage installation owners have come to terms with the need for conditions monitoring process of PD in equipment such as power transformers, gas insulated substations (GIS) and cable installations [3]. The detector locates the site of PD by studying the amplitude attenuation or phase delay of the acoustic waves. PD generates mechanical wave (acoustic wave) which is propagated in a radial manner along the medium from the site of discharge. The acoustic wave is produced by the explosion of mechanical energy due to the vaporization of material inside the transformer tank forming a pressure field [4],[5],[6],[7],[8]. The optical fiber sensor can measure a wide range of chemical and physical parameters due to its small size, high sensitivity, light weight, high frequency response and immune electromagnetic interference. Optical fiber acoustic sensors has been shown advantages in many applications, such as underwater hydrophones civil structure non-destructive diagnosis, material property analysis [9] traffic monitoring and vehicle detection and PD detection[10]. Usually, optical detection technique is based on fiber optic intrinsic interferometers such as Michelson interferometers, Mach–Zehnder interferometers, multimode fiber and fiber optic extrinsic such as Fabry–Perot interferometric sensors. The Michelson interferometers, Mach–Zehnder interferometers sensors were suffer from the fringe fading problems due to random polarization rotation. Fabry–Perot interferometric sensors are compact in size compared to Michelson and Mach–Zehnderfiber sensors, and therefore achieve virtually single-point measurement. But until now, using an optical method in PD detection has limitation due to measurements sensitivity of sensors are not enough for PD detection. In this study detection of PD using step-index MMF has been done. Also analysis of breakdown arc in insulation oil is described.

1.2 Background

Electrical power transformers is usually the most critical and costly component in power transmission and distribution systems. The failure rate of extra high-voltage (EHV) power transformers is as high as 3% per year per device, which results in the loss of tens of millions of dollars for each failed unit due to serious insulation oil spills resulting in major disruption of service [11].

PD is reported to be involved in all transformer insulation failure. It can degrade electrical insulation and eventually lead to failure of the transformer. Therefore, it is important to monitor the partial discharge activity in a transformer in order to detect incipient insulation problems, and to prevent further catastrophic failure. One of the methods of monitoring PDs is to detect the acoustic waves they generate. An obvious advantage of the acoustic method is that it can locate the site of PD from the phase delay or the amplitude attenuation of the acoustic waves. Piezoelectric acoustic sensor is typically used for realizing PDs while being mounted externally on the walls of the power transformer. The external method offers the advantage of easy installation and replacement. However, piezoelectric sensors often suffer from corruption of the signal due to environmental disturbances such as electro-magnetic interference (EMI). Another problem associated with the externally mounted piezoelectric sensors is that the multi-path of the acoustic wave transmission makes it difficult to locate the exact site of the PD. It is thus desirable to have sensors that can be reliably operated inside a transformer, even within the transformer windings, with high enough pressure sensitivity and frequency response (up to 1 MHz) to pick up PD induced acoustic signals. The sensor should also be sensitive to the direction of the acoustic wave from which the location source of the PD can be recovered. These sensors need to be chemically inert, electrically non-conducting, and small in size. An optical fiber-based sensor is an attractive set-up to measure a wide range of physical and chemical parameters because of its small size, light weight, high sensitivity, high frequency response, and immunity to electromagnetic interference.

Electrical Power Research Institute (EPRI), the Center for Photonics Technology (CPT) at the Bradley Department of Electrical and Computer Engineering are currently leading the effort in developing novel fiber-based sensors that can provide the desirable sensitivity and frequency response for real-time on-line detection of acoustic emissions (AE) in power transformers [12-14]. In previous research on PD, the discharge was detected using a tube to listen for any ticking or hissing generated by PD within the tank [15,16].In 1771, Lichtenberg detected PD and wrote an experimental report on his discovery. In 1873, Maxwell extended the work of Lichtenberg by designing instrumentations for electrical PD detection and created fundamental relevance of physical models for better understanding of complex PD phenomena. The hypothesis of MAXWELL on the existence of electromagnetic waves and their propagation in space and time was demonstrated with an impressive experiment by Hertz. In 1919, SCHERING developed the first loss factor bridge for the electrical measurements of PD. This instrument continued to be a useful device for this purpose until 1924. The radio frequency was used to recognize the character of corona discharges in 1925 by SCHWAIGER. One method that can be employed to detect PD is by measuring the properties of radio interference (radio interference voltage-RIV) generated by the random corona discharges. This technique was first use by DENNHARD in 1937 and is still being used widely today. The equivalent circuit method for the assessment of PD losses under AC stresses was introduced by BYRSTLYN in 1928 [17]. In 1932, his technique was systematically investigated by GEMANT and PHILIPPOFF with the aid of oscillograghic techniques to ascertain the sequence of discharge events per cycle of the applied AC voltage [18].

1.3 Problem Statement

Due to the harsh environment and the continuing usage of the high voltage transformers, many problems of insulation can be produced leading to the failure of the transformer. The primary 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. The problem with current acoustic PD detection systems is that the acoustic signal must be observed outside of the transformer tank because there are no developed sensors that can survive the environment of the tank interior and be electrically and chemically neutral. Because the path between a PD and the acoustic sensors includes the wall of the tank, multi-path interference can severely limit the accuracy of any positioning system. The interference is caused by the differing acoustic velocity of the wave in the oil and the transformer tank. Therefore, it would be an enormous advantage if a sensor could be designed to operate within the transformer tank without inhibiting or changing the functionality of the transformer.

In the absence of the insulation diagnostics many transformer failed before reaching their designed technical life. The failure of such transformer costs several million dollars either to repair or to replace. In high voltage power apparatus one of the most common liquid insulating materials used for insulation is the transformer oil. Degradation of transformer oil is due to the combination of the ageing processes such as thermal ageing, electrical arcing and partial discharge (PDs) while it is under operation during its long period of service. The insulating oil of HV equipment is degraded due to the combination of the ageing processes such as electrical arcing, thermal ageing and oxidation while it is operating in long period of service. Apart from the ageing process as described above, partial discharges are also responsible for insulation degradation process [19, 20]

1.4 Objectives

1. To Detect of partial discharge in insulation oil using optical sensor and acoustic sensor
2. To Calculate the insulation oil temperature during partial discharge

1.5 Scope of Work

1. Detection of partial discharge in transformer oil
2. Calculation of insulation oil temperature
3. Detection of partial discharge signal using optical and acoustic technique

1.6 Thesis Organization

The thesis consists of five chapters, organized as following:

- Chapter one in this research presents an overview as a whole. The background, problem statement, objectives and scope have been described.
- In chapter two literature review of arc discharge have been described.
- In chapter three, the experimental set-ups and procedures employed and the equipment in this study are described.
- In chapter four present the result and discussion of experimental work.
- Finally, chapter five will contains the conclusion of the main finding of this work.

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