COMPARISON BETWEEN PIEZOELECTRIC AND CAPACITIVE SENSORS FOR PD DETECTION AND SIGNAL MONITORING IN PALM OIL

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Dedicated to my family.

Thank you for your perseverance

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ABSTRACT

High-voltage transformer is the most critical and expensive component in a power system network in order to ensure the stability of the system. Partial discharge (PD) detection is a technique widely used for high voltage equipment insulation condition monitoring and assessment. PD phenomenon causes gradual deterioration of the insulating materials, sometimes over a period of several years, leading perhaps to eventual failure. Detecting PD in power transformers is vital both in industries and utilities to avoid damage of high-voltage equipment. The objectives for this thesis are: To detect and analysis the PD activity using acoustic sensor (piezoelectric sensor) and capacitive sensor in natural palm-oil and to compare the sensitivity of the two sensors. The capacitive sensor and PZT sensors were immersed in palm oil tank fitted with two steel electrodes which were connected to range of high voltage (0-15KV) from high voltage source, the detecting signal that gained by the acoustic and electric sensors would pass through high pass filter to eliminate the noise range below 100-KHz then it is connected to the oscilloscope by wiring connections means. These data will evaluate in time and frequency domain by using analyzing software program (Origin-Pro). The conclusion that can acquire from this software and from the experimental lap results shown impressive characteristic for the PD detection and recommend the both sensors as a good tools for monitor and assessment the insulation condition when the discharge emission occur.

ABSTRAK

Transformer bervoltan tinggi adalah komponen yang paling mahal dan penting dalam rangkaian sistem kuasa bagi memastikan kestabilan sistem. Pengesanan nyahcas separa (PD) adalah teknik yang digunakan secara meluas sebagai pemantau dan penilai keadaan penebat bagi peralatan bervoltan tinggi. Fenomena PD menyebabkan kemerosotan bahan penebat secara beransur-ansur, kadang-kadang dalam tempoh beberapa tahun, yang mungkin berakhir dengan kegagalan penebat. Pengesanan PD dalam transformer kuasa adalah penting dalam industri mahupun utiliti untk mengelakkan kerosakan peralatan bervoltan tinggi. Objektif kajian ini adalah: Untuk mengesan dan menganalisis aktiviti PD menggunakan pengesan/sensor akustik (sensor piezoeletrik) dan dan sensor kapasitif dalam minyak sawit semulajadi dan untuk membandingkan sensitiviti kedua-dua sensor. Sensor kapasitif dan PZT direndam dalam tangki minyak sawit yang dipasang dengan dua elektrod keluli yang bersambung ke pelbagai voltan tinggi (0 – 15 kV) daripada sumber bervoltan tinggi. Isyarat pengesan yang diperoleh/ditangkap sensor akustik dan elektrik akan disalurkan melalui turas laluan tinggi untuk menyingkirkan hingar yang berjulat bawah 100 kHz. Sensor kemudiannya disambung kepada osiloskop secara sambungan pendawaian. Data-data akan dinilai dalam domain masa frekuensi menggunakan program perisian menganalisis (Origin-Pro). Kesimpulan yang boleh diperolehi daripada perisian ini dan daripada keputusan ujikaji makmal menunjukkan ciri-ciri yang impresif untuk pengesanan PD dan kedua-dua sensor disarankan sebagai alat yang baik untuk memantau dan menilai keadaan penebat apabila pancaran nyahcas berlaku.

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LIST OF ABBREVIATIONS

PD	-	Partial discharge
μm	-	Micro meter
μS	-	Micro second
AC	-	Alternative voltage
AE	-	Acoustic emissions
CH	-	Channel
Cm	-	Centimeter
dB	-	Decibel
DC	-	Direct current
EHV	-	Extra high-voltage
EMI	-	Electro-magnetic interference
F	-	Frequency
FFT	-	Fast Fourier transform
GHz	-	Giga hertz
GIS	-	Gas insulated switcher
HF	-	High frequency
HV	-	High Voltage
kHz	-	Kilo hertz
kV	-	kilo volt
M	-	Meter
MHz	-	Mega hertz
mm	-	Millimeter
mW	-	milli watt
Nm	-	Nanometer
Pc	-	Pico Column

VHF	-	Very High Frequency
V	-	Voltage
UT	-	Ultrasound transducer
UHF	-	Ultra high frequency
SNR	-	Signal to noise ratio
PZT	-	Piezoelectric

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CHAPTER 1

INTRODUCTION

1.1 Introduction

High voltage equipment is considered as one of the essential elements in electrical network. Any failure in this equipment directly reduces network reliability and increases maintenance costs [1]. Under the high voltage stress micro level electrical sparks appears in an insulator medium which is known as partial discharge phenomenon. These micro discharges ultimately lead to electrical breakdown of the insulator [2]. In any fabricated material some micro void spaces exist which is filled by the gas e.g. e air. This gas is ionized due to highly non-uniform electric field and ultimately ruptures the void space in the weakest direction. The sudden release of energy due to PD phenomenon would produce a number of effects such as chemical and structural changes in the materials [3]. The measurement level indicates the quantity and magnitude of partial discharge.

In partial discharge (PD) phenomenon energy is emitted in the form of electromagnetic emission, radio waves, light and heat and also as acoustic emissions (AE) in the audible and ultrasonic ranges. PD is an electrical discharge or sparks that bridge small part of insulating between two conducting electrodes. PD can occur when electric field strength exceeds the breakdown strength of insulation, and can lead to flashover [3]. A good understanding of PD mechanisms, characteristics and its development processes is essential for power systems designer and power systems installation maintenance engineer. PD detection is necessary as precautionary measures to ensure that high voltage equipment insulation is not exposed to any unnecessary hazards.

1.2 Detection of Partial Discharge

PD detection is a technique widely used for high voltage equipment insulation condition monitoring and assessment [1]. The insulation system has high risk for dielectric stability when PD occurs. Therefore, measurement of PD is important preventive tool to safeguard high-voltage equipment from wanton damage. Partial discharge (PD) phenomenon is a hidden activity which deteriorates the insulation media that leads to breakdown of electricity in high voltage systems [4]. PD phenomenon causes gradual deterioration of the insulating materials, depends upon the insulation characteristics of the material. Sometimes it may occur over a period of several days, weeks and years that will produce a complete failure of insulation. The reliability of high voltage (HV) insulation systems depend accurate detection and measurements of partial discharge. High-voltage transformer are used in a power system network which is the most critical and expensive component needs proper caring for protection to avoid complete shutdown[2][3].

Detecting of PD in power transformers becomes vital for both industries and utilities to avoid damage of high-voltage equipment. In order to ensure the stability of the system, PD measurements are made to extract information about insulation defects, which is used for estimating the risk of insulation failure of the equipment. Several detection techniques are used for the diagnostic of Partial Discharge in which some sensors are used to monitor and assess the condition of high voltage insulation.

The ultrasonic pressure waves can be used to detect the intensity and location of PD signal. The frequency band of discharge in oil has wideband range (10-500 kHz) [5]. A popular method of PD detection in high-voltage power equipment utilizes electrical, chemical, acoustic and optical measurements.

PD detection and location work is carried out in the factory and in the field, the latter being done with the transformer either connected to the grid or supplied by a separate power source [6].

The detection and coarse location of one or more sources can be accomplished by moving one or more externally mounted sensors to different locations on the transformer tank [7]. A more precise location of a PD source may be determined by the relative arrival times of the acoustic signals at each of the sensors. No voltage or current readings are required on the transformer. The energy creating the acoustic signal is from PD and mechanical and thermal sources inside and outside transformers and reactors. The sharp rise of the wave front indicates that a direct wave has impinged on the inside tank wall within the critical angle for a pressure wave. The horizontal axis shows time in microseconds. The burst had a length of 144 μs from the first threshold crossing to the last threshold crossing. The vertical axis is a dimensionless indication of amplitude. The number of acoustic bursts in a unit of time, usually 1 s, is a measure of acoustic activity [8] [9].

Acoustic method detects and locates the position of PD by studying the amplitude attenuation or phase delay of the acoustic waves propagated from the PD. This mechanical wave (acoustic wave) is caused by the mechanical energy explosion due to the vaporization of material inside the transformer tank creating a form of pressure field, Acoustic wave in the transformer oil can be detected using acoustic sensors (Piezoelectric Transducers – PZT)[10]. When PZT is mounted outside, on the transformer wall, it will capture interferences from the very noisy environment and this can make PZT sensors' usefulness limited. The PZT sensor can be placed inside the oil tank of the transformer to reduce noise and attenuation of signal .

Location of PD can be estimated by measuring the time of arrival of acoustic wave and position information is ascertained by using sensors at multiple locations [11].

This makes acoustic emission sensing a more preferable measuring tool in real time. Measurement using the acoustic approach has an additional advantage of possessing better noise immunity for online real time applications. Acoustic method experiences difficulty in locating the exact origin of PD due to interference and degradation of signals from environmental noise [12] [13]. Here, sensitivity is certainly compromised. In this work will study, the characteristics of (PD) using acoustic sensor with natural oil in two state (outside the oil tank and inside the oil tank) explored and monitor the condition of high voltage equipment insulation the data obtained by both states were then analysed in time and frequency domain, and make a comparison with the electrical detection method [14].

1.3 Research Background

The use of acoustic emission (AE) techniques to detect and locate partial discharge activity in power transformers is in common practice since the mid 1960's [15]. Despite the considerable time passed, there are still interests in refining the methods using recent developments in instrumentation, see, e.g., [16]. It is, however, hard to estimate the total activity in the field as the individual diagnostic results seldom appear in the open literature. Judging from both the persistent appearance of papers describing developments of the technique and from the authors own experience, it is a very powerful method, which, however, require special skill. Actually any high voltage equipment contained insulation; the principle media of insulation are gases, vacuum, solid and liquid .this insulation Exposed to deterioration, knowledge of the causes of deterioration is essential to achieve reliability and economy [17].

The sudden release of energy caused when a PD occurs produces a number of effects like chemical and structural changes in the materials [18]. PD is an electrical discharge or spark that partially bridges a small section of insulation when two conducting electrodes emerge from the separation of distinct high concentration of positive and negative charges. It is a random localized discharge formed by transient gas ionization in an insulated system when the stress voltage exceeds a certain critical value [19]. PD often occurs when electric field strength exceeds the breakdown strength of insulation, and can lead to a flashover. PD phenomenon causes gradual deterioration of the insulating materials, sometimes over a period of several years, leading perhaps to eventual failure. Locating and detecting PD in power transformers is vital both in industries and utilities to avoid damage of high-voltage equipment.

The use of acoustic emission (AE) techniques to detect and locate partial discharge activity in power transformers are in common practice since the mid 1960's. In1967 [15][16], four acoustic sensors were mounted on the cladding of the power transformer, and the PD source could be detected and located. An earlier study of the behaviour of dielectric liquids under electrical stress had shown that partial discharges always produced Mechanical stress waves. Moreover, although the predominant frequency content of these mechanical pulses appeared to vary with the particular liquid being stressed, it was generally located in the 100 kHz to 200 kHz frequency band.

As these signals were similar to "those" produced in mechanically stressed solids, it appeared to be expedient to utilize some of the instrumentation and techniques which were associated with that particular area of technology called acoustic emission [20] [21]. Acoustic emission technique has been utilized for partial discharge detection in different components of the electric network like cables, gas insulated substations generators, and power transformers. Moreover, multiple acoustic sensors were used to precisely locate the partial discharge source in power transformers [22].

PD signals have been detected and located using piezoelectric (PZT) ultrasound sensor for typical frequency about 150 kHz mounted on tank wall. The main problem of PZT sensor, it suffers from degeneration of signal-to-noise ratio due to environmental noises such as electromagnetic interference [10, 23]. Another problem related with externally mounted PZT sensor is multi-path signal, due to the ultrasound signal transport from the source to the sensor along different speed and different path, this mean low level of precision is achieved. Therefore, the sensor must be located inside tank of transformer, close to PD source to overcome to this problem [25, 26]. This sensor which is electrically non-conductive, chemically inert, passive and small in size is the best choice for the detection of PD phenomenon.

1.4 Problem Statement

Electrical insulation plays an important role in the performance of high-voltage apparatus as it has to withstand high electrical stress during operation. Most power equipment failures are caused by breakdowns of the insulation. This in turn is often the consequence of gradually and cumulatively damaging effects of partial discharges (PD) on the insulation over the years. The main focus of research has been to expand PD technology so it can be more practically applied to diagnostic testing to determine the condition of the insulation that has seen operation. Condition assessment can include both online PD testing. Electrical detection especially on-line testing required developing better and better ways of suppressing electrical inference (which can lead to false indications). In addition, 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 [10, 11]. The most possible reason for a failure of a transformer is insulation breakdown Oil-impregnated pressboard and paper is commonly used as an insulation system in power transformers [22, 23]. In this experiment the natural oil (palm oil) is the substituational oil in the power transformer as insulation medium due to it is cheap price and availability in the market (especially in Malaysia).

1.5 Research Objectives

This study would focus on the following objectives:

i. To detect the partial discharge phenomena using acoustic sensor (PZT) in natural oil palm inside the tank.
ii. To detect the partial discharge phenomena using capacitive sensor in Natural oil palm inside the tank.
iii. To analysis and compare the result and the data gained from the both sensor in this experiment.

1.6 Scope of Research

- In this study investigate the possibility of two method of detecting partial discharges in high voltage equipment in palm oil**.**

- Partial discharges are small events that occur in insulation In the presence of high electric field intensity by increasing the applied high voltage signal on the oil tank.
- PD activity can monitor and measure through piezoelectric sensor and capacitive sensor in the oil tank.
- These data would be analysed in time and frequency domain by the aid of software program (Origin-Pro).
- Analaysis and observation made for the PD signal to distinguish the characteristics of PZT and the capacitive sensors

1.7 Significance of the Study

This study would confind in the detection and analysis the partial discharge phenomena performance using acoustic sensor (piezoelectric sensor) and capacitive sensor in Natural palm-oil inside the tank. The data of the both sensors obtained by applying high voltage signal in voltage range (0KV-15KV) from the high voltage source to the oil tank which contain two electrodes and natural oil (palm-oil), the detecting signal that gained by the acoustic and electric sensors that connected to the oscilloscope by wiring connections means, these data would be studied in time and frequency domain by using analysing software program (Origin-Pro).

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