PARTIAL DISCHARGE DETECTION USING LEAKAGE CURRENT AND OPTICAL TECHNIQUE IN INSULATION OIL OF HIGH VOLTAGE TRANSFORMER

QUSAY OTHMAN HASAN

UNIVERSITI TEKNOLOGI MALAYSIA

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QUSAY OTHMAN HASAN

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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 conduct an experiment for the detection of PD using multi-mode optical fiber sensors under high voltage insulation oil conditions .To characterize the Partial discharges through leakage current sensor and signal monitoring in Palm oil insulation. Comparison of optical and conventional (leakage current) and analyze the output in time and frequency domain of the waveform. 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 voltan tinggi-adalah komponen yang paling kritikal dan mahal dalam rangkaian sistem kuasa bagi memastikan kestabilan sistem. Pengesanan pelepasan separa (PD) adalah teknik yang digunakan secara meluas untuk memantau keadaan dan penilaian penebat peralatan voltan tinggi. Fenomena PD menyebabkan kemerosotan beransur-ansur dalam bahan penebat. Kadangkala dalam tempoh beberapa tahun, mungkin membawa kepada kegagalan akhirnya. Mengesan PD dalam transformer kuasa adalah penting baik dalam industri dan utiliti untuk mengelakkan kerosakan peralatan voltan tinggi. Untuk mencirikan pelepasan separa melalui kebocoran arus sensor isyarat dan pemantauan dalam penebat minyak sawit. Untuk mencirikan pelepasan separa melalui kebocoran arus sensor isyarat dan pemantauan dalam penebat minyak sawit. Perbandingan optikal dan konvensional (kebocoran semasa) dan menganalisis output dalam domain masa dan frekuensi gelombang. Data-data ini akan dinilai dalam domain masa dan frekuensi menggunakan program perisian menganalisis (Asal-Pro). Kesimpulan yang boleh memperolehi daripada perisian ini dan dari hasil lap eksperimen ditunjukkan characteristbe ic mengagumkan untuk mengesan PD dan mengesyorkan sensor kedua-dua sebagai alat yang baik untuk memantau dan penilaian keadaan penebat apabila pelepasan pelepasan yang berlaku.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The insulation breakdown in high-voltage equipment is a high risk in power transmission system which happens due to partial discharge (PD) phenomenon. It is responsible for many power transformer failures and appears when the insulating material remains continuously under high voltage stress. PD pulses are small electrical sparks appear inside an insulator due to micro void spaces as result breakdown occurs. The void acts as a micro capacitor whose discharge energy is released suddenly and Pd pulses appear. However occurrence of PD phenomenon depend a number of factors such as chemical composition and structural changes in the materials. PD measurement and monitoring is very important to avoid huge losses in power transmission system as preventive tool. There are many methods for the diagnostics of PD in high-voltage power equipments such as electrical, chemical, acoustic and optical techniques that can measure the level and magnitude of partial discharge. The level of PD emitted energy is in the range of acoustic emission that can be detected by applying the suitable sensor. In current scenario, it is the best method for the detection of PD in high power transformer. The optical sensor consist of fibre optic that has some advantages such as high sensitivity, more accuracy and easy to install. It can be easily collect online information that can help to improve the reliability of high voltage (HV) insulation systems.

1.2 Background of Research

The economic development and social welfare of any modern society depends upon the availability of a cheap and reliable supply of electrical energy. The system of electrical energy consists of three parts such as generation, transmission and distribution. These parts are connected together synchronously and any part consists of high voltage equipment such as transformer, circuit breaker, bus bar, isolator, and others. Generally, all the high voltage equipment has some sort of insulation such as gases, vacuum, solid and liquid. Under continuous stress of high voltage the insulation material deteriorate which depend on many factors whose prior knowledge could predict the safe limit of the devices to achieve reliability and sustainable operation. Partial discharge (PD) phenomenon is one of the main causes of insulation failure in power transmission network system because its appliance and accessories remain continuously under stress of high voltage for a long time. The power transformer is heart of the transmission network that needs proper caring and monitoring to avoid any failure of power. The PD phenomenon is a hidden activity that appears due to small electrical spark present in insulation as a result electrical breakdown occurs in the cable or equipment. The PD phenomenon occurs when the electric field exceed local ionization threshold of dielectric insulation [1]. In the 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. 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) [2].

The accuracy of the acoustic PD location approach depends upon being able to detect the PD pressure wave, and to separate the resulting signals from background noise. These problems can be avoided using optical-fibre sensors that can be placed inside the transformer tank without affecting the insulation integrity. This intrusive configuration is particularly useful in substations environments where there is a high level of outside interference.

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. 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. Here, sensitivity is certainly compromised.

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. 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 [3, 4]. This sensor which is electrically non-conductive, chemically inert, passive and small in size is the best choice for the detection of PD phenomenon.

The optical fibre sensor (OFS) has been used which has some advantages like it has a simple structure, low power consumption, small size, light weight, immunity to electromagnetic interference noises, high sensitivity, corrosion resistance, low prices and large wideband. These advantages make OFS perfect candidate for acoustic detection. The use of interferometric technique using OFS inside transformer could provide high level of sensitivity that can be achieved due to PD phenomenon [5,6]. Recently single-mode OFS has been used using interferometric measurement of AE inside the transformer oil insulation [7, 8]. The single-mode optical fibre sensor has high sensitivity by using long fibre in sensing arm, but the frequency response is a drawback in this case.

The PD signal can be detected by the electrical quantity measurement. Generally, two techniques the Ultra High Frequency (UHF) method and Pulse Capacitive Coupler method are very common. In UHF method PD excitation signal is measured by the electrical resonance at the frequency range of up to 1.5 GHz. This method is capable of detecting as well as locating a PD source. UHF method has inherent advantages such as low noise levels due to shielding effect of the transformer and very low signal attenuation. This method has immunity against external noise as the UHF sensor is connected inside the transformer. The connection between UHF sensor and power transformer is non-electrical and hence there is reliability and safety against any induced current at the power secondary. The Pulse

Capacitive Coupler method collects and measures the PD induced current at the detection coil which has a connection loop through some impedance to the earth line.

The PD phenomenon could change the chemistry of the associated gas and oil used in the high voltage devices. In chemical measurement PD is detected by the analysis of oil and gas samples released during the operation of high voltage transformer which provides information of the PD process. Usually, two chemical measurement techniques are used named as the High Performance Liquid Chromatography method (HPLC) and the Dissolved Gas Analysis method (DGA). HPLC analyses PD expelled by-products such as degraded forms of glucose induced by degradation of insulation. The DGA analyses provide information about the accumulated volume of gas produced by the PD process. In chemical measurements, sufficient expelled by-products or gas has to be collected before analysis can begin. Hence there is some time delay between collection and analysis. Chemical measurement techniques are therefore not suitable for real time monitoring. Chemical as well as electrical approaches are incapable of locating the exact position of PD sources.

1.3 Problem Statement

Electrical insulation is an important component in high voltage power equipment. After many years in-service, deterioration of the insulation system is inevitable due to the cumulative effect of mechanical, thermal and electrical stresses. The level of partial discharge (PD) activity is one of the leading indicators that may be used to assess the plant insulation quality. Furthermore, the identification of the exact location of the PD source is common problem and delay in diagnostics is also a cause of many failures of electrical transmission. If the fault is diagnosed at its initial stage it can be quickly rectified and can save the severe losses.

The accuracy level of the diagnostics of PD and to locate the exact position of its existence is still a great problem for the electrical power transmission. It requires exploration in many dimensions such as viable solution for cost effective fabrication of sensors and measurements techniques. Although there are many approaches to detect the PD pressure wave signal but the resulting signals have background noise. These problems can be avoided using optical-fibre sensors that can be placed inside the transformer tank without affecting the insulation integrity. This intrusive configuration is particularly useful in substations environments where there is a high level of outside interference.

The exact location of PD is a tedious job using conventional techniques such as leakage current method. But by measuring the time of arrival of acoustic wave the position information could be ascertained through sensors at multiple locations. In this perspective acoustic emission sensing is more preferable measuring tool in real time monitoring. It has an additional advantage of possessing better noise immunity for online real time applications. However, the exact origin of PD using acoustic method experiences difficulty due to interference and degradation of signals from environmental noise. Recent advancements in optical fibre technology have opened new areas of its applications which enable much more accurate measurement than conventional instrumentation. Furthermore, optical fibre sensors are well suited for use in hostile environments, often encountered in HV power engineering.

PD phenomena create deterioration in insulation of high voltage devices. The detection techniques could not provide high assurance that gives wrong prediction. The problem is seeking available solution best on poor sensing systems. The literature on the subject is scarce and the technique needs more extensive study to establish it. In this research PD phenomenon would be detected by the help of FOS and leakage current detection the results would be compared between them.

1.4 Research Objectives

This study would focus on the following objectives:

1. To conduct an experiment for the detection of PD using multi-mode optical fiber sensors under high voltage insulation oil conditions
2. To characterize the Partial discharges through leakage current sensor and signal monitoring in Palm oil insulation.
3. Comparison of optical and conventional (leakage current) and analyse the output in time and frequency domain of the waveform.

1.5 Scope of Research

The scope of this work is confined to the tasks mentioned below:
In this work a multi-mode optical fibre sensor would be used to detect PD signal in palm oil transformer. This study would remain confined in the high voltage range up to 1-50 kV applied to the electrode of the discharge reactor. This study would also remain confined in the comparison of two sensors; optical fibre sensor and electrical sensor.

The optical fibre sensor technique is inexpensive that can provide cost effective solution for the detection of PD in heavy transformers to monitor the efficiency and working of the transformer. The optical fibre sensor technique is inexpensive and more reliable than conventional sensors and provides safety due to total isolation from the line high voltage.

1.6 Significance of the Study

At present, the convention techniques of detection for partial discharges are expensive and have drawbacks in accuracy. The optical fibre sensor technique can also be used as an inexpensive alternative for the detection of PD in heavy transformers to monitor the efficiency and working of the transformer. The optical fibre sensor technique is inexpensive and more reliable than conventional sensors and provides safety due to total isolation from the line high voltage. Besides the advantage of immunity to electrical interference, the presence of optical fibre sensors inside the transformer does not affect its insulation integrity.

The leakage current method is a well-established method for the measurement of PD signal in the high voltage devices and insulators. This technique would be also employed for the detection of PD for comparison. Generally FFT spectrum is estimated to find the harmonic spectrum in the leakage currents. Implementation of both techniques could provide interesting information regarding the signal shape and spikes generation in both type of sensors. The work performed may be extended to monitor other parameters which are critical in the maintenance of power transformers.

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