

EFFECT OF THERMAL STRESS ON PARTIAL DISCHARGE CHARACTERISTICS
OF OIL IMPREGNATED PRESSBOARD

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Special dedicated
to my supervisor and family who encouraged
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ABSTRACT

Power Transformer insulation system is part of protection scheme that acquired by the transmission and distribution transformer to ensure the reliability and safety operation of the power transformer. Partial discharge (PD) is one of the event that occurs within insulation material located adjacent to the conductor that needs to be taken care of during condition-based assessment monitoring. Temperature is among factors that are known to severely degrade the dielectric properties of transformer insulation. Power transformer cannot operate without energy losses, which lead to rises in temperature. Failing to identify the root cause results in premature aging and ultimately to failure of the equipment. This report discusses about the characteristic of PD with influence of thermal stress. The insulation material characteristics was tested and measured through PD activities using CIGRE Method II test to study the electrical performance of samples. Applied voltage was set at 3 kVrms for half an hour ageing time and PD characteristics were investigated using PD Detector as per IEC60270 standard. The test was conducted inside Thermal Tank to imposed the sample with real-time temperature setting along with high voltage application. The result revealed that PDIV (Partial Discharge Inception Voltage) value decreased because of the effect of high temperature to the sample and PD numbers and magnitude increased also contributed by the effect of high temperature.

ABSTRAK

Sistem penebat kuasa alat ubah adalah sebahagian daripada skim perlindungan yang boleh didapati pada alat ubah penghantaran dan pengedaran untuk memastikan kebolehharp dan operasi keselamatan pengubah kuasa. Pelepasan separa (PD) adalah salah satu peristiwa yang berlaku dalam bahan penebat yang bersebelahan dengan konduktor yang perlu diberi perhatian semasa pemantauan penilaian berdasarkan keadaan. Suhu adalah antara faktor-faktor yang diketahui sangat merosakkan sifat-sifat dielektrik penebat transformer. Pengubah kuasa tidak boleh beroperasi tanpa kehilangan tenaga, yang mengakibatkan kenaikan suhu. Gagal mengenalpasti sebab penyebab utama penuaan pramatang dan akhirnya kegagalan peralatan. Laporan ini membincangkan ciri-ciri PD dengan pengaruh tekanan haba. Ciri-ciri bahan penebat diuji dan diukur melalui aktiviti PD menggunakan ujian CIGRE Method II untuk mengkaji prestasi elektrik sampel. Voltan terpakai ditetapkan pada 3 kVrms untuk masa penuaan setengah jam dan ciri-ciri PD disiasat menggunakan Pengesan PD seperti standard IEC60270. Ujian ini dijalankan di dalam tangki terma untuk mengenakan sampel dengan tetapan suhu masa nyata bersama dengan aplikasi voltan tinggi. Keputusan ujian menunjukkan bahawa nilai volum PDIV (Permulaan Pelepasan Permulaan) menurun kerana kesan suhu tinggi kepada sampel dan nombor PD dan peningkatan magnitud turut disumbangkan oleh kesan suhu tinggi.

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LIST OF ABBREVIATIONS

PD	-	Partial Discharge
IEC	-	International Electrotechnical Commission
PPM	-	Particles Per Million
SEM	-	Scanning Electron Microscope
P	-	Proportional
I	-	Integral
D	-	Derivative
PDIV	-	Partial Discharge Inception Voltage
PRPD	-	Phase Resolve Partial Discharge
LED	-	Light Emitting Diode
LCD	-	Liquid Crystal Display

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Transformer is one of the key essential equipment in an electric power system and it plays a significant role to provide reliable and optimize the electricity network across the country. Its reliability is important as its failure of operation can cost so much expenditure and will disturb the electricity network which cause power interruption. Figure 1.1 shows typical power transformer in power system network. Protection scheme on transformer and the material for insulation gives the transformer to operate accordingly over the time. Apart from protection scheme, transformer's performance and operation rely on insulation system, thus the insulation is one of the most critical transformer part to be taken care of [1] as depicted on Figure 1.2. The wide range of high voltage components whose successful operation depends on the correct choice of the electrical insulation for particular application and voltage level. The condition of the insulating materials is important or critical factor in the determining the life time of transformer.



Figure 1.1: Typical Power Transformer In Power System Network

Energy losses at winding, flux leakage, eddy currents, hysteresis which cause by the magnetization of core that produced during operation of the transformer give contribution to rises in temperature. One of part that get affected by temperature rises over the time is insulation in transformer itself. Figure 1.3 shows the results of insulation failure that occur over the time.



Figure 1.2: Winding Insulation Inside Power Transformer

The deterioration of insulation material closely related to the aging of the equipment, transformer. The process called depolymerization is process which the insulation material has loss or encounter problem of degradation of cellulose during the operation of the transformer. Depolymerization process release moisture in the cellulose as one of its by-products which cause by rises of temperature [2, 3]. Temperature and moisture are the major factors that cause degradation and deterioration of cellulose. The presence of this moisture due to the temperature and equipment aging in the cellulose weakens its dielectric strength, therefore making it vulnerable to possible failure [4]. Figure 1.4 shows the damage inside insulation of transformer due to the temperature and moisture existence between insulation. For the purpose of service longevity, insulation oil should absorb moisture from cellulose so as to keep it dryer and consequently reduce its rate of depolymerization.



Figure 1.3: Insulation Failure Lead To Equipment (Transformer) Loss



Figure 1.4: The Damage Of Winding Insulation

A good dielectric material is a must as the material is used as the insulator in transformer. This insulating materials property can be effected by electrical discharge phenomena in the insulating material. Electrical discharge can occur within insulating medium including gaseous, liquid or solid insulating material. Partial discharge is one of the phenomena that can occur within the insulating medium. According to the standard IEC 60270, partial discharge is defined as ‘localized electrical discharges that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharges are in general a consequence of local electrical stress concentrations in the insulation or on the surface of the insulation’. Usually, PD occurs due to local electrical stress focus on in the insulation or on its surface that can breakdown the insulation surface and properties.

The importance of understanding how temperature is related to transformer operation over the time, influence partial discharge characteristics motivated this research. This research studied the real-time responses of partial discharge activities under high voltage and temperature stress on pressboard when immersed in mineral oil.

1.2 Problem Statement

Partial discharge is one of the phenomena that occur in or at the surface of the insulating dielectric material and is one of the important things to be monitored during condition-based monitoring assessment activities. Partial discharge causes insulation to deteriorate progressively, which may lead to electrical breakdown. The integrity and quality of the insulation of high voltage equipment should be confirmed using partial discharge method as one of the quality need to be taken off during manufacturing, commissioning and lifetime. As the power transformer operation over the time, the losses created inside the transformer will cause temperature rise that contribute to the degradation of the insulating material. The internal temperature rise accelerates the rate of cellulose degradation particularly in paper-based insulation, for example pressboard. Cellulose degradation in pressboard will increase the rate of moisture by-products from cellulose.

Study on the effect of various factors on partial discharge activity is important for the condition monitoring of high voltage insulators. Many works, research have been reported on the effects of important factors on the partial discharge characteristics of high voltage insulator. The most important factors reported are the magnitude of applied voltage, applied frequency, inception voltage, extinction voltage of the partial discharge, size of the cavity or void and others. However, there are still problems occur in terms of practical applications and there is still no ideal way of monitoring the real-time application for thermal stress and electrical stress. Real-time PD testing can help determining loose, overheated and contaminated windings in motors and generator stators before these problems lead to insulation failure. During aging process, the PD data obtained certain time were analyzed, characterized and thus, the data are very close to the real aging condition of pressboard paper. The study of partial discharge behavior in depth as the transformer operation influenced by temperature need to be done to ensure the reliability and continuity of electricity supply across the nation.

1.3 Objectives of Project

The objectives of this project are as follows:

- i. To characterize partial discharge activities in pressboard with artificial void/cavity.
- ii. To study effect of thermal stress on partial discharge patterns of the pressboard.

1.4 Scope of Project

This research project discovered about the partial discharge characteristics on pressboard as insulating material. After producing the sample according to the specified size of void, signal partial discharge was obtained by conducting experiment. The sample then immersed in mineral oil for specified time for thermal aging effect. The setup for the experiment follows IEC 60270 standard test method. Analysis on partial discharge characteristics was carried out at PC by using LABVIEW software. To simulate real time monitoring for effect of temperature continuously, Thermal Tank is used in this experiment where test sample was put inside the Thermal Tank with applying high voltage with desired temperature test. The partial discharge characteristics is observed on the magnitude voltage of partial discharge occur, inception voltage and the of partial discharge distribution.

1.5 Project Report Outline

Chapter 1 generally describes on the insulation system on power transformer and partial discharge. This chapter also provides information on the objectives of the study, problem statement and the scope of the study.

Chapter 2 focused on the previous work done to setup an experimental research for evaluated and analyse partial discharge activities and methods available to achieve the optimization. This chapter also include the condition of the samples, types of samples, temperature setting and aging time that will be used in the experiment.

Chapter 3 discuss on the experimental setup for evaluating and analyse partial discharge activities on the sample.

Chapter 4 analysed the result obtained from LabVIEW. The analysis of partial discharge activities was discussed in this chapter.

Chapter 5 explains the conclusion of the experimental setup and condition for analyse the partial discharge activities and the suggestion for future works.

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