INVESTIGATION OF KRAFT INSULATING PAPER PROPERTIES UNDER ACCELERATED THERMAL AGEING ENVIRONMENT

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DECLARATION

I declare that this thesis entitled "INVESTIGATION OF KRAFT INSULATING PAPER PROPERTIES UNDER ACCELERATED THERMAL AGEING ENVIRONMENT is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MOHD NUR HISYAMUDDIN AJMAL BIN HAMID

Date : 30 MAY 2019

APPROVAL

I hereby declare that I have checked this report entitled "INVESTIGATION OF KRAFT INSULATING PAPER PROPERTIES UNDER ACCELERATED THERMAL AGEING ENVIRONMENT" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

I dedicate this project to almighty god, Allah S.W.T as always give me inspiration in doing this project. I also dedicate this project to my beloved mother who always encourage me all the way in the project and my studies. Not forgotten, I also would like to dedicate my project to my friends and lecturers that always give me support and sharing idea when implement this project. Lot of love for everyone of you from me. Thank you.

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ABSTRACT

Insulation material in power transformer is very crucial in protecting the material inside the transformer itself. Majority of transformers failure are caused by the insufficient protections that were provided by insulation material itself. When the power transformer operated, presence of moisture content, acidity and oxygen in the transformer can manipulate the properties of the insulation material. Therefore, this project is aim to investigate the most ideal combination between insulating paper and three types of insulating oil types in terms of their acidity, moisture content for insulating oil and tensile strength and colour change for insulating paper after thermal aging process happen. The paper be combines with the different types of insulating oils and be put in the oven to act as accelerated thermal aging process. The accelerated thermal aging be at 110 and 130 degree celcius and were run for 750 hours. The samples with different combination of insulating materials be removed from the oven every 250, 500 and 750 hours. The standards by ASTM were used along this project were implemented as guidance for every tests that had been made. After the samples were collect for different 250 hours duration of time, they go on test to check for their moisture, acidity, UV-Vis for insulating oil while tensile strength and colour changed for insulating paper. After all the samples be removed and tests, the data for the test will be analyze before the combination that have high quality to be the most suitable combination of insulating material will be suggest to be use in the power transformers.

ABSTRAK

Bahan penebat dalam transformer kuasa sangat penting dalam melindungi bahan di dalam transformer itu sendiri. Sebahagian besar kegagalan transformer disebabkan oleh perlindungan yang tidak mencukupi yang disediakan oleh bahan penebat itu sendiri. Apabila pengubah kuasa dikendalikan, kehadiran kandungan kelembapan, keasidan dan oksigen dalam pengubah boleh memanipulasi sifat-sifat bahan penebat. Oleh itu, projek ini bertujuan untuk menyiasat kombinasi paling ideal antara kertas penebat dan tiga jenis minyak penebat dari segi keasidan, kandungan lembapan dan kekuatan tegangan selepas proses penuaan haba berlaku. Kertas akan digabungkan dengan pelbagai jenis minyak penebat dan akan dimasukkan ke dalam ketuhar untuk bertindak sebagai proses penuaan terma yang dipercepatkan. Penuaan terma yang dipercepatkan ialah dalam keadaan 110 dan 130 darjah Celsius dan dijalankan selama 750 jam. Sampel dengan gabungan bahan penebat yang berbeza akan dikeluarkan daripada oven setiap 250, 500 dan 750 jam. Piawaian oleh ASTM digunakan sepanjang projek ini telah dilaksanakan sebagai panduan bagi setiap ujian yang telah dibuat. Setelah sampel dikumpul untuk setiap 250 jam masa yang berlainan, sampel akan menjalani ujian untuk memeriksa kelembapan, keasidan, UV-Vis untuk penebat minyak dan kekuatan tegangan dan perubahan warna untuk penebat kertas. Setelah semua sampel dikeluarkan, data untuk ujian akan dianalisis sebelum kombinasi yang mempunyai kualiti yang tinggi untuk menjadi gabungan bahan penebat yang paling sesuai akan dicadangkan untuk digunakan dalam transformer kuasa.

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LIST OF SYMBOLS AND ABBREVIATIONS

PFAE	-	Palm Fatty Acid Ester
TAN	-	Total Acid Number
ASTM	-	American Society For Testing and Material

CHAPTER 1

INTRODUCTION

1.1 Overview

A research background, problem statement, project objective and scope of the project were discussed in this chapter. The purposed of the project were exposed in the project background. The problem statements were a short brief about the issues what to avoid and to be solved. The purposed and goal of the project were explained in objective and scope of the project.

1.2 Research Background

Nowadays, the electrical power is really important in daily lives to start up the electrical appliance in surrounding. Power transformer is the most valuable appliance in terms of delivering the electrical power. Transformer is device that can changes the level reading of electricity. The lifetime of insulating material in the transformers can affect the electricity that is distributed in the system. Unexpected failure of transformer can occur after long run in-service which can cause highly loss and cost to company that provide the electrical power to consumer.

Thus it is important to slow down the process of aging occur in transformer by study the insulation conditions in the transformer. Insulation can involve in three forms; gas, solid and liquid. This project focuses on liquid and solid insulations in transformer. The function of liquid insulation that is transformer oil is to provide the cooling effect by dissipating the heat between the core and coils to radiator [1].The function of solid insulation or insulating paper is to create turns of wire which can build emf on each turn contributing to the total emf between end terminals.

When in operating condition, power transformers can suffer from the thermal process. The thermal process accelerates the process of aging in the transformer and potentially can be a threat to the safety of the power transformer. Aging process can cause the material properties of the power transformer changed. Generally, the operate temperature of power transformer need to be control by reducing the temperature using different type of insulating oil. The type of insulate paper also need to use different type so that the life span of insulating paper can be increase. So, a study to improve the lifetime of insulating paper needs to carry out by controlling the type of paper and type of oil of the transformer.

1.3 Problem Statement

Damage in power transformer will cause interruption in the process of electrical distribution system network. Mostly of damage in transformer happen because of the insulation problems in the transformer itself. The dielectric insulation problem can be in several factors such as moisture, acidity and many more. This problem can decrease the lifespan of the transformers and the users need to invest lot of money to repair them. Thus this project will focus on comparison of the insulation properties of different type of insulating oil including the tensile strength of the insulating paper. It is quite important to choose the most suitable combination of the insulating material in power transformers because not only it can increase the lifespan, it also can increase the efficiency of the power transformers. Based on the research by Stefan Tenbohlen in 2008, he only focused on different type of insulating oils with a type of insulating paper. Moreover, there are no researcher that making research about which combination of different types of oils and insulating paper is the most suitable to be use in power transformers. Therefore the aging using high temperature are carried out to act as the process of thermal aging in the transformer. The aging process using the Stefan Tenbohlen method were choose before the test on properties of the insulations can be carry on.

1.4 Objective

The purposes of the projects are:

1. To investigate the insulation behavior and properties of insulating materials under accelerated thermal aging process.
2. To analyze the relation in insulation properties between different combination of insulating oil with Kraft paper after different period of aging process in different temperatures.
3. To obtain the optimum combination of insulating material based on tensile strength and structural of the Kraft paper after different period of aging process in different temperatures.

1.5 Scope Of Work

The scopes of the research are:

1. Three different types of insulating oil that are used in this experiment are PFAE, Midel En and Gemini-X while insulating papers that were used was Kraft paper.
2. Accelerated thermal aging process are run for 750 hours at 110 Celcius and 130 Celcius and the sample were collected every 250, 500 and 750 hours.
3. The tests that were done after aging process are to check moisture, acidity and UV-Vis for insulating oils while tensile strength and structural test for insulating paper.

1.6 Research Contribution

The research were expect to help the power transformer user choose the best type of insulating paper and type oil to be used in their transformer in term of solid insulation for winding. The decisions are to compare the insulation characteristic after the aging process using Stefan Tenbohlen technique. The role of temperature was to stimulate the process of aging. When the temperature was increased, the aging process of the insulation materials in transformer also increased including the

moisture content. The moisture content can manipulate the properties of oil and degradation rate of paper.

1.7 Thesis Outline

This project report consisted of five chapters. Chapter 1 briefed about the background, problems, objectives and scope of the project. In Chapter 2, the theories and some knowledge that related to the project were explained. Next, Chapter 3 described the methodologies that were used to get the result of the project that were run. Chapter 4 illustrated and interpreted the result that has been received when project were carry on. Lastly, Chapter 5 was the conclusion that has been concluded throughout this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about theory of power transformer**,** characteristic of insulation material, type of oils that were used in power transformer, type of insulating paper used in power transformer, aging process and method of analysis that were used to monitoring the condition of insulation in power transformer.

2.2 Power Transformer

Power transformer is a device with two or more winding which by electromagnetic induction, transform a system of alternating voltage and current into another system voltage or current with different value but have same frequency for the purpose if transmitting electrical power **[2]**. When electric current flows through a wire, it generates a magnetic field or magnetic flux along the wire. The strength of magnetic flux density is related to the size of the electric current that flow. The bigger the current , the stronger the magnetic field. Current in the wire will generate electric when magnetic exists around a piece of wire. So when there is a second coil of wire next to the first one fluctuating electric current were send into the first coil, we will create an electric current in the second wire. The current in the first coil were called as the primary current and the current in the second wire is the secondary current. What we've done here is pass an electric current through empty space from one coil of wire to another through a process of electromagnetic induction where the current in the first coil induces the current in the second coil. We can make electrical energy pass more efficiently from one coil to another by wrapping them around an iron core. To make a coil of wire, just simply curl the wire round into loops. If the second coil has the same number of turns as the first coil, the electric current in the second coil will have the same size as the first coil. But if primary coil have more of

turns in the second coil, we can make the secondary current and voltage bigger than the primary current and voltage. Figure 2.1 shows the structure of power transformer while Figure 2.2 illustrates the winding at a coil of transformer.

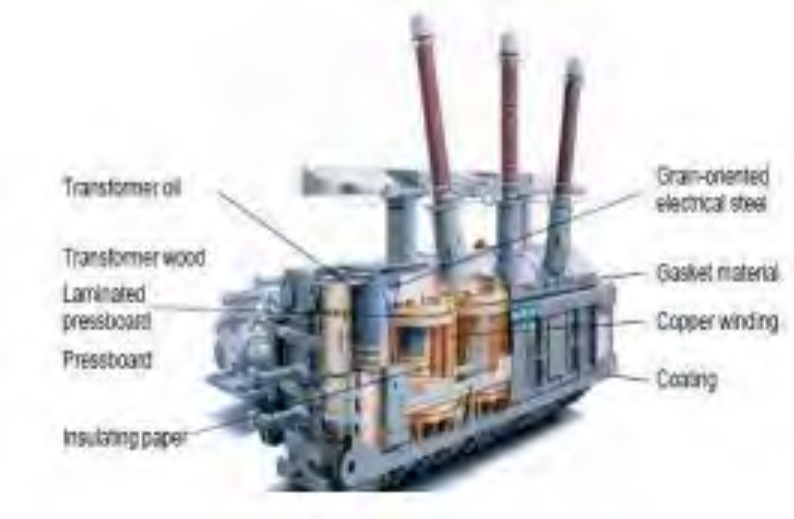

Figure 2.1: The structure of power transformer

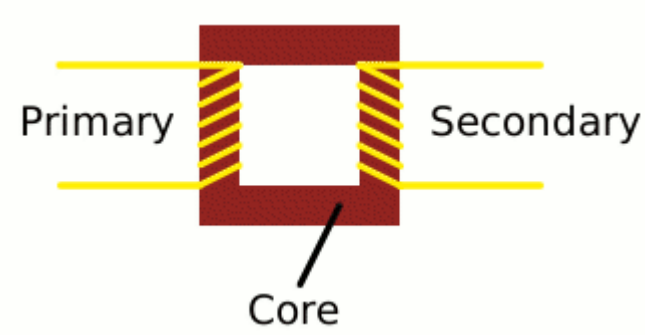

Figure 2.2: The winding at core in transformer

2.3 Insulation Material in Power Transformer

The lifespan of the power transformer depend heavily on the insulation system. The insulation system in power transformer can be consists of liquid, gas and together with the solid material [3]. The insulation material must have good insulating properties to protect the component in the power transformer from damage. The large power transformer is subjected to has different characteristic due to demand of the

users. So, the insulation in transformer had to be modeled properly according to the characteristic of the transformer itself

2.3.1 Liquid Insulation

The liquid insulation in transformer is known as the transformer oil. The transformer oil in the power transformer is used to dissipate the heat from the transformer. Oil that used in the transformer are produce from special grade of the petroleum oil and ester oil that had different level of viscosity and specific gravity **[4]**. There are three groups of transformer oil that usually used such as mineral oil, synthetic oil and ester oil as shown in Figure 2.3. This project only focused on mineral oil and two types of ester oil.

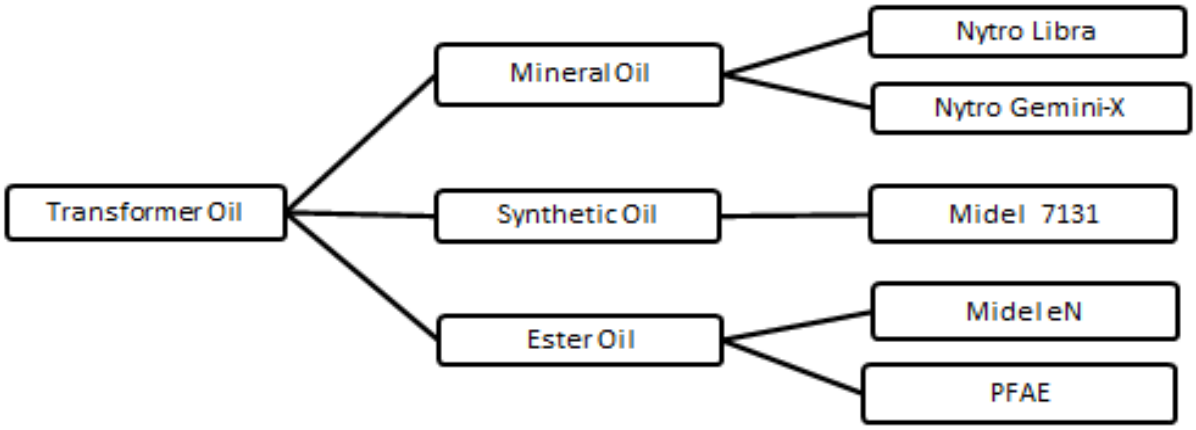

Figure 2.3: Type of transformer oil

2.3.1.1 Mineral Oil

Mineral oil need to be right away refined from the prevalently naphthenic crude oil before it can be used as a part of electrical assembly. Distillates from the crude oil can be refined with different procedure such as dissolvable extraction, hydro treating or hydro cracking. Transformer oil is a mixture of paraffinic, naphthenic, and aromatic hydrocarbons as shown in Figure 2.4 that is prone to oxidation.

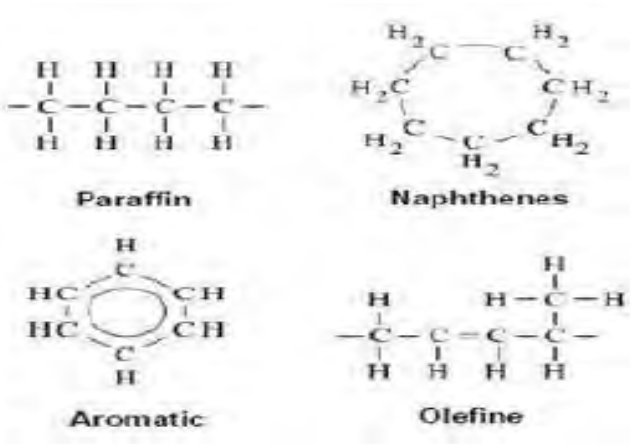

Figure 2.4: Hydrocarbon structure of mineral oil [14]

Oxidation of the oil leads to formation of more polar compound such as acid, ketone and alcohol. These not only can affect the insulating properties of the oil but also will form sludge that can affect the heat transfer properties of the mineral oil. This can manipulate the performance of power transformers including reducing the life span of the power transformer itself **[5]**. So, it is quite important to check the condition of the power transformer by monitor their solid and oil insulation properties. Some example of mineral based insulation oils that available in the market are Hirax, Nytro Libra and Nytro Gemini-X.

2.3.1.2 Natural Ester

Natural Ester is a vegetable oil type. These oils are normally integrated from living life forms and come specifically from soya, sunflower, or rapeseed. In particular, natural esters are made from an esterification response between a tri-liquor and fatty acids. Different procedures permit the last item to be acquired by the trans-esterification response or a blend of mono and tri-esters **[6]**. Since the middle of the 1990 and on account of ecological concerns, a great deal of studies were propel for the advancement of vegetable oils. These days, its utilization begins to be escalating in the distribution transformer market and the test of these in a year from now is to extend its utilization to the power transformer user. In any case, with natural issues now turning out to be critical, the utilization of an item with a high fire point temperature and high biodegradability is turning out to be amazingly appealing.

In this way, the latest accessibility of characteristic ester liquids in view of "renewably sourced" vegetable oils have given another insulating liquid to use with transformers.

2.3.2 Gas Insulation

Gas insulation is air at the atmospheric pressure. Collisional ionization between the free electron and gas molecule will result an occur breakdown in gasses. Insulating gases are chosen based on their chemical inertness and stability. Nitrogen (NS), carbon dioxide (CO_2), Freon (CCL_2F_2) and sulphur hexafluoride (SF_6) are some of insulating gases. A vacuum condition is an ideally condition, where collisional ionization is prevented due to absence of gas molecule. Hence, significantly large breakdown voltages occur for ideally condition [7].

2.3.3 Solid Insulation

A material must have good mechanical and bonding strength before it can be choose as solid insulation in power transformer. There are two type of material that usually used that is organic and inorganic material. Solid insulation inside the power transformer is the largest insulation in electrical equipment. It can be in form of Kraft paper (electro-technical), thermal upgraded paper and pressboard as shown in Figure 2.5. Some of the functions of solid insulation are electrical insulation, direction of oil flow and the mechanical stability. Aging can occur in solid insulation and can affect the electrical and mechanical properties of the transformer. Temperature, water and oxygen are the caused why aging can occur.