"I hereby declare that I have read this report and in my opinion this project is sufficient in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering (Industrial Power) with Honors".

Signature : ……...

Supervisor's Name : Imran Bin Sutan Chairul

Date :

ENHANCING THE BREAKDOWN VOLTAGE OF MINERAL OIL MIXED WITH NATURAL ESTER OIL

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A thesis is submitted in fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

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"I declare that this report entitled "*Enhancing the Breakdown Voltage of Mineral Oil mixed with Natural Ester Oil*" is the results of my own research except cited in references. The report has not been accepted for any degree and is not currently submitted in candidature of any other degree".

Signature : …….

Name : Ahmad Firdaus Bin Hashim

Date :

Dedicated to my beloved father and mother,

Hashim Bin Mat Ali & Ruhaida Binti Sulaiman

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ABSTRACT

Insulating liquid in the power transformer applications functioning as a coolant and an insulator. Till now many researcher do many research and find an alternative in replacement of conventional Mineral Oil (MO) that usually used in the transformer. Besides that, Palm Fatty Acid Ester (PFAE) oil is one of the Natural Ester Oil (NEO) that offers many advantages and because of that reason, PFAE oil is preferred and suggested to be used in mixed with MO in order to enhance the breakdown voltage (BDV) for this project. Thus, the main objective in this study is to obtain the best ratio of mixed insulating oil between MO and PFAE oil without reducing too much quantity of MO in order to enhance the BDV and ensuring the best ratio is non-corrosive and has great flash point. The BDV test is carried out using Megger OTS60PB in accordance with the ASTM D1816 standards with 1 mm electrode gap and Coulometric Karl Fischer Titration in accordance with the ASTM D1533 standard is used for the water measurement. Hence, the measurement of corrosive sulfur is performed using Method B from ASTM D1275 standard while Pensky-Martens closed cup tester according to ISO 2719:2002 standard is used for flash point measurement. Throughout the experiment that conducted, the ratio of 70% MO + 30% PFAE represents the best ratio in enhancing the BDV with the properties for flash point which is 156°C. Besides that, the ratio of 70% MO + 30% PFAE has great properties for corrosive sulfur where the copper strip that immersed in insulating oil for this ratio shows slight tarnish or other word is non-corrosive. Hence, it is take into account of 30% of ester content of PFAE oil can improve the dielectric strength without degrade the heat transfer and gives less significantly BDV when presence of moisture content as well as non-corrosive with great the flash point measurement.

ABSTRAK

Penebat cecair dalam aplikasi kuasa pengubah berfungsi sebagai penyejuk dan penebat. Sehingga kini ramai penyelidik melakukan banyak penyelidikan dan mencari alternatif dalam penggantian minyak mineral (MO) konvensional yang biasanya digunakan dalam pengubah. Selain itu, minyak ester asid lemak sawit (PFAE) adalah salah satu daripada minyak ester semulajadi (NEO) yang menawarkan banyak kelebihan dan kerana sebab itu, minyak PFAE adalah pilihan dan dicadangkan untuk digunakan dalam campuran dengan MO untuk meningkatkan voltan kerosakan (BDV) bagi projek ini. Oleh itu, objektif utama dalam kajian ini adalah untuk mendapatkan nisbah yang terbaik minyak penebat campuran antara MO dan minyak PFAE tanpa mengurangkan terlalu banyak kuantiti MO bagi meningkatkan BDV dan memastikan nisbah yang terbaik adalah bukan menghakis dan mempunyai takat kilat yang bagus. Ujian BDV dijalankan menggunakan Megger OTS60PB mengikut piawaian ASTM D1816 dengan jurang 1 mm elektrod dan Coulometric Karl Fischer Titration mengikut piawaian ASTM D1533 digunakan untuk mengukur air. Oleh itu, pengukuran sulfur menghakis dilakukan dengan menggunakan Kaedah B dari piawaian ASTM D1275 manakala Pensky-Martens tester mengikut piawaian ISO 2719: 2002 digunakan untuk mengukur takat kilat. Sepanjang eksperimen yang dijalankan, nisbah 70% MO + 30% PFAE mewakili nisbah terbaik dalam meningkatkan BDV dengan sifat-sifat untuk takat kilat iaitu 156°C. Selain itu, nisbah 70% MO + 30% PFAE mempunyai ciri-ciri yang bagus untuk sulfur menghakis di mana jalur tembaga yang tenggelam dalam penebat minyak untuk nisbah ini menunjukkan sedikit cemar atau perkataan lain adalah bukan menghakis. Oleh itu, adalah mengambil kira 30% daripada kandungan ester minyak PFAE boleh meningkatkan kekuatan dielektrik tanpa merendahkan pemindahan haba dan memberi kurang ketara BDV apabila kehadiran kandungan kelembapan serta bukan menghakis dengan potensi yang bagus pengukuran takat kilat.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
BDV	-	Breakdown Voltage
ECT	-	Electrostatic Charging Tendency
IEC	-	International Electro Technical Commission
ISO	-	International Organization for Standardization
MO	-	Mineral Oil
MS	-	Malaysia Standard
NEO	-	Natural Ester Oil
PB	-	Portable
PCB	-	Polychlorinated Biphenyl
PFAE	-	Palm Fatty Acid Ester
PPM	-	Parts Per Million
RBDPO	-	Refined Bleached Deodorized Palm Oil
SOP	-	Standard of Procedure

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will review about the research background and motivations, problem statement, objectives of this study, scopes of works, contribution of research and end with thesis outline. The general overview of this study will briefly explain in research background and motivations. Hence, the issues that need to be solved during this study will be explained in the problem statement. For objectives of this study and scopes of works will be described about the main purpose of this study conducted that need to be achieved in order to solve the problems that have been identified. Lastly, the report outline will shows the summary of chapter provided in this thesis.

1.2 Research Background and Motivations

In the electric power transmission and distribution system, the transformer has very important responsibility in providing a reliable and efficient electricity supply. The transformer is listed as the most critical equipment for high voltage equipment. The liquid that filled in the power transformers applications are working as an electrical insulation and as a cooling medium. Usually, mineral oil is one of the liquid insulation that often used in the high voltage transformer which is associated with the reason of lower cost and good properties besides low in losses of dielectric, high the strength of electric field and good performance for a long term. However, in considering the environmental factor makes the mineral oil has a limited point. The first one is mineral oil is well known as non-biodegradable which can contaminate soil and water when

there is serious oil spills. Hence, mineral oil also is non-renewable because mineral oil is produced from the base of petroleum and it will run out in the future because of petroleum is nonrenewable [1].

For that reason, many researchers gives an efforts rapidly on developing a fully biodegradable insulating fluid that were started in the mid-1990s [2]. Natural ester oil (NEO) gives more advantages compared to mineral oil in terms of fire safety, environmental friendly and insulation ageing. In fact, NEO is a non-toxic, more biodegradable, and less flammable and it will be more suitable that can be used in the transformer insulation system [1, 3]. Malaysia is well known in palm plantation and palm oil also gives a lot of impact in a variety of application use. Many researchers [4] are studied to make palm-oil as based transformer oil as one of the alternative. There are a lot of benefits of palm oil which are the cooling stability of palm oil is the highest and very good oxidation stability. A knowledge to know about palm oil, it can be potential to substitute to mineral oil due to has excellent in dielectric properties. Since 2006, Lion Corporation take initiatives to develop Palm Fatty Acid Ester (PFAE) as an insulation oil for transformer. PFAE has superior insulation performances in high voltage transformer and environmental friendly [4, 5].

In recent years, investigations on mixed insulating oil between mineral oil and natural ester oil are being worked out and become interested from many researchers. I. Fofana [6] propose the mixed insulating oil in order to enhance its stability of insulating oil which consists of dielectric, flash point, and thermal properties. Mixed insulating oil which mixtures of mineral and ester oils have been reported that having a good thermal performance in term of improved oxidation stability besides to minimize the lower cost of transformer. Since development of the mixed insulating oil become popular among researcher, a report stated that the optimal ratio of mixed insulating oil is consists of 80% of mineral oil and 20% of ester oil [7].

In the last decade, the presence of corrosive sulfur compound have been reported as typical winding failures in transformers and shunt reactors due to the resultant formation of copper sulfide (Cu_2S). Corrosive sulfur is discussed as unexpected failure in electric power transformer and caused the power grid has great loss [8, 9]. In transformer oil, the corrosive sulfur originates mainly from the refining process of mineral oil in which process there were residual sulfur ingredients. The content of corrosive sulfur in transformer oil is probably 5% or more and sulfur was named due to can occur with the copper wire active sulfur. Copper sulfide

is the main component of the deposition on the copper and insulation paper which had experienced the corrosion. The reaction between the corrosive sulfide in the transformer and the copper wire at 80~150°C produces the product which is copper sulfide. On the other hand, Dibenzyl Disulfide (DBDS) is pointed out that the main corrosive sulfide occurred in the transformer oil. The concentration of oxygen in the oils is take into account that affects the deposition of copper sulfide on the paper surface [10].

Since insulating oil is taking into account of safety in terms of flammable liquids and fire hazards, many researchers are carried out the study in terms of physical properties especially conducting the flash point. The requirement to do study the flash point on insulating liquid due to quality control purposes as well as for controlling the flammability risk and classification of liquid where to warn a risk and enable the correct precautions to be taken when using, storing or transporting the insulating oil [11].

Therefore, many researchers have been carried out the research and gives the efforts to identify the optimal ratio of mixing of mineral oil and PFAE oil to produce as a liquid insulating materials for power transformer applications. Besides that, a further studies need to be done to resolve the issue of corrosive sulfur in transformer oil and propose effective suppression measures. From this way can ensure the safe and stable operation of the power transformer.

1.3 Problem Statement

Up to now, recent studies showed that mineral oil (MO) as insulating oil that often used in power transformer application has been reported has weakness in terms of environmental factors, non-biodegradable, non-renewable and lowest moisture content. Meanwhile, previous studies stated that PFAE oil based natural ester oil (NEO) has promoted many advantages in terms of fire safety, environmental friendly, more biodegradable, less flammable, non-corrosive and highest moisture content. Therefore, the best ratio of mixed insulating oil between MO and PFAE oil will be produced in order to enhance its stability which consists of breakdown voltage (BDV) without reducing the quantity of MO too much. Since the effect of corrosive sulfur on mixed insulating oil is not be done research widely by any researchers and it is thus necessary gives opportunity to carry out of study the effect of corrosive sulfur on mixed insulating oil. In ensuring the mixed insulating oil that produced is presents the best ratio of concentration of mixed insulating oil, the study of flash point is conducted on mixed insulating oil in order to determine the minimum temperature at which heated of mixed insulating oil gives off sufficient vapor to form a flammable mixture with air.

1.4 Objectives

There are three objective that need to be accomplished in order to make this project successful which are:

1. To obtain the mixed insulating oil with the best ratio for the concentration of mineral oil mixed with natural ester oil by assessing the AC breakdown voltage.
2. To study the effect of the presence of corrosive sulfur compound that react on contact with copper in the mixed insulating oil.
3. To study the flash point of insulating oil in order to determine which the ratio of concentration of mixed insulating oil that gives the best result for the flash point.

1.5 Scope of Works

The scopes of this study are:

1. The ratio of concentration of mixed insulating oil used the types of mineral oil is Nytro Libra oil and types of natural ester oil used is Palm Fatty Acid Ester (PFAE) oil. The baseline liquid used in this study is 500 milliliter.
2. Breakdown Voltage (BDV) measurement performed by following ASTM D1816 standards which using the gap of electrode 1 mm.
3. The test method for measuring moisture content in insulating oil is complies with ASTM D1533 standards where the test known as Karl Fischer.
4. ASTM D1275 standards is applied as test methods to detect corrosive sulfur in insulating oil while ASTM D130 standards is used as reference of copper strip tarnish level classifications.
5. The test method for the test of flash point is performed in according to ISO 2719:2002 standards which using Pensky-Martens closed cup method.

1.6 Contribution of Research

The expected from this research is by mixing of mineral oil (MO) and natural ester oil (NEO) will give improvement of characteristic and behavior in terms of electrical, chemical and physical properties. This research will be carried out on various sample of mixed insulating oil with differences ratio of concentration in identifying which types of ratio of concentration could enhancing the breakdown voltage (BDV). Since PFAE oil does not contain of any sulfur compound, it could give an advantage for doing mixed with MO in this experiment and thus can provide the best protection from corrosive sulfur in producing the mixed insulating that be used in power transformer application. Hence, the properties of mixed insulating oil can be identified through this experiment which is the value of flash point for mixed insulating oil that conducted in the experiment will be compared with the physical properties which is flash point for both MO and NEO in providing benchmarks. Thus, by this study can acknowledge and identify which type of ratio of concentration of mixed insulating oil will presents the best ratio of mixed insulating oil in terms of dielectric strength, corrosive sulfur and flash point.