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FINAL YEAR PROJECT REPORT II

STUDY OF MOISTURE EFFECT ON BREAKDOWN VOLTAGE AND STRUCTURE OF MINERAL AND PALM OIL BASED INSULATION OILS

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STUDY OF MOISTURE EFFECT ON BREAKDOWN VOLTAGE AND STRUCTURE OF MINERAL AND PALM OIL BASED INSULATION OILS

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

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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I declare that this report entitle "*Study of Moisture Effect on Breakdown Voltage and Structure of Mineral and Palm Oil Based Insulation Oils*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature :…….

Name : NORHASHIDAH BINTI MOHD NAJRI

Date :…….

To my beloved mother and father

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ABSTRACT

Theoretically, insulation oil of transformer purposely used to cool down the power transformer when heat dissipation condition occurs during operation. Most of power transformer failure is caused by physicochemical reaction such as heat, moisture content and oxygen in transformer oil. Therefore, the aim of this project is to measure Breakdown Voltage (BdV) and to obtain the spectral characteristic for mineral and vegetables-based transformer insulating oil under moisture influence. Besides that, relationship between BdV and Fourier Transform Infrared Spectrometry (FTIR) test are studied. In order to achieve objectives of this project, two type of testing are used namely BdV and FTIR. The standard of IEC 60156:1995 and ASTM D2144 are used as a guidelines in testing procedure and confirmation of the finding. The result shows that influence of moisture gave effect of the breakdown voltage and spectral characteristic in mineral and vegetables-based transformer insulating oil. It also showed that BdV and FTIR test have similarities in determining the condition or performances of transformer insulating oil.

ABSTRAK

Secara teorinya, tujuan sebenar minyak penebat alat pengubah digunakan untuk menyejukkan pengubah kuasa apabila keadaan pelesapan haba berlaku semasa operasi. Kebanyakan kegagalan kuasa pengubah adalah disebabkan oleh reaksi fizikokimia seperti haba, kelembapan dan oksigen dalam minyak pengubah. Oleh itu, tujuan kajian ini adalah untuk mengukur Voltan Pecahan (BdV) dan untuk mendapatkan ciri-ciri spektrum minyak penebat alat pengubah yang berasaskan mineral dan sayur-sayuran di bawah pengaruh kelembapan. Selain itu, hubungan antara BdV dan *Fourier Transform Infrared Spektrometri* (FTIR) ujian dikaji. Dalam usaha untuk mencapai objektif projek ini, dua jenis ujian digunakan iaitu BDV dan FTIR. Piawaian IEC 60156: 1995 dan ASTM D2144 digunakan sebagai garis panduan dalam prosedur ujian dan pengesahan dapatan. Hasil kajian menunjukkan bahawa pengaruh kelembapan memberi kesan kepada nilai voltan pecahan dan sifat spektrum dalam minyak penebat alat pengubah yang berasaskan mineral dan sayur-sayuran. Ia juga menunjukkan bahawa BDV dan FTIR mempunyai persamaan dalam menentukan keadaan minyak penebat alat pengubah.

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LIST OF ABBREVIATIONS

BdV	-	Breakdown Voltage
FTIR	-	Fourier Transform Infared Spectrometry
PFAE	-	Palm Oil Fatty Acid Ester
DGA	-	Dissolved Gas Analysis
UV	-	Ultra Violet
kV	-	kilovott
ATR	-	Attenuated total reflectance
IR	-	InfraRed

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Power Transformer is one of the valuable assets in delivering power throughout nation. There are many types of transformer in industry such as dry type and liquid oil type. Generally in Malaysia, liquid oil type transformer is used in distribution phases. Breakdown event of transformer may cause highly loss and cost to power provider companies. Each parts of it need to be monitored and diagnosed for reducing the breakdown event. One major parts of transformer is the insulation oil; used for heat dissipation medium, arc quenching media and insulator. There are two types of insulation oil currently used in transformer such as mineral-based oil and vegetables-based oil. Mineral oil is used in Malaysian transformer for many years.

The primary factor of failure of the power transformer which consist of oil is due to physicochemical reaction in presence of heat, oxygen and moisture during the operation. There are many diagnostic technique that been used to measure the quality and performance of the insulation oil of the transformer in laboratory. The traditional diagnostic technique of insulation oil are interfacial tension (IFT), dissipation factor (Tan Delta), water content, and acidity are widely used in oil laboratory. There is an alternative diagnostic technique of insulation oil that can be used such as Fourier Transform Infrared Spectrometry (FTIR). FTIR is one of the monitoring tool to evaluate the condition of the insulation oil. This alternative technique can identify the changing or difference of the structure in insulation oil with the original finger print of the waveform of the insulation oil. This experimental project were done by using mineral and vegetables based insulating oil. In this project, the result

were analyzed to determine the effect of moisture on both insulation oil by using BdV test and FTIR.

1.2 Project Motivation

The motivation to conduct and contribute into this project is to measure dielectric strength and analyses structure of different type of oil used in transformer. The common insulation oil used in transformer is mineral oil. But a few years back, vegetable oil was introduced as an insulation of transformer such Palm Oil Fatty Acid Ester (PFAE), MIDEL and Envirotemp FR3. This project is proposed to investigate the physicochemical reaction changes in presence of moisture that affecting the transformer oil. The physicochemical reaction in presence of heat, oxygen and moisture will affect the operation of power transformer and can cause failure to a transformer. FTIR is one of the chemical testing that can be used to measure the properties of the oil. FTIR and BdV will be used in this project to measure the properties for both transformer oil based.

1.3 Problem Statement

The diagnostic for transformer oil is divided into chemical properties and electrical properties. The example of electrical properties tests are BdV and dielectric dissipation factor. This is used for measure the dielectric strength of the transformer oil. In chemical properties part, Dissolve Gas Analysis (DGA) and moisture content are widely used in laboratory. In fact, there is an alternative technique for chemical properties test that can be introduced. The technique is FTIR. This technique is infrequently used for transformer oil and mostly this technique commonly used in lubricants oil condition monitoring. Thus, this project applied FTIR to analyze the functional group of the transformer oil under moisture effect.

1.4 Project Objectives

The objectives of this project are stated below:

1. To measure Breakdown Voltage (BdV) for both mineral and vegetable based transformer insulating oil under moisture influence.

2. To obtain the spectral characteristics for both mineral and vegetable based transformer insulating oil under moisture influence by using Fourier Transform Infrared Spectrometry (FTIR).

3. To study the relationship between Breakdown Voltage (BdV) and Fourier Transform Infrared Spectrometry (FTIR) tests.

1.5 Project Scopes

The scope of this project necessitated as followed:

1) Magnetic Hot Stirrer is used to well stir the water droplets in the insulating oil sample.

2) The moisture effect in insulating oil sample is conducted using water addition in milliliter unit (ml).

3) The *International Electrotechnical Commission* (IEC) 60156:1995 standard is used as a guide for the result of Breakdown Voltage (BdV) while *American Society for Testing and Materials* (ASTM) D2144 used for procedure of FTIR.

4) The insulation mineral oil based is Hyrax Hypertran, meanwhile insulation vegetables oil based is Lion PFAE.

1.6 Report Outlines

The thesis of the project covered the five chapter. Chapter 1 explained about the project background, problem statement, objective and scope of project. Chapter 2 describes the theory or general concept that related to the project and review from previous research works. It will be more focusing on the performances of the insulation oil that been affected by the moisture. Then, Chapter 3 illustrated methodology applied in order to get the required output. The flow of project development will be explained by a flow chart. Chapter 4 interpreted and explained the result by represents tables, graph and diagrams. Analysis and discussion on the problem issued were discussed. Lastly, Chapter 5 gives a summarized work and conclusion for overall of this project. Suggestion for further research of this study were also stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principles

This topic will discuss about theory of transformer, properties of insulation material, type of transformer oil in power transformer, diagnostic technique that widely used for monitoring the condition of insulation and the software that will be used.

2.2 Transformer

Transformer is an important device that used in electrical power system. Transformer is a mechanism that transmit energy by electromagnetic induction from one circuit to another circuit. Function of the transformer is to step up and step down voltage [1]. The main component of the transformer is core, winding and insulation material. Insulation material that used in transformer are kraft paper and insulation oil. The insulation material should provide high insulating to protect the other component from collapse.

2.3 Insulating Material Properties

The basic properties of insulating material are resistivity, breakdown voltage, permittivity, and dielectric loss. However, the insulating material properties should be high dielectric strength, resistivity, tensile strength for solid insulation, degree of thermal stability and good thermal conductivity to become perfect. Besides that, the insulating material must have well mechanical properties for example capable to withstand moisture, vibration,

bending and it also should have competence to withstand chemical strike and condition of service in other adversative. [2]

2.4 Transformer Oil

Power transformer is one of the important device in electrical power system. Transformer can be categorized depend on the purpose and different ways. There are five categorized in power transformer which is pole mounted transformer, house hold transformer, dry type distribution transformer, current transformer (CT), and oil immersed power transformer. [3]

Power transformer is filled with the liquid insulation oil. The purpose of the liquid insulation oil is to dissipate heat inside the transformer. In addition, the insulating oil also prevent direct contact of oxygen with cellulose paper insulation of winding and preserve the core and winding.

There are many type of the liquid insulation oil in industry. But the mineral oil is widely used as a liquid insulation for insulation of transformer. In few year back, many researcher is investigated more about the vegetable oil for using as an insulation oil for transformer because of the characteristic is similarly to the mineral oil.

Mineral oil is known as a petroleum based oil. The function of the mineral oil is a coolant or thermal fluid in electric component but not as a conduct electricity and this oil widely used in industry and also for mechanical part. This mineral oil is made up from mixtures of different organic compound that composed mainly of carbon and hydrogen in molecules. Mineral oil is divided into three categories crudes oil which are paraffinic, napthenic and mixed crude. Mixed crudes is the combination of paraffinic and napthenic crude. The advantages of the mineral oil are good resistance to oxidation, good viscosity index, relatively low fire point but mineral oil are low moisture tolerance and possible to sulphur corrosion.[4]

Vegetable oil is one of the new liquid insulation oil of the transformer to replacing the mineral oil and known as a natural ester. Ester is the reaction of an acid with oil in elimination of water. The esterification of glycerin and fatty acid produce the fat and oil. The

collective term for mono- carboxylic acids, which consist of a carboxyl group (-COOH) and of a variable long, but nearly exclusively unbranched hydrocarbon chains is called a "fattyacid". [5] Figure 2.1 shows the process of the esterification and the inverse reaction called hydrolysis. The chemical constitution of rapeseed oil and all natural ester molecules are similar in composition as shown in Figure 2.2. The advantages of the vegetables oil are low dielectric losses at frequency higher than 1 kHz, readily biodegradable but is low oxidation stability. [4]

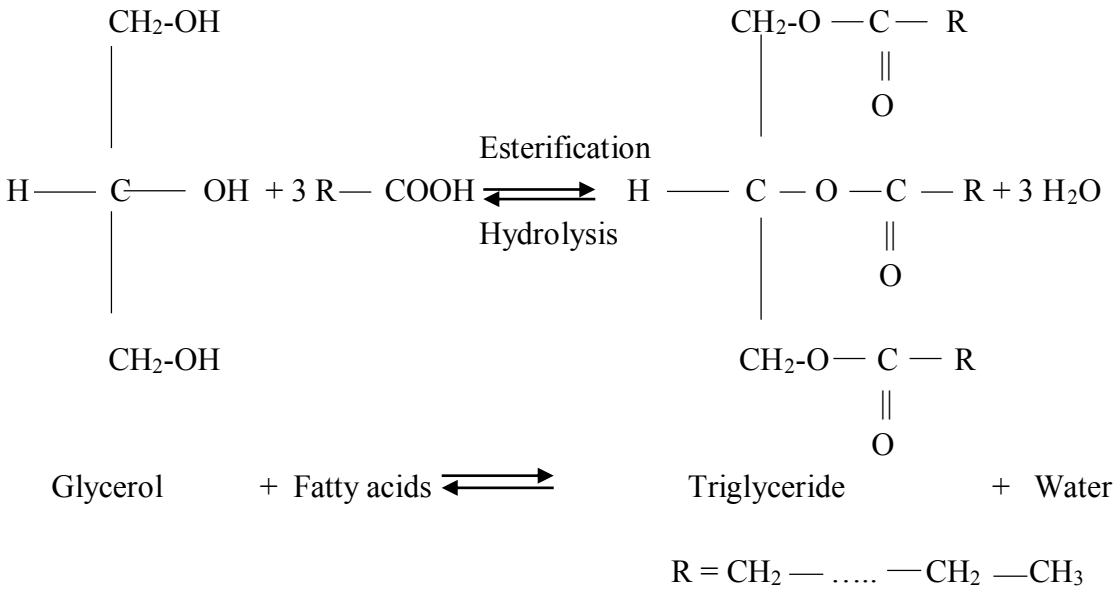

Figure 2.1: Synthesis of triglyceride by esterification. [5]

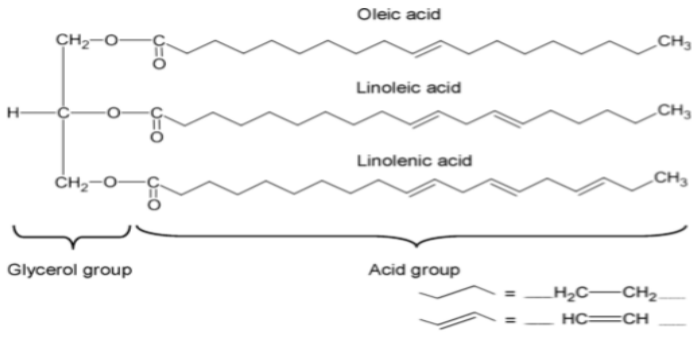

Figure 2.2: Chemical constitution of natural ester. [5]

There are many type of the vegetables oil such as palm fatty acid ester (PFAE), Envirotemp FR3 Fluid (Cooper Power Systems), Midel eN (M&I Materials Ltd.), and Midel 7131 (M&I Materials Ltd.). This research only focusing on Palm Oil Fatty Acid Ester

(PFAE). PFAE is the new vegetables based insulation oil for transformer. PFAE is contains a wide composition of fatty acids that include carbons 8 to 18 as shown in Table 2.1.[6] PFAE has a few advantages such as good biodegradability, excellent insulating performance, high cooling ability and good oxidation stability and a potential substitute of mineral oil. The properties of PFAE are listed in Table 2.2 is compared with different oil. It show that the value of the relative permittivity and breakdown voltage is higher. This shows PFAE is able to replace the mineral oil as insulation oil for transformer.

Table 2.1: Composition of fatty acid in oils [6]

Fatty Acid	Soy-bean oil	Rape-seed oil	Sun-flower oil	Palm		Coconut oil	Beef feat
				Palm oil	Palm kernel oil		
C8:caprylic acid	-	-	-	-	3.3	7.8	-
C10:capric acid	-	-	-	-	3.1	7.6	-
C12:lauricacid	-	-	-	-	45.7	44.8	-
C14:myristic acid	-	-	0.2	1.1	16.4	18.1	2.0
C16:palmitic acid	6.7	5.4	7.1	44.4	8.9	9.5	32.5
C18:stearic acid	3.3	2.0	2.8	4.3	2.3	2.4	14.5
C18:oleic acid	41.7	68.0	30.0	39.9	17.1	8.2	48.3
C18:linoleic acid	41.3	21.0	59.5	9.4	2.7	1.5	2.7
C18:linolenic acid	5.9	-	-	-	-	-	-
others	1.1	3.6	0.4	0.9	0.5	0.1	-

Table 2.2: The properties of PFAE, mineral oil and vegetable oil [7]

Items	Condition unit	PFAE	Mineral oil	Vegetable oil
Density	(15°C)g/cm^3	0.86	0.88	0.93
Kinetic Viscosity 40°C	Mm^2/s	5.1	8.1	32.9
Flash point COC	°C	186	152	330
Pour point	°C	-32.5	-45	-20
Total acid value	mgKOH/g	0.005	<0.01	0.035
Moisture	Mg/kg	15	<10	43
Relative Permittivity	(80°C)	2.95	2.2	2.91
tan δ	(80°C)%	0.31	0.001	0.67
Volume resistivity	(80°C)Ω.cm	1.9 x 10^{13}	7.6 x 10^{15}	3.7 x 10^{12}
Breakdown voltage	(2.5mm)kV	81	70.75	77