

**INVESTIGATION ON INSULATION CHARACTERISTICS  
OF VARIOUS STAGES OF PALM OIL**

**Mohd Halmi Bin Asmani**

**Bachelor of Electrical Engineering  
(Industrial Power)**

**May 2010**

“ I hereby declare that I have read through this report entitle “Investigation on Insulation Characteristics of Various Stages of Palm oil” and found that it has comply the partial fulfillment for awarding the degree in Bachelor of Electrical Engineering (Industrial Power)”

Signature : .....

Supervisor's Name : EN MOHD FARRIZ BIN HJ BASAR

Date : .....

**INVESTIGATION ON INSULATION CHARACTERISTICS OF VARIOUS  
STAGES OF PALM OIL**

**MOHD HALMI BIN ASMANI**

**This report is submitted in partial fulfillment of the requirement for the degree of  
Bachelor of Electrical Engineering (Industrial Power)**

**Faculty of Electrical Engineering  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**MAY 2010**

“ I hereby declare this report entitle “Investigation on Insulation Characteristics of Various Stages of Palm oil” is a result of my own work except for the excerpts that have been cited clearly in the references.”

Signature : .....

Name : MOHD HALMI BIN ASMANI

Date : .....

Dedicated to my beloved parents...

## ACKNOWLEDGEMENT

Assalamualaikum warahmatullahi wabarakatuh,

First and foremost, I would like to thanks to Allah the Almighty for blessing me the ability to complete my overall Projek Sarjana Muda 1 and 2. I would like to enlarge my appreciation to my supervisors, En Mohd Farriz Bin Hj. Basar and En Hidayat Bin Zainuddin because of the kindness heart to accept me as one of the student under his supervision. Special thanks also dedicated to them for all comments, ideas, and guidelines from the first day I start doing this project until it's completed.

I would also like to thanks all my lecturers that always give support, opinion, and advices for me to complete this thesis especially to En Farhan Bin Hanaffi and En MohdYusri Bin Jamil.

To my family especially my beloved parents: Asmani Bin Ahmad and Dalijah Bte Tubimin, I would like to forward my obliged for their continuous support during my study period, their patience and benevolence.

I would also like to thanks to all my friend that always gives support, opinion, and advices to complete this thesis. All suggestion for further improvement of this thesis are welcome and will be gratefully acknowledged.

Lastly, I would like to thanks to everyone who has contributed during my Projek Sarjana Muda 1 and 2. Your kindness and cooperation in completion of my thesis is much appreciated.

Thank you very much.

## ABSTRACT

One of the most important parts in a high voltage apparatus is insulation. For almost one century, petroleum and mineral oil have been used for cooling and insulation purpose. Researchers are now searching new type of insulating materials, which are environment friendly. This project purpose is to investigate the insulation characteristics of various stages of palm oil. Various stages of palm oil that involve in this investigation are Crude Palm Oil (CPO), Refined Bleaching and Deodorized Palm Oil (RBD Palm Oil), RBD Palm Stearin and RBD Palm Olein. These projects involve Withstand and Breakdown HVAC Voltage Test of the palm oil samples. Several parameters such as temperature and moisture are controlled to analyze the insulation characteristics of the palm oil. Comparison study between the characteristics of various stages of palm oils with the standard dielectric properties of transformer has also been conducted. Hence, at the end of this project, the status of palm oil as insulation material for oil type has been determined. The result of this project especially RBD Palm Oil has given a positive impact on the future study of various stage of palm oil as an insulating material. On the other hand, palm oil will be used for more function, and not only for cooking oil.

## ABSTRAK

Salah satu perkara yang sangat penting di dalam apparatus yang digunakan di dalam Voltan Tinggi ialah penebatan atau penyalutan. Hamper seabad yang lalu, petroleum dan minyak mineral digunakan sebagai penyejuk dan juga bahan penebatan di dalam apparatus Voltan Tinggi. Pada masa sekarang, penyelidik sedang menyelidik dan mencari bahan baru yang boleh digunakan bagi tujuan penebatan yang lebih mesra kepada alam sekitar dan pengguna. Tujuan projek ini dijalankan adalah untuk mengkaji kriteria penebatan yang terdapat di dalam minyak kelapa sawit. Kajian ini dilakukan di setiap peringkat pemprosesan minyak kelapa sawit. Minyak yang terlibat di dalam kajian ini adalah, minyak mentah kelapa sawit (*CPO*) minyak kelapa sawit bertapis (*RBD Palm Oil*), *RBD Palm Stearin* dan *RBD Palm Olein*. Bagi projek ini, terdapat dua bentuk pengujian Voltan Tinggi Arus Ulang-alik (*HVAC*) yang digunakan iaitu ketahanan voltan dan kepecahan voltan pada semua minyak yang diuji. Selain itu, terdapat beberapa perkara yang di kawal seperti suhu dan juga tahap kelembapan minyak bagi menguji kriteria penebatan yang terdapat di dalam minyak kelapa sawit. Perbandingan kriteria penebatan di antara setiap peringkat dijalankan serta perbandingan kriteria dengan minyak transformer yang sedia ada. Oleh sebab itu, pada akhir projek ini, status minyak sawit sebagai bahan penebatan akan dapat diketahui. Keputusan daripada kajian ini terutamanya minyak sawit *RBD Palm Oil* dapat memberi kesan yang positif kepada kajian pada masa hadapan bagi menjadikan minyak kelapa sawit sebagai bahan penebat. Selain itu kegunaan minyak kelapa sawit juga dapat diperluaskan dan bukan hanya untuk masakan sahaja.





2.4	Standard Transformer Oil Characteristics	10
2.5	Standard of Testing	10
	2.5.1 IEEE Standard	11
	2.5.2 IEC 156 Standard	11
	2.5.3 BS 148 Standard	12
2.6	Testing Equipment	12
2.7	Past Researcher's Work	13
	2.7.1 Effect of Temperature	14
	2.7.2 Effect of Moisture	14
	2.7.3 Contamination of Oil	14
2.8	Summary	15

### **3 PROJECT METHODOLOGY**

3.1	Introduction	16
3.2	Project Planning	16
3.3	Methodology	17
3.4	Equipment Setup	20
3.5	Safety Precautions	21
	3.5.1 OTS 60PB Safety	21
3.6	Testing Procedure Manual	22
3.7	Flowchart of Testing	25
3.8	Testing Works	29
3.9	Summary	31

### **4 RESULTS AND DISCUSSION**

4.1	Introduction	32
4.2	Part 1: HVAC Breakdown Voltage Testing on Palm Oil (Temperature Control)	32
	4.2.1 Lab Testing Result	32
4.3	Part 2: HVAC Breakdown Voltage Testing on Palm Oil (Moisture Control)	36
	4.3.1 Lab Testing Result	36

4.4	Part 3: HVAC Withstand Voltage on Palm Oil	40
4.5	Comparison among Various Stages of Palm Oil	41
	4.5.1 Temperature Effect	41
	4.5.2 Moisture Effect	42
	4.5.3 Withstand Voltage	43
4.6	Comparison between Experimental Results with Past Researchers Work Data	44
4.7	Comparison between Experimental Results with Standard Transformer Oil Data	45
<b>5</b>	<b>CONCLUSION AND RECOMMENDATION</b>	
5.1	Conclusion	46
5.2	Recommendation	47
	<b>REFERENCES</b>	48
	<b>APPENDICES</b>	49

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Specification of Palm Oil	8
2.2	Comparison of physical properties between transformer oil and palm oil	10
3.1	Project Planning Schedule	17
4.1	AC Breakdown Voltage of CPO with varying of temperature	33
4.2	AC Breakdown Voltage of RBD Palm Oil with varying the temperature	33
4.3	AC Breakdown Voltage of with RBD Palm Olein with varying the temperature	34
4.4	AC Breakdown Voltage of RBD Palm Stearin with varying the temperature	34
4.5	AC Breakdown Voltage of CPO (Moisture)	37
4.6	AC Breakdown Voltage of RBD Palm Oil (Moisture)	37
4.7	AC Breakdown Voltage of RBD Palm Olein (Moisture)	37
4.8	AC Breakdown Voltage of RBD Palm Stearin (Moisture)	38
4.9	AC Withstand Voltage of Various Stages of Palm Oil	40
4.10	Comparison of Breakdown Voltage with Past Researcher Work	44
4.11	Comparison of Breakdown Voltage with Standard Transformer Oil Data	45

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Flowchart of the palm oil process	7
2.2	Megger Oil Test Set	13
3.1	Methodology flowchart	19
3.2	Flowchart of the effect of temperature experiment	26
3.3	Flowchart of the effect of moisture experiment	28
3.4	Test Vessel	29
3.5	Digital Thermometer	29
3.6	Portable Gas and Cooking Vessel	29
3.7	Megger Oil Test Set (OTS 60PB) and Test Chamber	30
3.8	Test vessel with 500 ml sample of palm oil	30
3.9	Read the temperature of sample	30
3.10	Sample of palm oil in Megger Oil Test Set (OTS 60PB)	31
3.11	Reading of Breakdown Voltage	31
5.1	Graph of Breakdown Voltage of CPO with varying the temperature	34
4.2	Graph of Breakdown Voltage of RBD Palm Oil with varying the temperature	35
4.3	Graph of Breakdown Voltage of RBD Palm Olein with varying the temperature	35
4.4	Graph of Breakdown Voltage of RBD Palm Stearin with varying the temperature	36
4.5	Graph of Breakdown Voltage of CPO (Moisture)	38
4.6	Graph of Breakdown Voltage of RBD Palm Oil (Moisture)	39

4.7	Graph of Breakdown Voltage of RBD Palm Olein (Moisture)	39
4.8	Graph of Breakdown Voltage of RBD Palm Stearin (Moisture)	40
4.9	Average HVAC Breakdown Voltage of Palm Oil with varying the temperature	41
4.10	Average HVAC Breakdown Voltage of Palm Oil (Moisture)	42
4.11	HVAC Withstand Voltage of Palm Oil	43

## LIST OF ABBREVIATIONS

HVAC	High Voltage Alternating Current
RBD	Refined, Bleached and Deodorizing
CPO	Crude Palm Oil
IEEE	Institute of Electrical and Electronic Engineers
IEC	International Electrotechnical Commission
BS	British Standard
OTS PB	Portable Oil Test Set
Vrms	Voltage root mean square

## LIST OF APPENDICES

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	Average Breakdown Voltage of CPO (Temperature)	51
B	Average Breakdown Voltage of RBD Palm Oil (Temperature)	52
C	Average Breakdown Voltage of RBD Palm Olein (Temperature)	53
D	Average Breakdown Voltage of RBD Palm Stearin (Temperature)	54
E	Average Breakdown Voltage of CPO (Moisture)	55
F	Average Breakdown Voltage of RBD Palm Oil (Moisture)	56
G	Average Breakdown Voltage of RBD Palm Olein (Moisture)	57
H	Average Breakdown Voltage of RBD Palm Stearin (Moisture)	58
I	Withstand Voltage	59
J	Megger Oil Test Set (OTS 60 PB) User Guidline	60



## CHAPTER 1

### INTRODUCTION

#### 1.1 Project Background

Transformer oil or insulating oil is usually a highly refined mineral oil that is stable at high temperature and has excellent electrical insulating properties. Besides that, transformer has traditionally used mineral oil as insulation and palm oil has been used mainly for edible purpose [7]. The mineral oil with the main roles of insulating and cooking in power transformer is similar to the blood in human body. Refining is the collective term for the processes involved in changing the oil into oil with the required properties for a particular application. Basically, the material of dielectric is will divided into gaseous, liquid, solid and vacuum [6]. For testing the material, there are technique and type of the testing like High Voltage Alternating Current (HVAC) testing, High Voltage Direct Current (HVDC) testing and Impulse testing.

This project is using the HVAC testing technique for all the testing of the sample palm oil. This project focuses on the testing of the insulation characteristics of various stages palm oil using the equipment that provided at the High Voltage Laboratory at Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM). All of the testing on palm oil is performed with the different condition like temperature and moisture. Temperature and moisture of the sample of palm oil is controlling to analyze the effect of this factor on withstand and breakdown voltage. The insulation characteristics of the various stages will be known after the testing has been done.

To check the quality of need oil and its suitability for further use, different standard such as IEC and British Standard need to performed. In this study, the electrical experiments testing (HVAC Withstand and Breakdown Voltage) were performed according to the IEC Standard and British Standard. IEC 156 and BS 148 standard is the

latest standard. Therefore, in this project, all the testing of the palm oil uses this standard. On the other hand, the standard of the testing is acceptable in the world.

The main objective of this project is focusing to find the insulation characteristics of palm oil through a number of experiments by controlling several parameters such as temperature and moisture. On the other hand, this project will be benefit for researcher's to find the new insulating materials which are friendly to the environment and have a good insulation properties compared to the mineral oil.

## 1.2 Problem Statement

Petroleum based mineral oils have been used for liquid insulation in high voltage equipment since long time ago. This is because petroleum has excellent dielectric properties such as high electric field strength, low dielectric losses and good long term performance. After that, synthetic hydrocarbon fluids, silicone and ester fluid were introduced in the latter half of the twentieth century, but their use is limited of distribution transformer [7], [8]. In transformer worldwide, several billion liters transformer oil has been used. The choice of an insulation or liquid dielectric for a given application is made mainly on the basis of its chemical stability [6]. Besides that, some of the aspect is also been considered such as cost, saving of space and effect for the environment.

However, the oils are non biodegradable. Therefore, they can cause serious problems to our environment. Therefore, there is the need for either an alternative or a total replacement, since petroleum is one of non-renewable energy source and may be gone one day. On the other hand, the function of petroleum will be focus on the energy source. Besides that, our environment will be safer if the non-renewable energy source is not used for the electrical field engineering. In the world, palm oil is one of the biggest industries and Malaysia is one of the countries that will supply the palm oil to the market. Hence, palm oil is one of the potential of insulating media that will be used for the next generation

### 1.3 Project Objectives

There are four objectives that need to be accomplished in order to make this project successful which are:

- i. To study and analyze the AC Withstand Voltage characteristics of palm oil, through a number of experiments by controlling several parameters such as temperature and moisture
- ii. To study and analyze the AC Breakdown Voltage characteristics of palm oil, through a number of experiments by controlling several parameters such as temperature and moisture.
- iii. To perform comparison study on the insulation characteristics of various stages of palm oil with standard characteristics of transformer oil.

### 1.4 Project Scopes

There are few scopes in doing this PSM project:

- i. Four various stage of palm oil (Crude Palm Oil (CPO), Refined, Bleaching and Deodorized (RBD Palm Oil), RBD Palm Stearin, RBD Palm Olein) are involved in this project.
- ii. Testing the sample on AC High Voltage (Withstand and Breakdown Voltage)
- iii. Several parameters such as temperature and moisture are controlled to analyze the characteristics of the palm oil.
- iv. Comparison study between the insulation characteristics of various stages of palm oil with standard characteristics of transformer oil also will be conducted.

## 1.5 Thesis Outline

Chapter 1 briefly summarizes the project background and problem statements as well as elaborates the objectives and scope of the project.

Chapter 2 discusses about the literature review of the project and the source achieved by gathering information through past researcher's work, internet and reference book that related to this project. Some of the method that used in HVAC testing is Withstand Voltage Testing and Breakdown Voltage Testing is elaborated. The brief elaboration on the various stages of palm oil including the physical condition and chemical properties are elaborated. In addition, the IEEE Standard, IEC Standard and British Standard for HVAC are also been discussed.

Chapter 3 explained about project methodology that used in this project. The overall project planning of this project is included in this chapter.

Chapter 4 explicit about the HVAC testing including the test equipment that have been used and the ways to setup the equipment and application. Besides that, it also discusses the safety precaution when conducting the experimental works. In addition, this chapter also explained the testing procedure for HVAC testing on various stages of palm oil by referring the IEC 156 and BS 148.

Chapter 5 details the result of this project. All the data that obtained has been presented in this chapter. The experimental result of the insulation characteristics of various stages of palm oil using the HVAC Withstand and Breakdown Voltage has been analyzed in this chapter. Comparison of the insulation characteristics among the various stage of palm oil are carried out in this chapter. In addition, the comparison of the insulation characteristics between the various stages of palm oil with standard dielectric of transformer is also discussed in this chapter.

Finally, chapter 6 discusses the conclusion and recommendation of these project activities. The recommendation given may be postulated as a contribution to future time to university and industry.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Transformer is the most expensive equipment in electrical network. The insulating oil has the main roles of insulating and cooling in it. Oil is subjected to the degradation because of the ageing, high temperature and chemical reactions such as oxidation [6]. The dielectric strength and insulation is the most important electrical property. In our transmission and distribution system, the most common testing high voltage apparatus is related to high AC voltages. It is obvious then that most research work in electrical insulation system has to be carried out with this type of voltage. In every laboratory, High Voltage Alternating Current (HVAC) supplies are therefore in common use.

#### **2.2 HVAC Testing**

Generally, the High Voltage testing has three technique including HVAC Testing, High Voltage Direct Current Testing and Impulse Testing. In this project, the testing of the insulation characteristics is focused on the HVAC Testing. The alternating voltage is defined by its RMS value and/or by its peak value depending on the purpose [1]. For HVAC testing, the testing is divided into two techniques where it is calls the Withstand Voltage and Breakdown Voltage testing.

##### **2.2.1 HVAC Withstand Voltage**

The Withstand Voltage is the maximum voltage level that can be applied between components without causing a breakdown. In other word, during the testing on the object,

no disruptive discharge occurs on the test voltage. Besides that, the withstand voltage also will be defined as the prospective value of the test voltage that equipment is capable of withstanding when tested under specified condition.

### **2.2.2 HVAC Breakdown Voltage**

Breakdown voltage is defined is the voltage reached at the time that the first spark between the electrodes occurs whether it be transient or total. Besides that, it is characteristics of an insulator that defines the maximum voltage difference that can be applied across the material before the insulator collapse and conduct [2], [4]. The breakdown voltage is not a definite value because it is form a failure and there is a statistical probability whether the material will fail at a given voltage. In other words, breakdown voltage of an insulator is the minimum voltage that causes a portion of an insulator to become electrically conductive.

### **2.3 Palm Oil Characteristics**

Palm oil is the most important thing that required in this project. In history, palm oil is an edible plant oil derived from the fruit and kernels (seeds) of the oil palm *Elaeis guineensis* [12]. Palm oil is naturally reddish because it contains a high amount of beta-carotene (though boiling it destroys the carotenoids and renders the oil colourless). Palm oil is one of the few vegetable oils relatively high in saturated fats (like coconut oil) and thus semi-solid at room temperature.

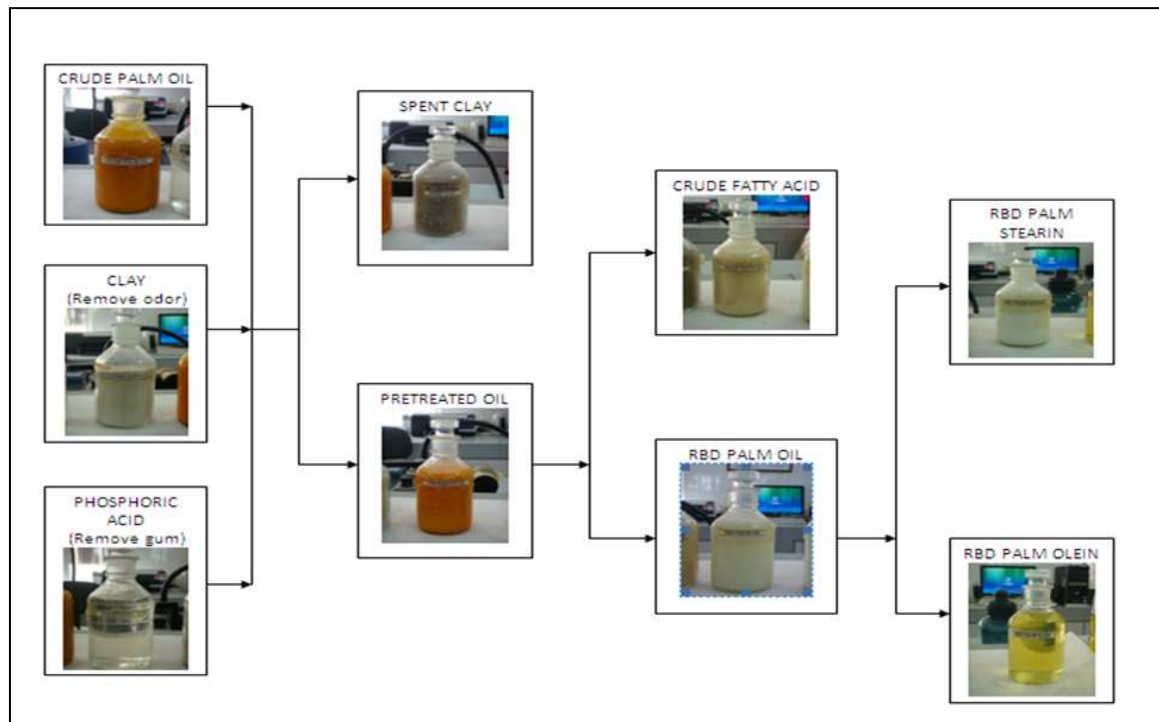


Figure 2.1: Flow Chart of the Palm Oil Process

### 2.3.1 Various Stages of Palm Oil

Palm oil basically has a four various stages during the process for edible purpose. Crude Palm Oil (CPO), Refined Bleached and Deodorized (RBD Palm Oil), RBD Palm Stearin and RBD Palm Olein are the stages [13]. The entire sample of these stages is included in this project.

Figure 2.1 shows the process of the palm oil from the CPO until it's refined to the RBD Palm Stearin and RBD Palm Olein. At the beginning of the process, the clay is added to the crude palm oil for removing the colour of the crude palm oil. If the colour is higher, more clay is needed. The amount of clay is depending on the quantity of the crude palm oil used.

Besides that, phosphoric acid also will mix with the crude palm oil to reduce the of the gum/degumming effect in crude palm oil and maximum value needed is 0.08% only and must less than 0.08% but depend also the quality of crude palm oil [3]. The amount of the phosphoric acid also depending on the quantity of the crude palm oil is used.

After that, the crude palm oil is divided into two stages that is pretreated oil and spent clay. Pretreated oil is spread into two type of oil that is RBD Palm Oil and crude fatty acid. Then, the RBD Palm Oil is elapse in refining, bleaching and deodorizing. After that, the palm oil is spread to RBD Palm Stearin and RBD Palm Oil. The percentage of the RBD Palm Stearin is 20% and for RBD Palm Olein is 80% after the refining, bleaching and deodorized process again from the RBD Palm Oil.

### 2.3.2 Specification and Physical Properties of Palm Oil

Table 2.1 below show the specification and physical properties of the various stages palm oil depend on the parameter in order to investigate the insulation characteristics of the palm oil. The melting point for each sample of oil is different and it's depending on the source of and the physical condition of the oil. Consequently, the heat blower is required to blowing the oil into the liquid condition. Besides that, the moisture and impurities of the palm oil is low.

**Table 2.1: Specification of Palm Oil**

<b>Parameter/Oil</b>	<b>Crude Palm Oil (CPO)</b>	<b>Refined Bleached and Deodorized (RBD Palm Oil)</b>	<b>Refined Bleached and Deodorized (RBD Palm Stearin)</b>	<b>Refined Bleached and Deodorized (RBD Palm Olein)</b>
Source	Obtained from the pericarp of palm fruit	Obtained from refining CPO	Obtained from fractionating RBD Palm Oil, to separate olein from stearin	Obtained from fractionating RBD Palm Oil to separate liquid parts from stearin.
Physical Condition	Orange liquid or semi solid at room temperature.	Light yellow liquid and semi solid at room temperature.	White solid at room temperature. Melting to a	Clear yellow liquid at room temperature