EFFECT OF MOISTURE LEVEL TO AC BREAKDOWN VOLTAGE OF PFAE BASED NANOFLUIDS

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A thesis submitted in fulfillment

of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

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2015

"I declare that this report entitled *"Effect of Moisture Level to AC Breakdown Voltage of PFAE Based Nanofluids"* is the results of my own research except as cited in references. The report has not been accepted for any degree and is not currently submitted in candidature of any other degree."

Signature : .....

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Date : 16 JUN 2015

"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 : .....

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Date : 16 JUN 2015

For my family who always give me strength and encouragement during this time and my beloved friends that always be there when needed and give me a support. May Allah bless each one of you always.

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Hopefully what we do in this project with a sincere heart to study in parallel to advance religion, race and nation.

Thank you.

ABSTRACT

Power transformer in high voltage application is important part of electricity generation and transmission network. Hence, it needs a proper insulation and cooling system during operation. During transformer operation, insulation oil performance in term of breakdown voltage is affected by moisture that exists in the oil. Due to this moisture, the electrical characteristics of the insulating oil must be improved to avoid failure of power transformer due to low breakdown voltage. So, this study will be conducted to investigate the influence of nanoparticle dispersed in natural oil with water to breakdown voltage value. The objective this study are to prepare nanofluids by mixing conductive nanoparticles and water into natural oil, to setup a breakdown voltage test apparatus purposely used for liquid insulation test, and to determine and analyses the breakdown voltage level of nanofluids in concerned. In this study, electrical properties testing were carried out in term of breakdown voltage test. The test were conducted under moisture stress until of 0.20 ml, at intervals of 0.05 ml. The nanofluids insulating oil and Palm Fatty Acid Ester (PFAE) oil was through vacuum drying oven process for 72 hours before the breakdown voltage testing. Another addition is to study the breakdown voltage of nanofluids insulating oil under moisture stress. Result from the breakdown voltage test, the performances of nanofluids were carried out of the increasing the breakdown voltage and under moisture stress of nanofluid insulating oil based. Hence, the nanofluids can improve the breakdown voltage and good performances under moisture stress.

ABSTRAK

Pengubah kuasa dalam aplikasi voltan tinggi adalah bahagian yang penting dalam penjanaan dan penghantaran rangkaian elektrik. Oleh itu, ia memerlukan penebat dan sistem penyejukan yang betul semasa beroperasi. Semasa pengubah kuasa beroperasi, prestasi minyak penebat dari segi tahap ketahanan voltan dipengaruhi oleh kelembapan yang wujud dalam minyak. Oleh kerana kelembapan ini, ciri-ciri minyak penebat perlu dipertingkatkan bagi mengelakkan kegagalan pengubah kuasa mengalami voltan rendah. Oleh itu, kajian ini akan dijalankan untuk menyiasat pengaruh nanopartikel dicampur dalam minyak semulajadi dengan air untuk ujian nilai voltan kerosakkan. Objektif kajian ini adalah untuk menyediakan nanofluids dengan mencampurkan nanopartikel konduktif dan air ke dalam minyak semula jadi, untuk menyediakan alat ujian voltan kerosakkan untuk tujuan ujian penebat cecair, dan untuk menentukan dan menganalisis tahap voltan kerosakkan nanofluids. Dalam kajian ini, ujian sifat elektrik telah dijalankan dalam tempoh ujian voltan kerosakan. Ujian ini dijalankan di bawah kesan kelembapan sehingga 0.20 ml, pada selang 0.05 ml. Minyak penebat nanofluids dan Palm Fatty Acid Ester (PFAE) minyak melalui proses vakum pengeringan selama 72 jam sebelum ujian voltan kerosakan dijalankan. Selain itu, ujian tambahan adalah untuk mengkaji perbandingan voltan kerosakkan antara nanofluids dan minyak PFAE baru di bawah kesan kelembapan. Keputusan daripada ujian voltan kerosakan, prestasi nanofluids telah dijalankan untuk meningkatkan voltan kerosakkan dan di bawah kesan kelembapan antara nanofluids dan minyak PFAE baru. Oleh itu, nanofluids boleh meningkatkan voltan kerosakkan sementara PFAE baru menunjukkan persembahan yang baik di bawah kesan kelembapan.

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Chapter 1

Introduction

1.1 Research Background

Power transformer in high voltage application is important part of electricity generation and transmission network. Hence, it needs a proper insulation and cooling system during operation. Mineral oil in power transformer serves as insulation liquid and as a coolant for the transformer. During transformer operation, insulation oil performance in term of breakdown voltage is affected by moisture that exists in the oil. Due to this moisture, the electrical characteristics of the insulating oil must be improved to avoid failure of power transformer due to low breakdown voltage. In recent years, nanofluids have been developed to improve both the breakdown voltage and insulating properties of mineral oil [1]. A nanofluid is a nanotechnology based heat transfer fluid, in which small amount of nano-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, or nano sheet) is stably suspended in a traditional heat transfer fluid such as mineral oil, water and ethyele glycol [2]. It shows that nanofluids display enhanced thermal properties, such as thermal conductivity and heat transfer coefficient, compare to their respective base fluids [3]. Up to recent years,

studies of nanofluid and its heat transfer capability are plentiful. However, research on the electrical characteristics of mineral oil based nanofluids is still limited [4][5][6]. With improves properties, nanofluids may help minimizing the size of HV components. Thus, in this study, the effect of nanoparticles dispersed in mineral oil with water to breakdown voltage will be carried out.

1.2 Problem Statement

The moisture content in the transformer oil is affecting the alternating current (AC) breakdown voltage of oil-immersed power transformer. Low breakdown voltage of insulating oil is one of factor towards transformer failure because if insulating oil is broke down, there will be no appropriate insulation left for the power transformer. Hence, normal transformer operations are effected. So, this study will be conducted to investigate the influence of nanoparticle dispersed in natural oil with water to breakdown voltage value.

1.3 Objective

The objectives of this study are to:

i. To prepare nanofluids by mixing conductive nanoparticles and water into natural oil.
ii. To setup a breakdown voltage test apparatus purposely used for liquid insulation test.
iii. To determine and analyse the breakdown voltage level of nanofluids in concerned.

1.4 Scope of Work

The scopes of this study are:

i. Types of nanoparticles used are conductive nanoparticles (Iron oxide, Fe_3O_4) only.
ii. Type of natural oil used is Palm Fatty Acid Ester Oil (PFAE), a Malaysian product.
iii. Alternating current (AC) high voltage testing, a breakdown voltage tests according to IEC 156/1995 standards under moisture effect.

1.5 Contribution of Research

This research is for insulating oil that can contribute for generation, transmission and distribution system network. This research is to prove that nanoparticle can improve the breakdown voltage of insulating oil. Thus, nanoparticle is studied for contribution to improvement of insulating oil.

Chapter 2

Literature Review

2.1 Introduction

This chapter contain a literature review that related to this research. All the information that needed to implement the experiment is studied and will show in this chapter. The main information that contain in this chapter is about nanoparticles, insulating oil and breakdown voltage. Furthermore, the previous work that researcher have been studied also explain in this chapter included the result that they have studied in past.

2.2 Theory and Basic Principal

The transformer oil for high voltage insulation has extensive research work aimed to enhancing both its breakdown voltage and characteristics. Moisture that exists in the transformer oil will affect the breakdown voltage and is possible transformer failure can be damage the transformer. The transformer oil that effect by moisture was in research to know

the breakdown voltage and improvement to increase the breakdown voltage. In this research, the innovative work to increase the breakdown voltage is the development of dielectric nanofluids. These nanofluids materials are manufactured by adding nanoparticle and disperse from powder into liquids. The breakdown voltage or dielectric strength was improved by adding nanoparticle into natural oil and water as moisture in the transformer oil. Nanoparticle is selected with different type were added into transformer mineral oil and water.

2.2.1 Insulating Oil

Transformer oil that has been use in power transformer for high voltage application is also called insulating oil. The reason why the transformer oil is same meaning with insulating oil because it was obtained by subsequent treatment of crude petroleum and fractional distillation processes. Four main proposes serves by transformer oil in electrical power transformer which is for liquid insulation and dissipates heat of the transformer or as a coolant for the transformer [6]. On the other function of transformer oil is to preserve the core and winding that is fully immersed inside oil. Besides that, the function of transformer oil is to prevent from direct contact of atmospheric oxygen with cellulose made paper insulation of winding, which is susceptible to oxidation [6].

2.2.2 Nanoparticle

A nanoparticle is defined as microorganism particle and micrscopic particle. A nanoparticle is easy to understand by compare the size of the particle. Another meaning of

nanoparticle is ultrafine particle. The size of the nanoparticle is 1-100 nanometers (nm) [8] [9].

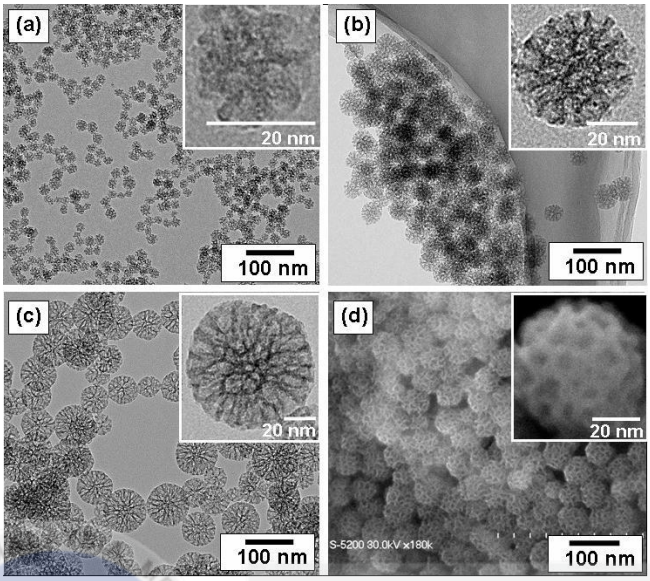


Figure 2. 1 : (a) 20 nm of diameter nanoparticle, (b) 45 nm of diameter nanoparticle, (c) 80 nm of diameter nanoparticle, (d) image corresponding to (b) [10].

In industry application, nanoparticle has different physical and chemical properties in their bulk metal. The nanoparticle can serve as a bridge between bulk materials and atomic or molecular structures. Generally, a bulk material must have same quantity properties if the nanoparticle is included. Nanoparticle can be dispersed or embedded with the liquid or bulk material. The change of the properties of materials is size influenced by nanoscale. Nanoparticles have a very high surface area to volume ratio [8]. With a high surface area this will force for diffusion especially at elevated temperature. Sintering can serve for low temperature and shorter time scales than for large materials [8]. This statement is not affect the density of the original product even nanoparticle influence the materials properties. A large surface area to volume ratio reduces the melting temperature of nanoparticle [8]. The types of nanoparticle that have been used in electricity system are conducting nanoparticle,

semiconducting nanoparticle and insulating nanoparticle. Recently, nanoparticle research was enhancing in different application which is in optical, biomedical and electronic fields.

2.2.3 Dielectric Strength

Dielectric strength in power transformer is also called breakdown voltage. Breakdown voltage is the maximum voltage can prevent the transformer failure that can be damage the insulating oil. It measured by maximum voltage that can be prevent and sparking between two electrodes immerged in the oil which is with separated by specific gap [6]. Moisture that exists in the transformer oil can reduced the value of breakdown voltage. To measure the breakdown voltage in lab or at site, a portable breakdown voltage measuring kit is available in market and used nowadays. The test needs the insulating oil and kept in a beaker then put the electrode for the test. There are standard that must be followed to valid the test.

Figure 2. 2 : Breakdown Voltage Tester Kit. [6]

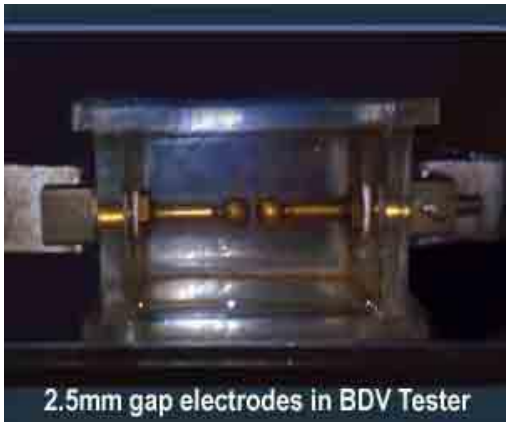


Figure 2. 3: 2.5mm gap electrodes in breakdown voltage tester [6].

To begin the test, applied the voltage between the electrodes and increase the voltage steadily. If the sparking can be seen at the electrode, the breakdown voltage of the transformer oil is achieved. So, the value breakdown voltage is satisfied. Generally, this test is repeat 3 to 6 time in same sample of oil and the average value is taken [6]. Breakdown voltage is important in transformer oil because to check of health of oil and moisture that exists in the oil. The breakdown voltage test of transformer oil is to confirmed that the oil is safely be used in the transformer operation.

2.2.4 Water Content in Transformer Oil

Moisture or water that exists in the power transformer oil is unwanted materials that affected the dielectric properties of oil. The paper insulation and winding of transformer is influenced by water that content in transformer oil. In nature, paper is highly hygroscopic [6]. Water in oil will absorbed by paper and affected the insulation properties as well as reduced its lifetime. In operation condition, transformer oil become hotter and makes the solubility of water in oil increases. Then, the paper will releases water and increase the moisture content in transformer oil. It is very important the temperature of the oil at the time of taking sample for

test [6]. Parts per million (ppm) is a units that measured water content in oil [6]. Recommended by IS-335(1993), up to 50 ppm is allowed water in oil [6]. But in this research, the water will measure by percentages (%).

2.2.5 Preparation of Nanofluid

From another researcher, they state there are two method for disperse the nanoparticle into mineral oil [11]. There are one-step method and two-step method. Most of them prefer used the two step method for mixing the nanoparticle and natural oil. In recent years, the two step methods are widely used than one step method because of their low cost [11]. Besides that, the two step methods have a large surface area and the high surface activity of the nanoparticle. For mixing the nanoparticle with natural oil, needs to improve the nanoparticle dispersion stability in the oil. For preparation nanofluids, mixing nanoparticle with oleic acid shows the good feedback for long term dispersing stability in transformer oil at room temperature over period of 24 months [11]. Furthermore, it is challenging for preparation nanofluids for use in industrial power transformer as well as good for long term dispersing stability. So, in this experiment will use two step method for nanofluids preparation.

2.3 Review of Previous Related Works

Research on nanotechnology is enhancing nowadays to improve the dielectric strength or breakdown voltage especially in power transformer oil. From time to time, some improvement is needed to a better system and reduces the error and failure in the system. In this research is focus on nanotechnology and transformer oil. Before this study is

implemented, there are some research is conducted by some researcher. In their research, they only focus the scope of the research and specific on their study and related in this study. Next, the research and experiment that previously done and can related by effect of nanoparticle on the electrical characteristic of insulating oil.

From article "AC Breakdown Voltage and Viscosity of Mineral Oil based silicon oxide (SiO_2) Nanofluids" (2012), the research is test the breakdown voltage as well as effect of nanofluid to the mineral oil. In their research, they use SiO_2 as a nanoparticle and mix with the mineral oil. The size between 10 nanometer (nm) and 20 nm of SiO_2 nanoparticle are used in this works. The mass fraction between 0.005% and 0.02% is the investigated nanofluids. They study the influence of nanoparticle centration and moisture content on the breakdown voltage. The transformer oil that has been used in their experiment is Diala S3ZXIG. From this article also explain the viscosity test. They test the effect of nanoparticle to the viscosity and effect viscosity to the breakdown voltage.

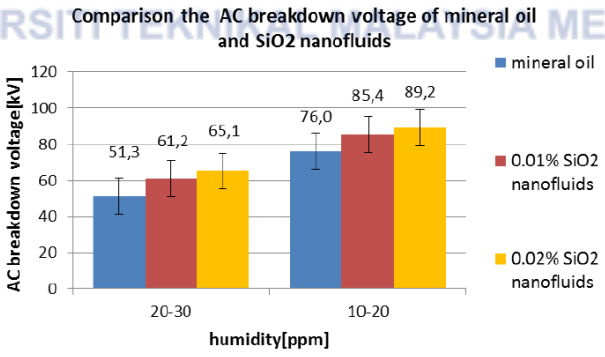


Figure 2. 4: The AC breakdown voltage [7].

Figure above shows the result of breakdown voltage test and comparison between affected by nanofluids and the original mineral oil. Its show positive feedback and the rated

of breakdown voltage is increases. So, the oil can works more in high voltage application in transformer oil.

According to Institute of Electrical and Electronics Engineers (IEEE) Electrical Magazine, the article of "Recent Progress in Nanofluids Based on Transformer Oil: Preparation and Electrical Insulation Properties" there are related works in this study. They are study preparation of nanofluids based on transformer oil and analyse the electrical insulation properties. In their study, the preparation of nanofluids is divided into three groups. First group is conducting nanoparticle as well as they disperse with nanoparticle type of magnetite (Fe_2O_3) and zinc oxide (ZnO). Second group is semiconducting nanoparticle which is the type is titanium dioxide (TiO_2), copper (ll) oxide (CuO) and copper (l) oxide (Cu_2O). The last group is insulating nanoparticle and the type used is aluminium oxide (Al_2O_3) and silicon oxide (SiO_2). The reason the mechanism of nanoparticle can increase the breakdown voltage of the transformer oil is still not fully understood. In their research, there are two step methods that have been used in the experiment.

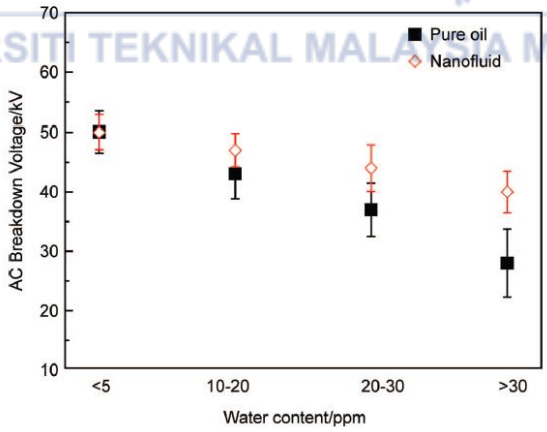


Figure 2. 5: The breakdown voltage for pure oil and mix with nanofluids (Fe3O4) [11].

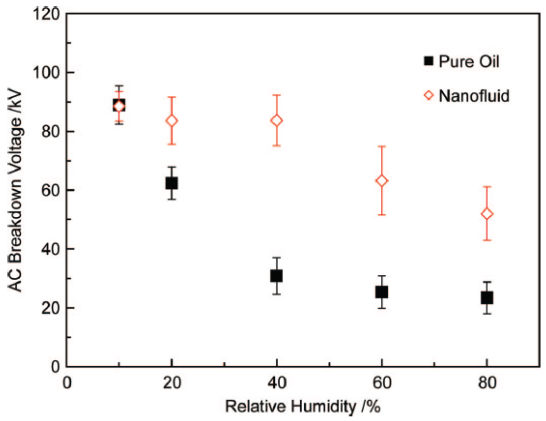


Figure 2. 6: The breakdown voltage for pure oil and nanofluid (TiO2) [11].

The result above shows the positive feedback for insulating oil and breakdown voltage test. The effect of nanofluids into the mineral oil will increase the breakdown voltage and resistance level of insulating oil. So that, it's improve that the nanoparticle can increase the breakdown voltage and can further the research on the effect of nanoparticle into the insulating oil.

2.4 Summary of the review

From the theory and basic principles and review of previous related works as well as the some research for fulfil in this study. The theory is needed to know all the information before the study is further. Basic principle must be understood as well as to know the flow and system that have been used. In this study, basic keyword that must know is nanoparticle and nanofluids, insulating and transformer oil, breakdown voltage or dielectric strength, and water or moisture. There are some keyword commonly used in this study and must understood clearly. Theory of review is help to do research and must update for more

information and understanding. Review of previous related works is important things because to know weakness, mistake and the result. Learn from previous research assist to improve the system and technique and easy to get the idea and better modification. This is not plagiarism but for further the research and improvement.

As a conclusion, all the information obtained will be used in the methodology in chapter 3 to carry out research experiment. This information will be used as a guideline during to implement the experiment. Thus, all methods of implementation will be described in more detail in the next chapter.

Chapter 3

Design Methodology

3.1 Introduction

In this chapter is about the method to implement the experiment. It will illustrate all the principles of method that be used in the research. Furthermore, this chapter will explain details the preparation of nanofluids, setup the apparatus for breakdown voltage test and discussion the methods that has been used. Besides that, the planning and schedule in this research is shown through Gantt chart and key milestone.

3.2 Principles of The Method

Based on the previous research, there is some method that have been used and related for this study. By referring varied of article previously research, mostly they used quite similar methods but different materials such as type of nanoparticle and so on.

3.3 Methodology

To implement this research there are several step must be follow. In this part will explain about the step by step as well as the way to prepare nanofluids, setup apparatus for test and test the breakdown voltage. The flow chart, table and so on will show detail with explanation.

3.3.1 Flowchart

To complete the research, several stages of progress will be involved and is shown in the flowchart in figure below. The stages will be explained details later.

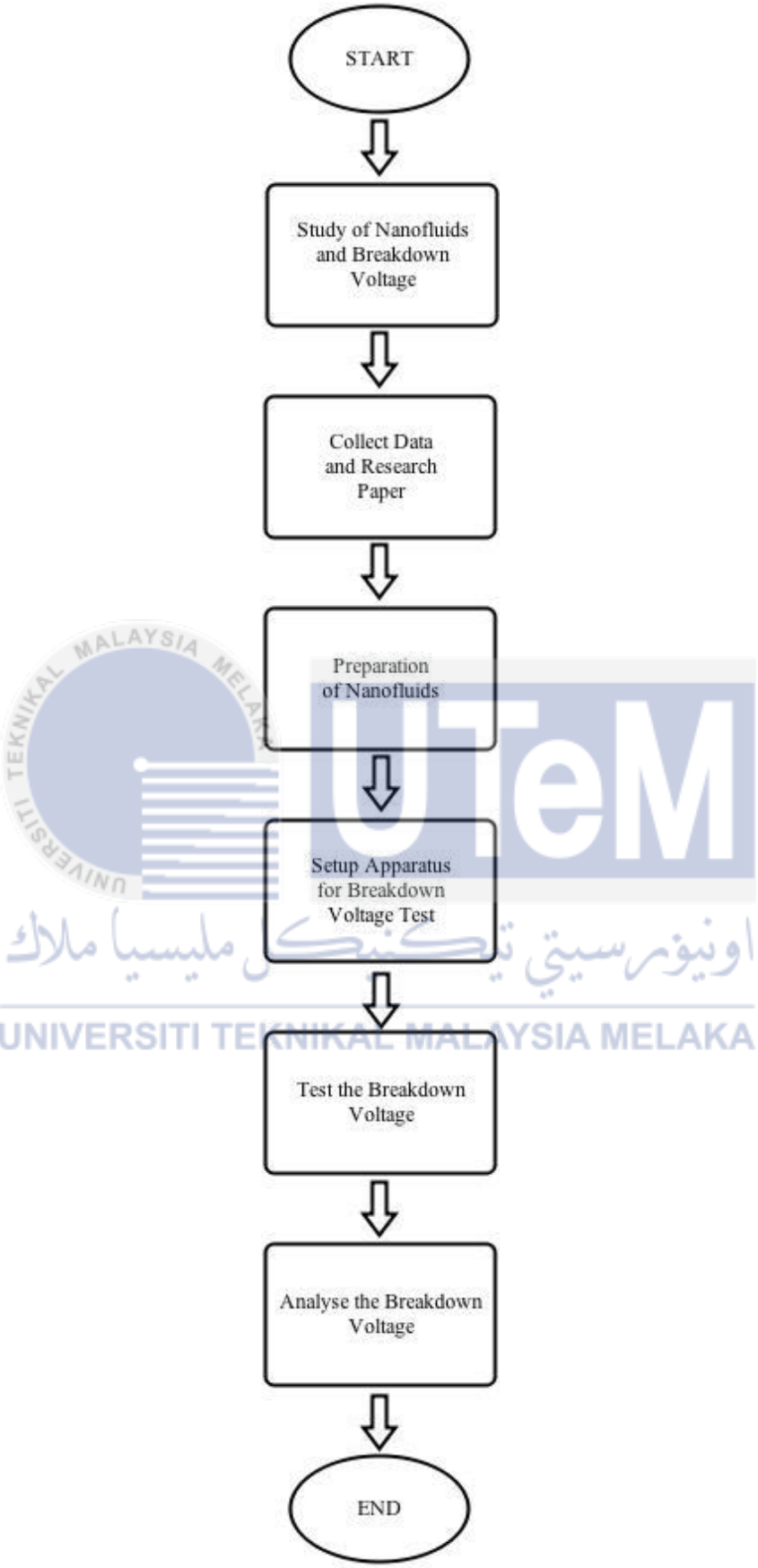


Figure 3. 1: Flowchart of implementation the breakdown voltage test.

Stage 1: Study of Nanofluids and Breakdown Voltage

First stage, it is the beginning of this study about nanofluids and breakdown voltage. The information about these things is find out to understand and can come out great idea for better improvement. In this stage, it's very important to know the type of nanoparticle which is that want to use. Then, how to transform nanoparticle into nanofluids must be clear of the method. However, when the preparation of nanofluids is achieve, the breakdown voltage test is next. For the breakdown voltage, there is need to know how it's works. For example, how much the distance for gap of electrode, what type of electrode and so on. Furthermore, the test must follow the standard for validity of result.

Stage 2: Collect Data and Research Paper

All the important of information to the research is collected and gathered the data based on the study done on previous research paper. All the information, data and result in previously research are presented in Chapter 2.

Stage 3: Preparation of Nanofluids

From the information obtained, preparation of nanofluids is conducted. The nanofluids are prepared one type only. For reference of test, the natural oil is mix with water as moisture in oil. Then, natural oil and water will mix for one type of nanoparticle which is conductive nanoparticles (Iron oxide, Fe_3O_4).

Stage 4: Setup Apparatus for Breakdown Voltage Test

The apparatus of breakdown voltage test is setup for the test. We may do testing in high voltage laboratory as well as a complete apparatus and equipment and also for safety reasons.

Stage 5: Test the Breakdown Voltage

After insulating oil and apparatus is setup, the test of breakdown voltage level is conducted. The test is according to IEC 156 standard. The test is repeated 6 times for each type of nanofluids instead of insulating oil.

Stage 6: Analyse the Breakdown Voltage

All the data is taken from the test conducted in laboratory. The data will analyse and compare under moisture stress of insulating oil that have been mix with nanoparticle. The level of breakdown voltage is analysing to shows the higher level of breakdown voltage.

3.4 Method of Experiment and Data Collection

The methods that have been used from beginning until the end of this experiment are shown. There are four main stages of flow to do the experiment and analyse the result which is preparation of nanofluids, apparatus setup for breakdown voltage test, test the breakdown voltage level and analyse the breakdown voltage. All the step of implementation of this experiment is shows with explanation.

3.4.1 Preparation of Nanofluids

First stage of the implementation of this experiment is preparation of nanofluids. In this stage, two step method is used for prepare the nanofluids. Before the preparation of nanofluids is conducted, the reference of insulating oil is prepared first. In this study, the original natural oil is used for references of experiment to make comparisons with effect of nanofluids. Natural oil is used to shows the natural oil that has been used is new idea for using in real conditions in industry.

In this experiment, the type of nanoparticles that has been used Iron Oxide Nanopowder (Fe3O4, high purity, 99.5+%, 15-20 nm). This nanoparticles is bought from NovaScientific, US Research Nanomaterials, Inc.

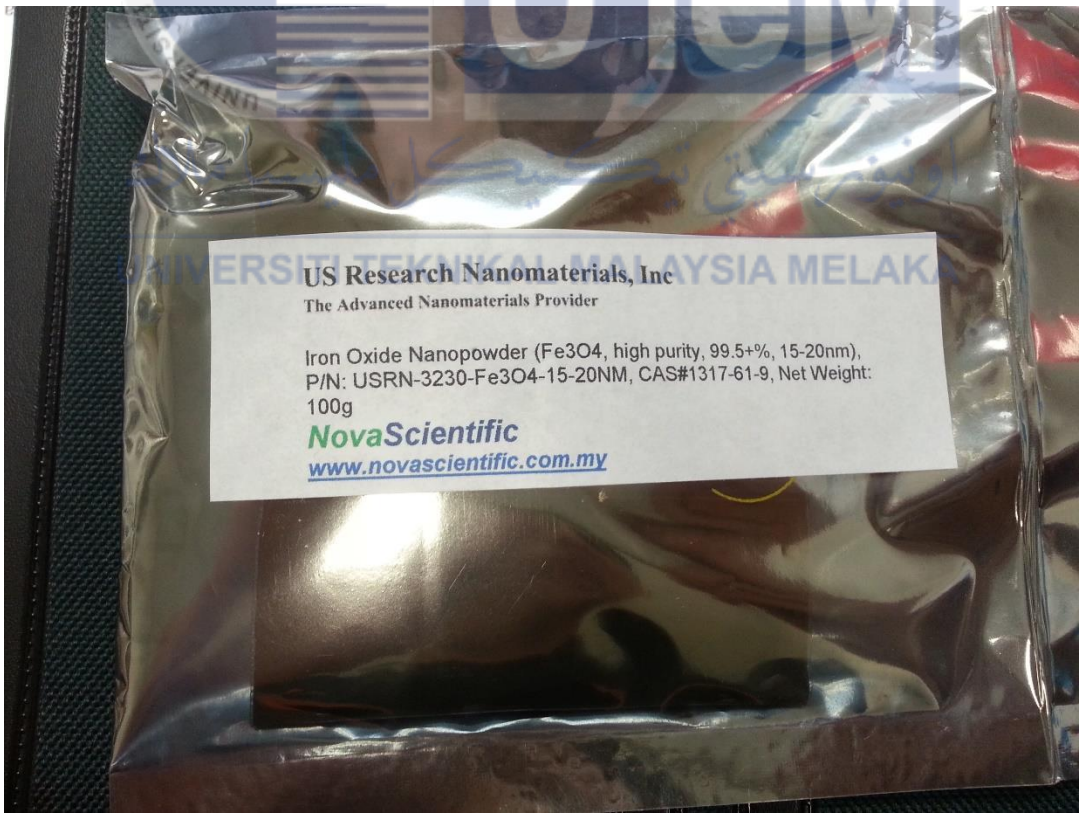


Figure 3. 2: Iron Oxide, Fe3O4 Nanopowder.

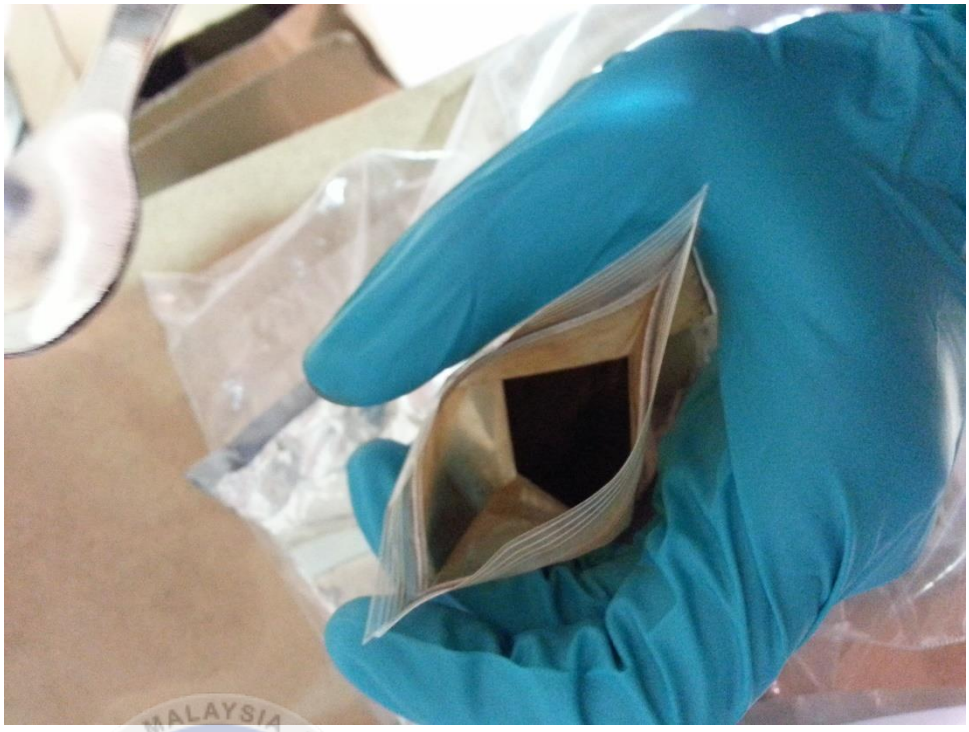


Figure 3. 3: Nanoparticles (Fe3O4).

The Palm Fatty Acid Ester (PFAE) oil mix with water is prepared for reference in this experiment to shows that the oil was affected by moisture. It's used for comparisons in term of breakdown level as well. Next, the preparation of nanofluids is conducted. There are conductive type of nanofluids should be prepared. The type of nanoparticle is used which is conductive nanoparticles (Iron oxide, Fe_3O_4). In this preparation for nanofluids is uses two step method. The size of nanoparticle is ranging between 10 and 20 nanometer (nm). First, the nanoparticles were weighted and then disperse nanoparticle with oleic acid to transform nanoparticle in term of powder into liquid using magnetic stir for two hours. Then, mix the nanoparticle solution with the natural oil through Ultrasonic process for two hours. After through all this step, the nanofluids is already completely process for making the samples. Flowchart below is shown how the process to make the nanofluids.

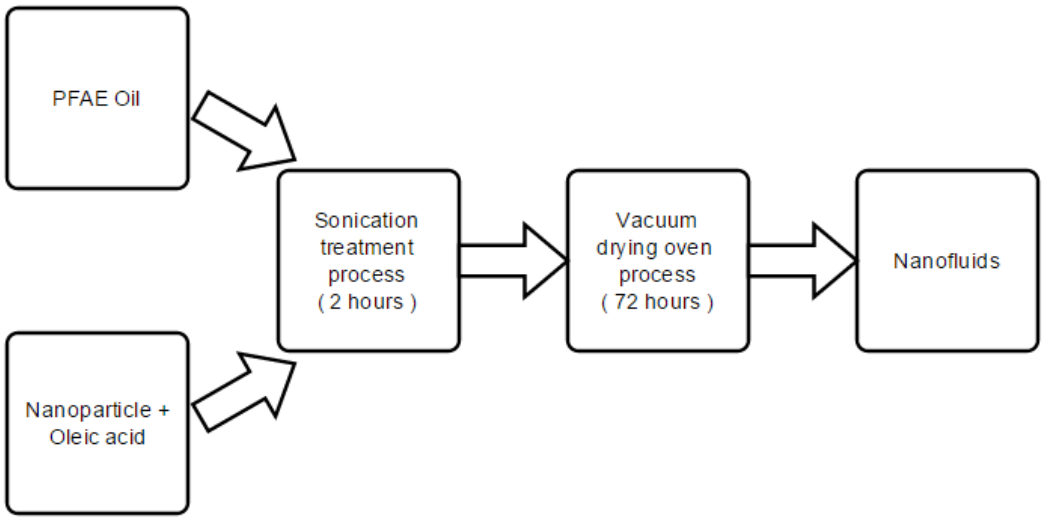


Figure 3. 4: Flowchart for preparing of nanofluids.

Based on the flowchart above the nanofluids is made it follow the process above. Next, step by step is shown and will explain more details. The procedure to prepare the nanofluids as below:

i. Weight the nanoparticles.

First step is weight the nanoparticles by using digital analytical balance. The weight for the nanoparticles is 0.01 gram per litter. In this experiment is needed two litter. So, the nanoparticles needs is 0.02 gram.

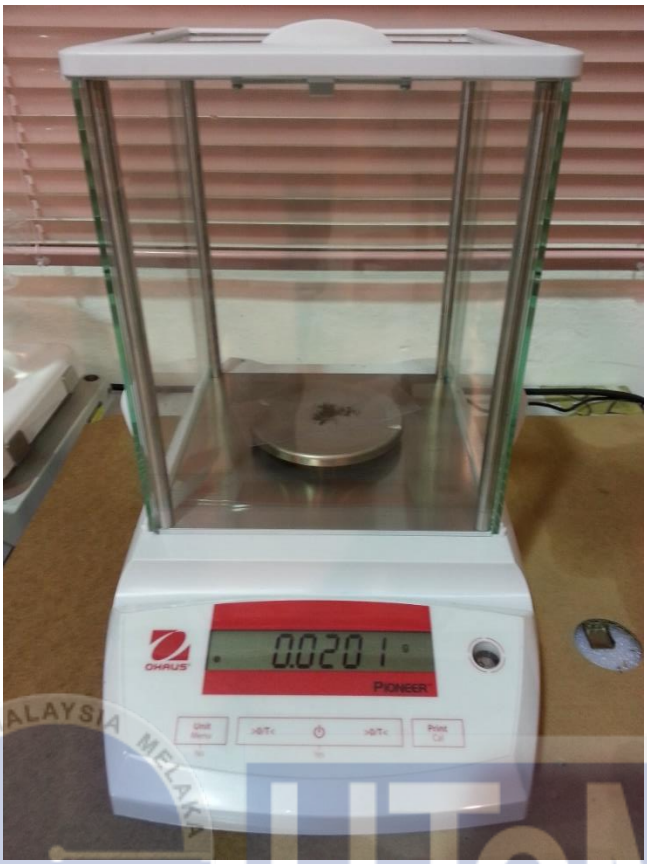


Figure 3. 5: Weight the nanoparticles.

ii. Measure oleic acid.

Second step is measure oleic acid. The purpose for using oleic acid for transform the nanoparticles in term of powder into liquid before mix with natural oil. The oleic acid also use for good long term dispersion stability in transformer oil at room temperature for over 24 months. The dosage of oleic acid needed is 0.5 millilitre per 0.01 gram nanoparticles.

Figure 3. 6: Measure oleic acid.

iii. Measure natural oil.

In this experiment, the oil that be used is Palm Fatty Acid Ester (PFAE) oil. The oil needed is two litter. So, measure two litter palm oil using beaker.

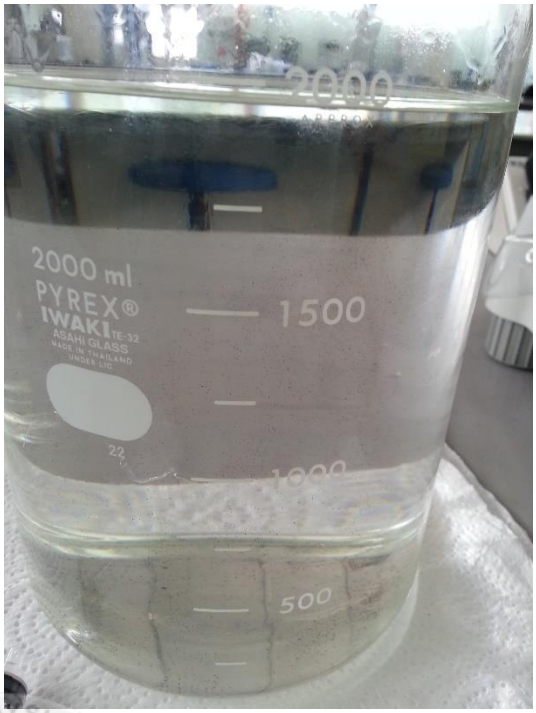


Figure 3. 7: Measuring two litter palm oil.

iv. Mix oleic acid, nanoparticles and natural oil.

Next step is mixing the oleic acid, nanoparticles and natural oil. After measure all the component that needed, mix all in one beaker.

Figure 3. 8: Put in the nanoparticles into palm oil.

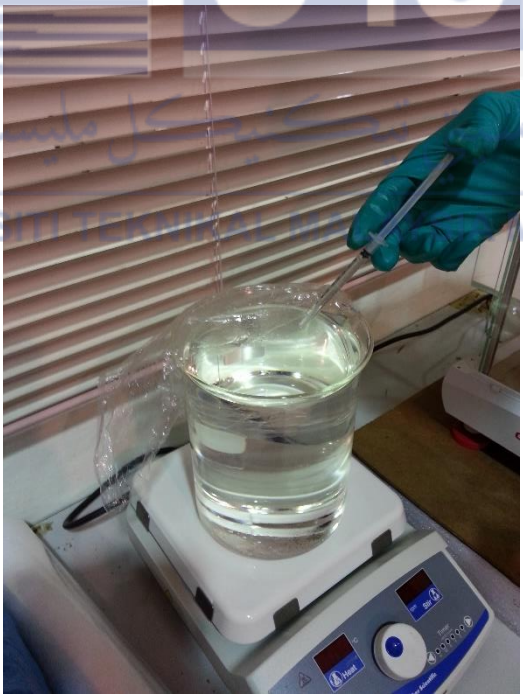


Figure 3. 9: Drop out the oleic acid.

v. Ultrasonic Treatment Process

After mix all the substances, the solution needs to go through the ultrasonic process. Through ultrasonic treatment, the process can disperse the aggregations and enough to break them. So, the substances needs go through ultrasonic treatment for two hours. This machine can produces longitudinal mechanical vibrations with a frequency of 24, 000 vibrations per second (24 kHz). The setting the ultrasonic process 50% for the pulsed-mode operation (Cycle) and 50% for the ultrasound power (Amplitude). The probe that's needs to disperse the nanoparticles is probe diameter 40 mm, approx., 100 mm long. This rating can process for sample volumes millilitre (ml) from 200-4000 ml.

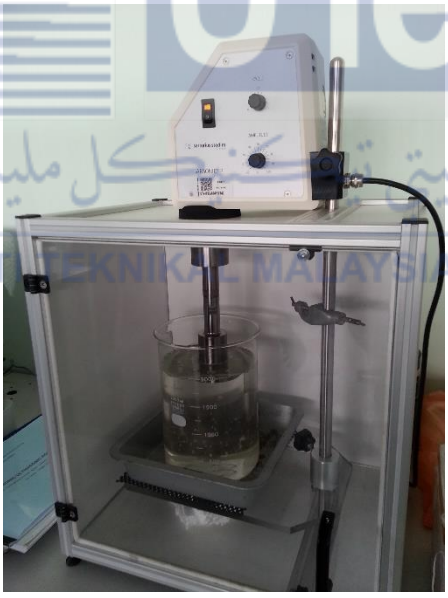


Figure 3. 10: Ultrasonic Treatment Process.

Figure 3. 11: Probe diameter 40 mm, approx., 100 mm long.

Figure 3. 12: The setting of 50% cycle and amplitude.

vi. Vacuum Drying Oven Process

After magnetic stir process, next the vacuum drying oven process will conducted. This process will remove bubble or moisture and gas that appear during the ultrasonic process and give a time nanofluids for relaxation. This process will be set for 72 hours with 70 degree Celsius and 1kPa of vacuum pressure.

Figure 3. 13: Vacuum drying Oven Process.

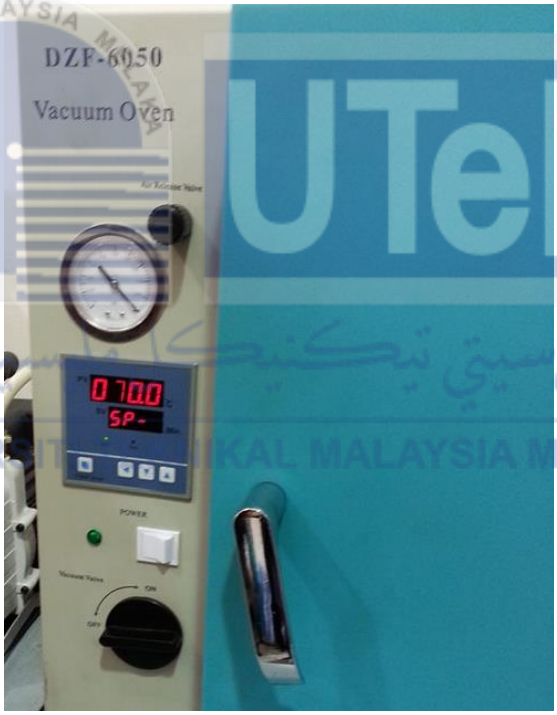


Figure 3. 14: Setting temperature at 70 ^{0}C.

Figure 3. 15: Setting time for 72 hours (4320 minutes).

3.4.2 Water Content into Oil

After preparation of nanofluids is done, water is measure and mix with the nanofluids to shows the effect of water as a moisture in the oil can decrease the breakdown voltage of the insulations or not. This sample will be prepared for five sample included the original nanofluids without water. The table below show the measurement of water into the nanofluids.

Table 3. 1: Water into nanofluids.

Sample	Nanofluids (ml)	Water (ml)	Water inserted in percentage (%)
1	350	0.00	0.00
2	350	0.05	0.01
3	350	0.10	0.03
4	350	0.15	0.04
5	350	0.20	0.06

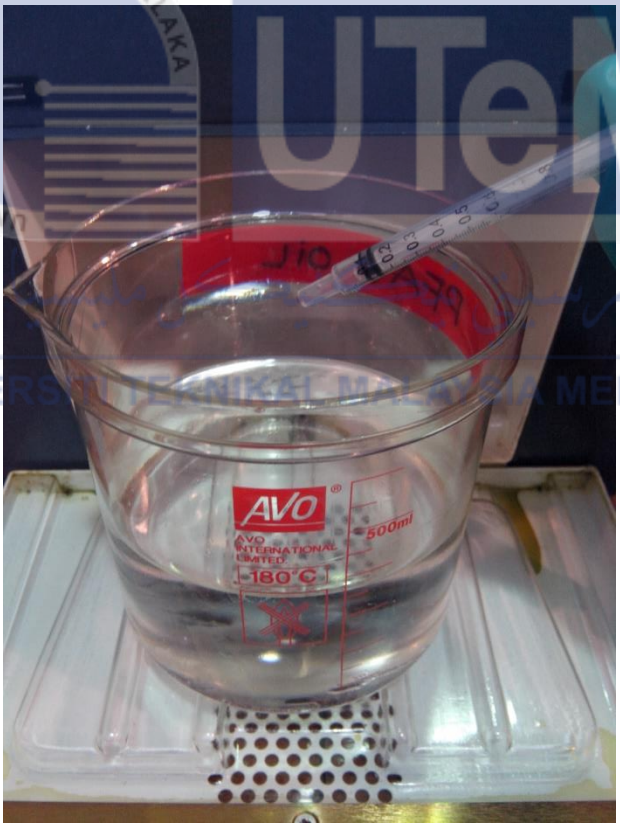


Figure 3. 16: Fill water into nanofluids.

3.4.3 Setup Breakdown Voltage Test Apparatus

For insulation breakdown voltage test, the setup of high voltage apparatus for breakdown voltage test is conducted. This test is conducted in high voltage laboratory. The apparatus that has been used to test the breakdown voltage is Portable Breakdown Voltage Measuring Kit. This thing is available in laboratory and also in site. The breakdown voltage test is according to IEC 156:1995 standard. The type of Portable Oil Test Set used is OTS60PB.

Figure 3. 17: OTS60PB Portable Oil Test Set.

The procedure for setup the breakdown voltage apparatus as below:

i. Preparation of the Portable Oil Test Set

First step for preparation of the Portable Oil Test Set is check the battery and earth connection. If the battery is low, the test set should be charging first to ensure that the supply is adequate to do the test.

Figure 3. 18: Charging the battery.

ii. Preparation of Electrode

Clean the electrode using the special tissue or paper. Make sure all the contaminant is cleaned. To remove the contaminant, used a special metal polish for removing the contaminant called AUTOSOL. After clean the electrode, rinsing with the oil sample that be used for testing. After the electrode is cleaned, setting the gap of the electrode for testing. The gap required for IEC 156 standard is 2.5 mm.

Figure 3. 19: AUTOSOL.

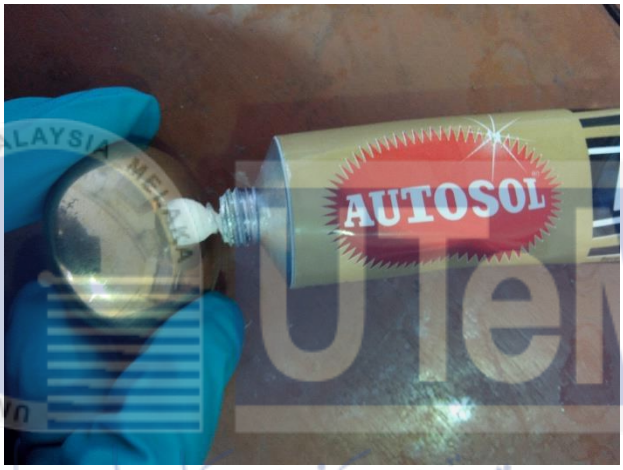


Figure 3. 20: Clean the electrode using AUTOSOL.

Figure 3. 21: The electrode after cleaned.

iii. Preparation of Test Vessel

Clean the oil test chamber or beaker that be used for testing before pouring the oil sample. Make sure all the contaminant should be cleaned. After the chamber or beaker is cleaned, rinsing the chamber or beaker with the oil sample that will be testing.

Figure 3. 22: Rinsing the beaker with the oil sample.

iv. Loading the Test Vessel

Open the test chamber door slowly by pulling it downward to the horizontal position. Enter the chamber or beaker safely and close the chamber door.

Figure 3. 23: Loading the test vessel.

v. Preparing the Oil Test Set

After the Oil Test Set is charging and ready to be used, push the switch ON. In a minute, select the standard that be used in the test. There are several standard can be choose. So, select IEC 156/1995 for this experiment. After that, push the switch START. The Oil Test Set is running and waiting for the breakdown voltage result.

Figure 3. 24: Switch ON the oil test set.

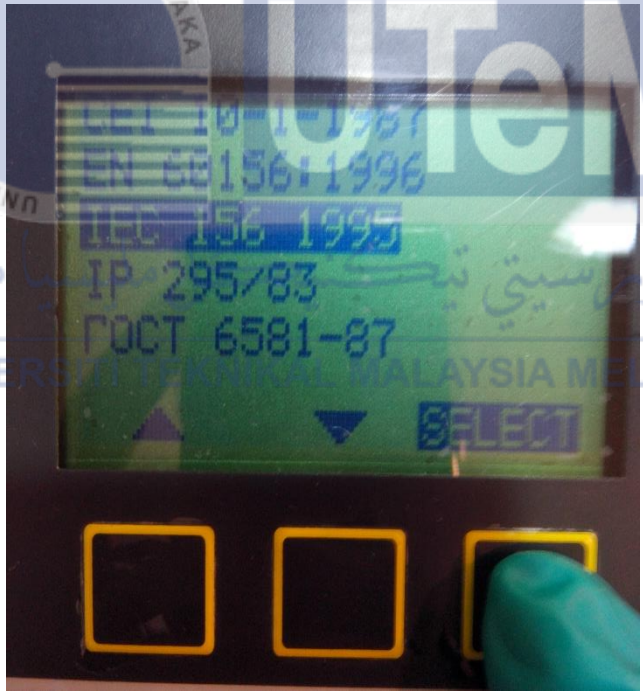


Figure 3. 25: Select the IEC 156 standard.

Figure 3. 26: Select START button.

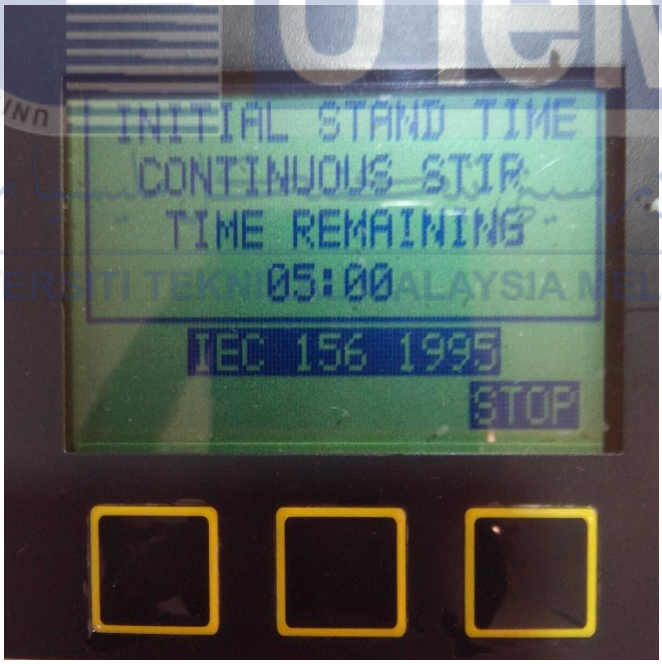


Figure 3. 27: The test begins.

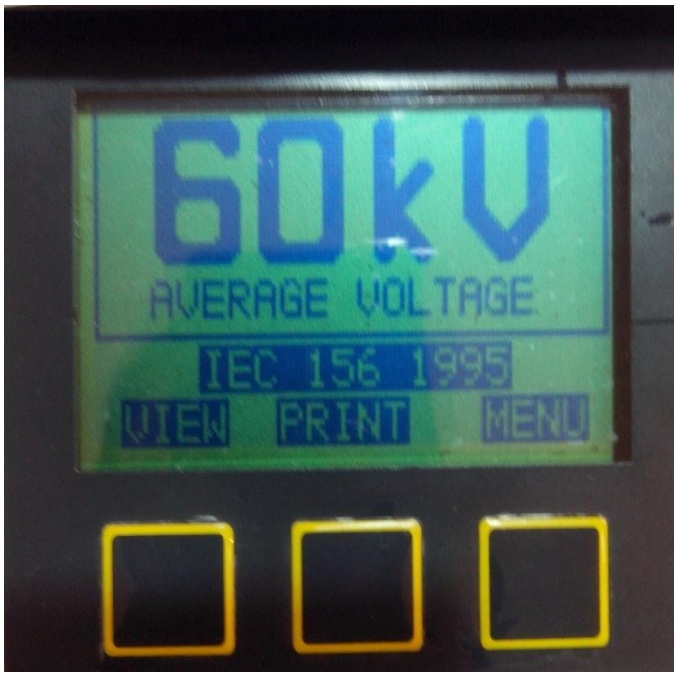


Figure 3. 28: Breakdown voltage result.

3.5 Timeline of Research Development (Gantt Chart)

In implementing the project, the planning should be done so that each process is done properly and on time. In this research, project planning was designed from the beginning to the end. Project planning Gantt chart described in the table.

Table 3. 2: Gantt chart.

Activities	Final Year Project 1 (2014)					Final Year Project 2 (2015)				
	Sep	Oct	Nov	Dis	Jan	Feb	Mac	Apr	May	Jun
Study theory and concept										
Literature review										
Preparation of Nanofluids										
Setup of apparatus for breakdown voltage test										
Test the breakdown voltage										
Analysis of the breakdown voltagte										
Report writing										

Table of Gantt chart shows the timeline of implementation of this study. There are seven major activities that needs to be done on time. In this study divided into two part which is Final Year Project (FYP) 1 and FYP 2. For FYP 1 begins from September 2014 until January 2015 while FYP 2 begins from February 2015 until June 2015.

3.6 Milestone Research

The key milestone of this study of effect of nanoparticles on the electrical characteristics of insulating oil as shown below:

Table 3. 3: Key Milestone.

Milestone	Item	Date
1	Completion of research and study on nanofluids and breakdown voltage.	30 April 2015
2	Completion of collect data and literature review on research paper and previous studies.	31 January 2015
3	Completion of preparation of nanofluids.	31 March 2015
4	Completion of setup apparatus for breakdown voltage test.	30 April 2015
5	Completion of test the breakdown voltage.	31 May 2015
6	Completion of determine and analyse the breakdown voltage.	31 May 2015
7	Completion of report writing.	31 May 2015

Chapter 4

Result and Discussion

4.1 Introduction

In this chapter, data is recorded and analysed from the experiments. Results presented are preparation of nanofluids and breakdown voltage. The physical changes of the oil after water is insert are also discussed.

4.2 Result

From the experiment that have been done, all the data is collected and recorded. The result will be shown in tables and pictures. The result is taken based on preparation of nanofluids and breakdown voltage under moisture effect.

4.2.1 Preparation of Nanofluids

Preparation of nanofluids is one of the objectives of this research. The process of implementation of nanofluids has been explained in previous chapter. So, the result of preparation of nanofluids is physical changed after through the process. The physical changed of nanofluids is shown below.

(a) (b)

Figure 4. 1: Preparation of Nanofluids (a) Before preparation (b) After preparation.

4.2.2 Breakdown Voltage

The breakdown voltage result for Fe_3O_4 nanofluids insulating oil and original Palm Fatty Acid Ester Oil (PFAE) are recorded in tables. Firstly, the result is shown comparison between Fe_3O_4 nanofluids and original PFAE after through vacuum drying process for three days. The

test will conducted to show that the nanofluids can increase the breakdown voltage or not. Then for testing under moisture stress, every type of insulation oil will be set of five samples. Each sample will be insert of water to shows the moisture effect into the insulating oil. First sample, the Fe_3O_4 nanofluids insulating oil and PFAE will be test without water as a references to get maximum breakdown voltage. Then, the test will be inserted water for 0.05 ml, 0.10 ml, 0.15 ml and 0.20 ml. The test will be conducted for six times for each sample and average breakdown voltage also recorded. The result of the breakdown voltage is shown below.

Table 4. 1: The breakdown voltage of PFAE and Fe3O4 nanofluids.

Insulating oil sample	Test						
	Breakdown Voltage (kV)						
	1	2	3	4	5	6	Average
PFAE	16	13	18	21	22	23	19
Fe_3O_4 Nanofluids	25	24	38	42	41	27	33

Table 4. 2: The breakdown voltage under moisture effect.

Insulating oil sample	Water inserted (ml)	Water inserted in percentage (%)	Test						
			Breakdown Voltage (kV)						
			1	2	3	4	5	6	Average
Fe_3O_4 Nanofluids	0.00	0.00	25	24	38	42	41	27	33
	0.05	0.01	33	30	30	27	28	29	30
	0.10	0.03	19	26	36	33	31	26	29
	0.15	0.04	28	26	22	22	27	22	25
	0.20	0.06	24	16	23	19	19	18	20

4.3 Analysis

The data that have been collected and recorded above is discussed and analysed. The data will be discussed by showing chart and graph. The discussion will be focussed on the breakdown voltage only for both nanofluids insulating oil and pure Palm Fatty Acid Ester Oil (PFAE) only. The analysis will discussed comparison which is better performances in term of breakdown voltage.

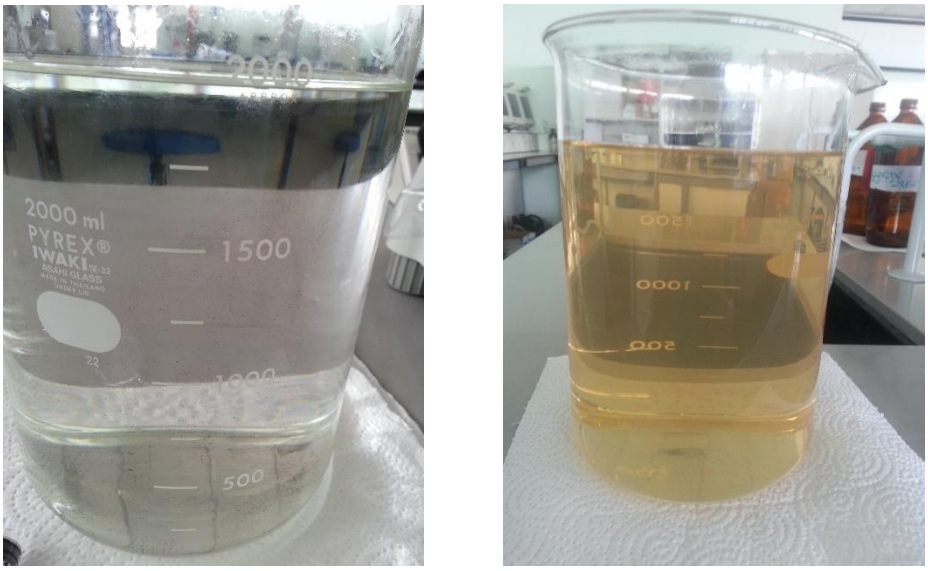
4.3.1 Preparation of Nanofluids

From the experiment that have been done shows the preparation of nanofluids is successfully. During the preparation can be analysed that have a physical changed of the nanofluids. The physical changed during the ultrasonic treatment processed.

(a) (b)

Figure 4. 2: The differences during ultrasonic treatment process (a) Before treatment (b) During treatment.

From Figure 4.2 above shows the differences during ultrasonic treatment process. Based on the experiment, the physical of nanofluids has a changes. In Figure 4.2 (b) shows the vibration is applied to the insulating oil. So, the vibration give the great movement to the particles in the oil. From that the physical has a changes against time.



(a) (b)

Figure 4. 3: The physical changed (a) Before treatment (b) After treatment.

Figure 4.3 above shows the physical changed after through ultrasonic treatment process. Based on the Figure 4.3 (b) illustrate that colour of nanofluids has been changed. During the ultrasonic treatment process is enough to break the nanoparticles and changed the colour of insulating oil. The impact of vibration that given to nanoparticle and insulating oil is enough to broke and disperse them together. So, a little bit of nanoparticle can changed the physical of insulating oil in term of colour. After through the ultrasonic treatment process the colour the nanofluids will changed.

4.3.2 Breakdown Voltage

The breakdown voltage is one of the objective of this research to be determining and analysed. The analysis will shows the nanofluids can withstands with moisture effect in term

of breakdown voltage or not. Figure below shows the breakdown voltage of PFAE and Fe_3O_4 nanofluids for six testing of the insulating oil.

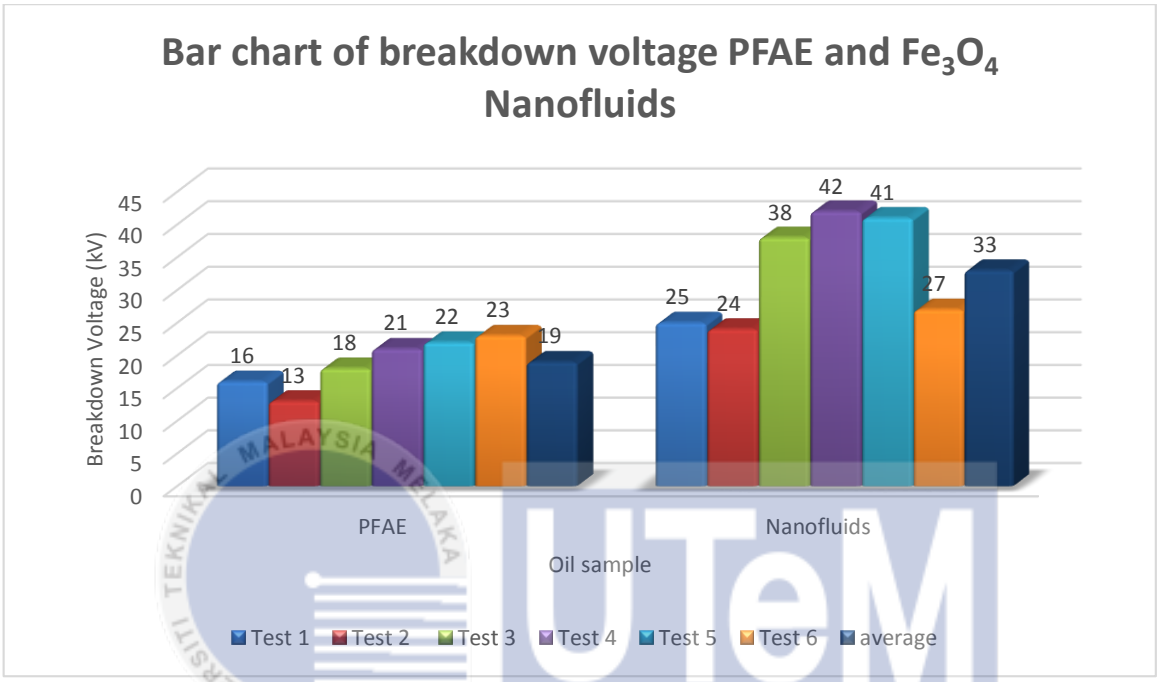


Figure 4. 4: Bar chart of breakdown voltage PFAE and Fe3O4 Nanofluids.

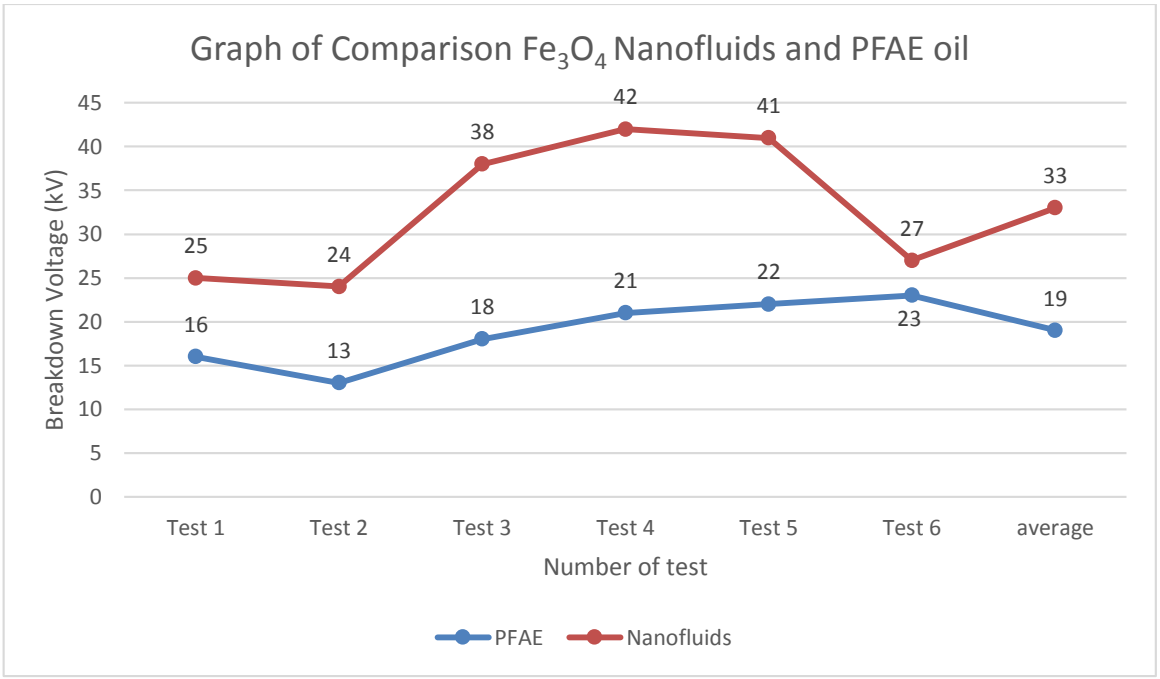


Figure 4. 5: Graph of Comparison Fe3O4 Nanofluids and PFAE oil.

Figure 4.4 and Figure 4.5 shows that the comparison the breakdown voltage between nanofluids insulating oil and PFAE oil. The both of insulating oil is through the vacuum drying oven process first for 72 hours. After that shows the PFAE oil cannot withstands in high breakdown voltage. PFAE oil shows the average breakdown voltage that can be withstands is about 19 kV. In this condition, PFAE oil is assume a damaged oil and cannot be used in transformer operation because for normal transformer operation needs average breakdown voltage of 30 kV. So, after PFAE oil dispersed with nanoparticle which is Iron Oxide, Fe3O4 illustrate that that improvement of breakdown voltage increase from 19 kV to 33 kV. The increases breakdown voltage is about 14 kV. Based on the calculation, the improvement that has been achieved is about 26.92% increasing. This is because the nanoparticle relaxation time is increase so that the permittivity of the insulation oil increase and increase the breakdown voltage. From the theory of high voltage, the highest of permittivity the highest of the breakdown voltage [31]. Based on the chart in Figure 4.5

above, the highest increasing breakdown voltage is Test 4 which is the improvement breakdown voltage from 21 kV to 42 kV. Thus, from the damaged oil of PFAE oil can be used again after disperse with nanoparticles because the improvement performances by nanoparticles. From the experiment, proved that the Fe_3O_4 nanoparticle can improve the PFAE oil in term of breakdown voltage. Next, the graph of the effect of moisture to the Fe_3O_4 nanofluids in term of breakdown voltage.

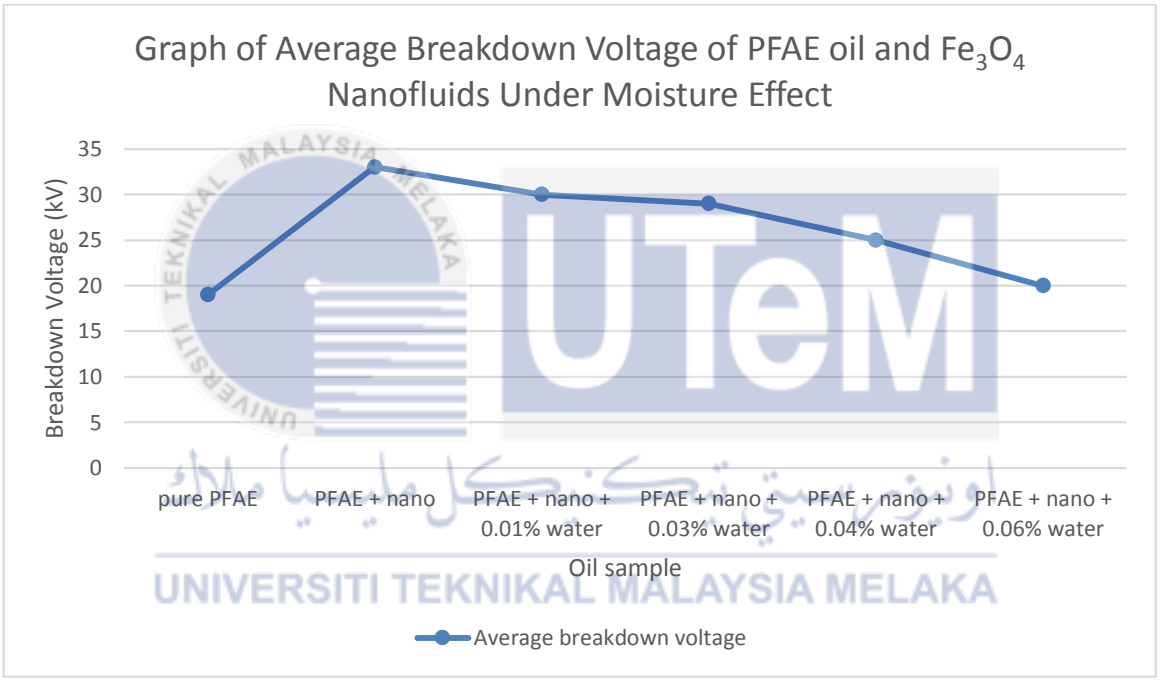


Figure 4. 6: Graph of Average breakdown voltage of PFAE oil and Fe3O4 nanofluids under moisture effect.

Figure 4.6 above illustrate the graph of average voltage of PFAE oil and Fe_3O_4 nanofluids under moisture stress. According to the graph shows that the Fe_3O_4 nanofluids improve the breakdown voltage of the PFAE based or increasing the value of breakdown voltage. By referring the graph, the increasing of the breakdown voltage of Fe_3O_4 nanofluids is directly proportional to the pure PFAE oil. That means the Fe_3O_4 nanofluids can increase

the breakdown voltage of pure PFAE oil. The Fe_3O_4 nanofluids increase the breakdown voltage is about 74% from the origin breakdown voltage. In addition, this is because the moving electron of nanoparticle into PFAE oil have a good relaxation time. The nanoparticles have a large number of electron traps that can capture and release the electron moving in the oil repeatedly. The moving of electron in the insulating oil through the trapping and de-trapping process that can be reduce the velocity of the movement of the electron. So, the trapping and de-trapping process will slow the movement of the electron. Thus, to broke this process need a high stress of voltage. This is evidence that the nanoparticles can increase the breakdown voltage.

According to the graph, the Fe_3O_4 nanofluids is affected by moisture stressed. Figure 4.6 illustrate the 0.01% of moisture decrease the breakdown voltage from 33 kV to 30 kV. The decreasing of the breakdown voltage is about 10 % of the origin breakdown voltage. Based on Naidu [31] 0.01% of moisture will decrease 20% of breakdown voltage. But, from this experiment shows that the decreasing of breakdown voltage 10% only. It is probable the effect of nanoparticle can reduce the moisture stressed. If compared between theoretical and experimental, the differences is about 10%. So, through this experiment it is likely the effect of nanoparticle can reduce the moisture stressed. For 0.03% of moisture reduce the breakdown voltage about 12%. The reason that can concluded is same previously stated that it is likely the nanoparticle can reduce the moisture stressed. When 0.04% is applied, the breakdown voltage reduce 24% while 0.06% moisture is applied the decreasing of breakdown voltage is about 40%. From the result shows that the decreasing of breakdown voltage compare to theoretical is totally different. Based on theory, if 0.06% of moisture will reduce 120% of breakdown voltage which is the insulating oil is totally damaged in term of breakdown voltage. Hence, from this experiment illustrate only 40% of breakdown voltage decreasing. It probably that nanoparticle can reduce the moisture stressed.

Chapter 5

Conclusion and Recommendation

5.1 Conclusions

This research have been studied in order to prepared the nanofluids and to prepared the apparatus for breakdown voltage test. The electrical characteristics of Palm Fatty Acid Ester (PFAE) oil and conductive nanoparticles have been studied and investigated based on the breakdown voltage under moisture stress.

This research have been proved that the Iron oxide, Fe_3O_4 nanoparticles can improve the breakdown voltage. The result shows that the effect of nanoparticles increase the breakdown voltage. Electrical and chemical properties of insulating oils are studied and compared which is better performances. In addition, nanoparticle can improve the breakdown voltage and can reduce the effect of moisture.

Furthermore, the study of nanoparticle should be continuous in order to investigate the speciality characteristics of nanoparticles. Thus, the recommendation of the further study will be suggest later in next sub topic.

5.2 Recommendations

Based on the research, it clearly illustrate that conductive nanofluids has a good potential to improve the breakdown voltage of PFAE oil. Thus, there are some recommendation for future studies on nanoparticles and PFAE oil:

i. Other nanoparticle such as semi-conductive nanoparticle and insulative nanoparticle need to be done.
ii. Other chemical properties such as natural ageing process could be more accurate.
iii. Permittivity test and viscosity test need to be done.
iv. Compare with other insulating oil such as mineral oil.

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