Faculty of Engineering

# EFFECT OF NANOPARTICLE AGAINST BREAKDOWN VOLTAGE OF PALM OIL-BASED ESTER NANOFLUID

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# EFFECT OF NANOPARTICLE AGAINST BREAKDOWN VOLTAGE OF PALM OIL-BASED ESTER NANOFLUID

**Effect Of Nanoparticle Against Breakdown Voltage Of Palm Oil-Based Ester Nanofluid**

MUHAMAD HARITH BIN ABDUL SANI

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# ABSTRACT

In In the electricity transmission system, transformers are utilised to alter voltage levels. As a cooler, insulating oil is required; hence, its longevity is dependent on the insulating oil. The factor of mineral oil is utilized as insulation oil because of its efficient heat transfer, long life and, has good insulating qualities. However, the negative effects of mineral oil on the environment and its slow rate of decomposition should be noted. If there is an oil leak or oil combustion, the present commercial mineral oils that are used as insulation oil can cause contamination of water bodies and the environment such as flora and fauna, air pollution, and soil infertility. Moreover, insulation oils of the organic kind can degrade completely in a short time and have a high breakdown voltage (BDV) strength. As a downside, organic oil has high viscosity and high-cost production. This study focuses on the development of nanofluid-based eco-friendly natural ester oil. The major purpose is to compare the technical performance of the palm-oil-based ester-titanium oxide as nanofluid with mineral oil that is commercially accessible and palm-based ester without nanofluid. Using the product of palm oil reacting with alcohol and titanium oxide nanofluid, a simple laboratory technique known as transesterification is used to make a natural ester with nanofluid. The breakdown voltage test will be focused in this project as the main topic for this study is breakdown voltage for nanoparticles added. The sample will go through thermal aging procedure for lengths of 0 hours to evaluate its performance compared with commercially available insulating oil before testing at the industry. The results revealed that by adding nanoparticle, it can enhance the breakdown voltage of the sample oil. The concentration of nanoparticle added also play an important role as different concentration also give different breakdown voltage. For this experiment concentration used was 0.01 g/L, 0.02 g/L, 0.05g/L and 0.10 g/L. From all the concentration 0.05g/L give the best breakdown voltage which is 31.37 kV.

# ABSTRAK

Transformer berfungsi untuk mengubah voltan dalam sistem penghantaran kuasa. Minyak penebat diperlukan sebagai penyejuk, oleh itu jangka hayatnya bergantung pada minyak penebat. Faktor minyak mineral digunakan sebagai minyak penebat adalah kerana ia menpunyai pemindahan haba yang sangat baik, tahan lama dan mempunyai sifat penebat yang baik. Tetapi, kesan minyak mineral terhadap persekitaran apabila terdedah dan kadar penguraian yang rendah harus dipertimbangkan. Minyak mineral komersial semasa yang digunakan sebagai minyak penebat boleh membahayakan alam sekitar kemudian menyebabkan pencemaran air, udara dan mengurangkan kesuburan tanah jika berlaku tumpahan minyak atau pembakaran. Sementara itu, minyak penebat dengan jenis organik dapat terurai sepenuhnya dalam masa yang singkat dan mempunyai kekuatan kerosakan voltan (BDV) yang baik. Tetapi, minyak organik mempunyai kelikatan dan kos pengeluaran yang tinggi. Kajian ini memberi tumpuan kepada penyelidikan minyak ester semula jadi yang mesra alam di tambah dengan nanofluid. Objektif utama adalah untuk mambandingkan kemampuan teknikal minyak sawit ester berasaskan titanium oksida, minyak mineral yang sudah tersedia ada dan minyak sawit ester tanpa titanium oksida. Kaedah transesterifikasi dipilih untuk menghasilkan ester semula jadi dengan nanofluid menggunakan produk minyak sawit yang bertindak balas dengan alkohol dan nanofluida titanium oksida. Ujian kekuatan kerosakan voltan akan difokuskan dalam pembelajaran ini kerana topik utama untuk pembelajaran ini ialah kesan titanium oksida kepada kesan kerosakan voltan. Setiap sampel akan melalui proses penuaan termal selama 0 jam untuk menilai prestasinya kemudian dibandingkan dengan minyak penebat yang tersedia secara komersial sebelum diuji di industri. Hasilnya mendedahkan bahawa dengan menambah nanopartikel, ia boleh meningkatkan tegangan pemecahan minyak sampel. Kepekatan nanopartikel yang ditambahkan juga memainkan peranan penting kerana kepekatan yang berbeza juga memberikan tegangan pemecahan yang berlainan. Untuk eksperimen ini, kepekatan yang digunakan ialah 0.01 g/L, 0.02 g / L, 0.05g / L dan 0.10 g /L. Daripada semua kepekatan 0.05g / L memberikan tegangan pemecahan terbaik yang ialah 31.37 kV.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

This research was undertaken to investigate the effect of nanoparticles on the breakdown voltage of nanofluid derived from palm oil. Transformers are utilized extensively in electric power production, transmission, and distribution in systems with high voltages. These power transformers are often oil-filled, as the oil serves as the transformer's insulating medium and cooling agent. The utilized oil must possess the necessary characteristics for optimal performance in the transformer. The liquid substances must possess exceptional chemical stability, dielectric strength, and thermal conductivity. Mineral oils are widely utilized in industries nowadays. Due to their superior electrical qualities, mineral oils are extensively used in power transformers. Due to the presence of polycyclic aromatic hydrocarbons that do not meet the standards for fire and safety, mineral insulating oils provide a high risk of initiating a fire or possibly an explosion in transformers. Mineral insulating oil derived from petroleum products is a non-renewable resource that is considered environmentally hazardous. [1]. MO has certain disadvantages, including the fact that it is extracted from fossil fuels, which are likely to run out in the long future. In addition, the biodegradability of MO is relatively poor, thus if a leak occurs, there is an environmental risk.[2].

In this project, experimental research will be undertaken to determine the influence of various nanoparticle kinds, including silica, titanium, etc., on the breakdown voltage of palm-based nanofluid as an electrical insulator. Vegetable oils are the type of oil that will be examined in this experiment (VOs). VOs has better biodegradability, flash, and ignition points.[2]. It was determined that VOs was the most likely candidate for a completely biodegradable insulating fluid. Vegetable oil is an abundant natural resource that is a good insulator and totally biodegradable.[3]. Malaysia is one of the greatest producers of palm oil in Asia, therefore locating a supply for this project will not be difficult and it can be tested without importing from other nations.

**Figure 1** POME Preparation

Nanofluids are nano-sized particles dispersed in a base fluid that have recently garnered a great deal of attention due to their unique and superior properties. However, scientists continue to investigate the optimal possible mixture of nanofluids with a desired attribute, which is unresolved. [4]. Nanofluids containing different types of nanoparticles offer intriguing potential uses in fields such as electrical engineering, microelectronics, healthcare, and energy storage. Nanofluids, which are produced by adding nanoparticles to a base fluid, are stable, homogenous suspensions with enhanced electrical insulation and thermal conductivity. [5].

## 1.2 Problem Statement

Liquid insulating materials are used as an electrical insulator and cooling agent in power transformers. Mineral oil now is the most often used liquid insulating material in power transformers. However, mineral oil's qualities such as limited biodegradability and high flammability are important drawbacks. Several studies on alternatives to mineral oils have been conducted. Minerals are non-renewable resources, making it challenging to use mineral oils. To replace mineral oils, the oil's fundamental properties, such as breakdown voltage, viscosity, ageing, flash point, dielectric constant, etc., must be evaluated.[6].

Typically, the natural esters discussed in this advice were produced to lessen health and environmental risks. Although there are no recognised risks related with the handling and consumption of natural ester liquids, the basic vegetable oils may include different additives. Users must obtain a safety data sheet (SDS) for any natural ester liquid they use. Typical values and value limitations for unused and used natural ester insulating liquid may range significantly from those provided for mineral oil. [7]. Due to a deficiency of research and publications on POME (palm oil methyl ester)-based liquids, there is uncertainty on the danger that they pose.

In the case of esters, which have substantially greater density and viscosity than mineral oil, the contact time with the heating surface is significantly longer. It causes the layers of the liquid to "stick" to the surface of the heater, resulting in the breakdown and disruption of molecular bonds due to overheating. The larger density of esters than mineral oil makes it more difficult for these liquids to circulate with the appropriate flow velocity in the narrow cooling channels of the windings and magnetic core.[8]

The technology utilised is a transesterification procedure that converts vegetable oil to natural ester oil. For the most recent trend, nanoparticles were used to enhance its properties. However, there are several types of nanoparticles, and the nanoparticle concentration must be optimal for the insulating oil improvement to be effective.

## 1.3 Objectives

The objective of this study is to:

a. To synthesize a biodegradable oil from palm oil through a transesterification process and blended with titanium oxide ($TiO_2$) nanoparticles.
b. To investigate the effect of nanoparticles against breakdown voltage of palm oil methyl ester (POME) nanofluids
c. To determine the optimal $TiO_2$ nanoparticle concentration for maximizing breakdown voltage performance

### 1.4 Project scope

This project focused on certain crucial components which are:

a. Palm-based cooking oil will be used as base oil to prepare the sample.
b. The oil sample prepared analysed with suitable laboratory testing.
c. Titanium Oxide (TiO2) will be used as nanoparticles.
d. Esterification methods result exclusively in palm oil methyl ester.
e. Four different concentrations of TiO2 will be used (0.01g/L, 0.02g/L, 0.05g/L and 0.10g/L) for synthetization of nanofluids.
f. Four different concentrations of CTAB will be used (0.005g/L, 0.01g/L, 0.025g/L and 0.05g/L) for synthetization of nanofluids.
g. All experiments for the oil sample preparation are at Chemical Department's Lab, Faculty of Engineering, UNIMAS.

### 1.5 Project outline

The summary of the report as explained below:

#### 1.5.1 Chapter 1: Introduction

This chapter focus on explaining the brief of this project while it contains of research background, problem statement, objectives, and scope of the work. It gives a general overview regarding the requirement of biodegradable insulating oil as a replacement of commercially available mineral oil. It also explains the necessity of proper concentration of nanoparticles for enhancement of biodegradable insulating oil.

#### 1.5.2 Chapter 2: Literature Review

This chapter deals with the newest study articles or concepts concerning the present commercial commodity of insulating oil over its modern biological oil predecessors termed palm oil. To be detail, all the dielectric characteristics will be discussed. This chapter also focused on the usage of nanoparticles on natural ester and described the standard concentration that could demonstrate the optimal concentration of nanoparticle to increase the dielectric characteristics.

### 1.5.3 Chapter 3: Methodology

This chapter discussed the methods that were done in this experiment thoroughly. The procedure focuses on synthesising of natural ester and adding of nanoparticle which is the result of this study. Following that, insulating oil is examined in a laboratory test to compare all the dielectric characteristics.

### 1.5.4 Chapter 4: Result and Discussion

This chapter study and discuss the result of the tests. The result compiled and expressed in graph to make is simpler to grasp and compared with the standard commercially available insulating oil or with its standard. It is necessary to justify the result to make sure how much improvement or how distant it is from the standard as an insulation oil. On top of that, the manufacturing cost of the sample also covered and compared with the other typical commercially available mineral transformer oil.

### 1.5.5 Chapter 5: Conclusion and Recommendation

This chapter outlines all the outcomes and the information gathered while overseeing the project. Limitations and restrictions are fully discussed while possible counter actions are usually offered to identify these problems.

# Chapter 2

# LITERATURE REVIEW

## 2.1 Overview

This chapter provided a quick overview of the significant responsibilities and many types of transformers insulating oil. To fulfil the demand for greener technology, a new product should be developed to replace conventional petroleum-based insulation oil, which is non-renewable and unfriendly to the environment. As an alternative, an eco-friendly and biodegradable insulation oil should be synthesized from naturally renewable sources such as palm oil that undergo a chemical process to improve its function as insulation oil to fulfil the requirements and be competitive with commercial insulation oil.

## 2.2 Insulating Oil

Transformers are essential components of any electrical transmission or distribution network. As a significant proportion of the world's power transformers have reached the end of their expected design life, utilities have placed a greater emphasis on transformer condition-based maintenance to extend the transformer operational life span and preserve the asset's highest viable efficiency[9].

The most crucial part of transformers is to have good insulation oil. Oil's primary function in a transformer is to create electrical insulation between the various live sections and to prevent oxidation of the metal surfaces. Enhanced heat dissipation is yet another essential feature of the oil. Various power losses cause the heating of transformer cores and windings during operation. Using conduction, oil transfers heat from the core and windings to the surrounding tank, where it is ultimately radiated into the atmosphere. Transformers generate a great deal of heat, which must be evacuated lest the copper melt and cause the transformer to fail.[10] According to a survey by the IEEE, the failure rate per unit year for oil-immersed transformers is 0.00625. In a fleet of 100 transformers, ten will fail within the following sixteen years [11] One of the solutions to this issue is Insulation oil must have appropriate values for its flash point, viscosity, break strength, and fire point. It must meet its chemical and physical requirements.

Most transformers in electrical power stations are filled with liquid that serves as an electrical insulator, coolant, and coating layer to keep metal surfaces from oxidizing. Without insulation oil, the transformer will hard utilize its function. The Figure 2 below provides an overview of the liquid and solid insulators in transformer oil.

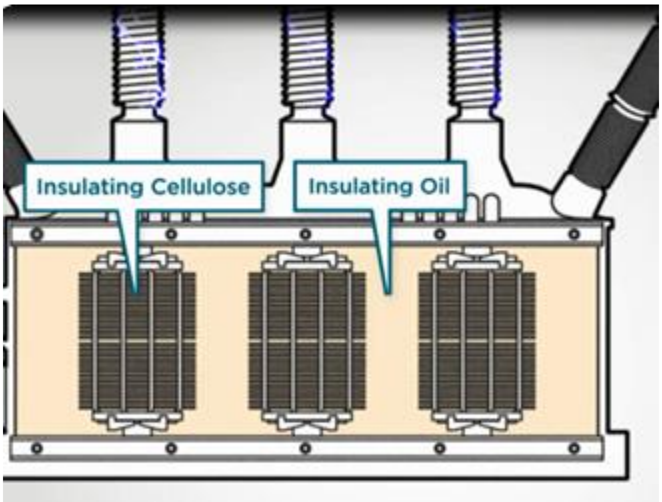


**Figure 2** Insulator oil in Transformer[12]

## 2.3 Mineral Oil

Mineral oil is the most widely utilized liquid in power transformers due to its low cost and excellent qualities. However, environmental considerations begin to limit the performance of mineral oil. Conventional transformer oils are often non-biodegradable and can contaminate soil and water in the event of a major spill. This might potentially disrupt the plantation and other organisms. Second, the mineral oils were taken from petroleum, which is a non-renewable resource that will run out in the future.[13]

Nevertheless, mineral oil has been selected as a liquid insulating substance because its electrical resistance is greater than that of air and, if necessary, it can operate as a cooling medium to keep the equipment's working temperature at a safe level. Manufacturers and users of high-voltage equipment, as well as oil producers and oil chemists, pay special attention to the service stability of mineral-insulating oils. Therefore, the efficient operation of mineral-oil-filled electrical equipment is highly dependent on the oil's ability to retain its initially good electrical properties, its inertness- towards the solid insulating materials that are also present in most of the oil-filled electrical equipment, and its ability to effect efficient cooling in the presence of degrading influences [14]

Presently, the primary raw materials for mineral insulating oil are paraffin- and naphthenic-based hydrocarbon-based crude oils. Alkanes, cycloalkanes (one-, two-, three-, and four-membered rings), and aromatic hydrocarbons are the hydrocarbon components [15]

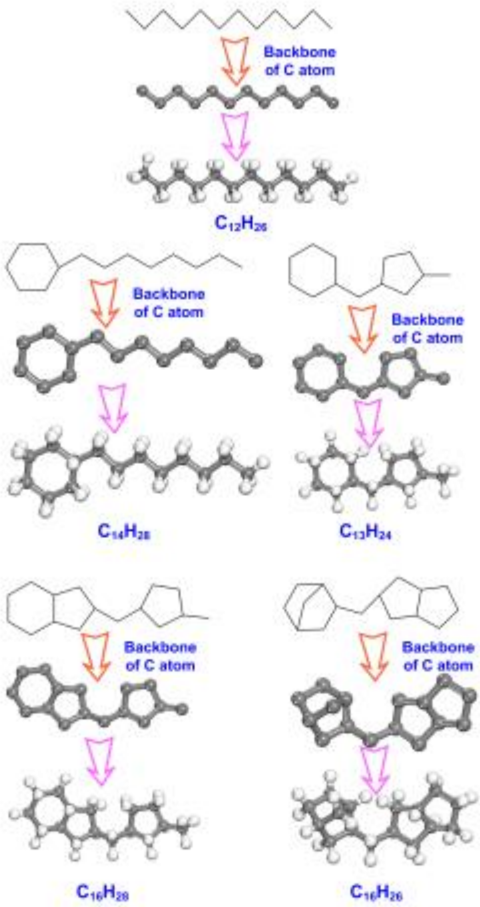


**Figure 3** Main Component of naphthenic mineral insulating oil[15]

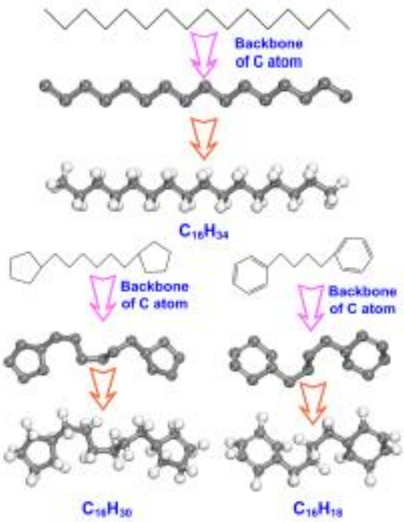


**Figure 4** Main component of paraffin-based transformer oil[15]

## 2.4 Vegetable Oil

Vegetable oils are triglycerides that are often extracted from plants. Humans have been using vegetable oils for generations. The definition of "vegetable oil" is a plant oil that is liquid at room temperature. Triglycerides are found in vegetable oils. While it is true that oil can be produced from a variety of plant components, commercially, oil is extracted mostly from seeds. Vegetable oils are regarded to be a viable substitute for mineral oil in transformers. Many researchers and industries are undertaking studies on vegetable oils for delivering them as insulating oils in transformers and pollution-free environments.[16]

Some vegetable oils with a lower poly instauration are more resistant to oxidation. These oils are appropriate replacements for mineral oil in applications with minimal electrical energy requirements. Below 130 °C, paper ages more rapidly in vegetable fluids than in mineral oil. However, at temperatures above 130°C, it contains less furaldehyde than mineral oil. Similarly, these oils have higher polymerization values for cellulose insulation than mineral oils, indicating that vegetable oil paper consumption is lower.[17]

Due to its function as a cooking oil, vegetable oil is in high demand in the modern market. Due to this, the availability of the oil will not be an issue, as it is readily available on the Malaysian market. Figure 5 below illustrates the molecular structure of vegetable oil (natural ester).

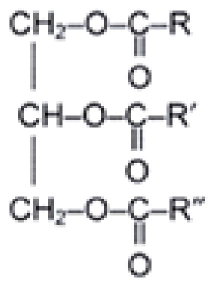

**Figure 5** Structure of triglyceride[18]

### 2.4.1 Palm Oil

As for this project, Palm oil will be the focus compared to other vegetable oil such as sunflower oil, kernel oil, coconut oil, etc. Refined, Bleached, and Deodorized Palm Oil (RBDPO) is refined from Crude Palm Oil (CPO) [19]. According to studies, Palm oil has the capabilities necessary to function as an insulating and cooling liquid in a transformer. In contrast to mineral oil, which has a maximum dielectric strength of 50 kV and a very high flash point of 242°C, its crude dielectric strength is 25 kV [10]

**Table 1** Mineral oil and Palm oil Property[10]

| Property | Mineral Oil | Palm Oil |
|---|---|---|
| BDV (kV) | 50 | 25 |
| Moisture Content (%) | 0.15 | 0.19 |
| Pour point (°C) | -40 | 15 |
| Flashpoint (°C) | 140 | 242` |
| Density (g/cc) | 0.89 | 1.5 |
| Viscosity (CST) at 40°C | 9.2 | 30 |

RBDPO that will be used in this study is raw cooking palm oil which is Cap Buruh that is easily purchased in the local groceries shop. This raw palm oil will undergo a transesterification process.