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FINAL YEAR PROJECT REPORT

INFLUENCE OF MOISTURE CONTENT TO AC BREAKDOWN VOLTAGE OF MINERAL OIL BASED NANOFLUIDS

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" I hereby declare that I have read through this report entitle "*Influence of Moisture Content to AC breakdown voltage of mineral oil based nanofluids*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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INFLUENCE OF MOISTURE CONTENT TO AC BREAKDOWN VOLTAGE OF MINERAL OIL BASED NANOFLUIDS

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "*Influence of Moisture Content to AC breakdown voltage of mineral oil based nanofluids*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : MUHAMAD YAHYA BIN RAZIFF

Date : .....

Dedicated to my beloved mother, father and whole family

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ABSTRACT

The power transformer is a very important and costly part of the electrical generation, transmission and distribution system network. Electric transformers depend on the high dielectric strength and cooling properties of insulating oil to maintain normal operation. Statistically, most of the transformer damages occur due to the dielectric insulation problems. The dielectric insulation problems affected by several factors, such as moisture, suspended particles, acidity, and pressure. The electrical strength of dry oil can be decreased due to the presence of water in the transformer oil. Hence, it is important to improve the insulating characteristics of transformer oil. Recently, transformer oil based nanofluids have been developed by dispersing nanoparticles in the oil. It has been shown that some of these nanofluids have much greater dielectric breakdown strength or thermal conductivities than the host transformer oil. Nanoparticles have affected changes in electrical properties when dispersed in insulating oil. Thus, this project aims to prepare nanofluids using mineral oil by dispersing it with Fe_3O_4 conducting nanoparticles. Then, a setup of High Voltage (HV) apparatus for breakdown voltage test according to IEC 156 standard will be prepared. Next, the nanofluids will be tested to determine their AC characteristic which is breakdown voltage under moisture effect. Mineral oil as a base oil is compared with the percentage of water presence in the Fe_3O_4 nanofluid. This project expected to give benefit to electrical generation, transmission and distribution system network by improving the breakdown voltage of transformer oil based nanofluids. This is because nanoparticles dispersed in insulating oil are promising to enhanced the AC breakdown voltage.

ABSTRAK

Pengubah kuasa sangat penting dan mahal dalam bahagian penjanaan elektrik, penghantaran dan sistem pengagihan rangkaian. Pengubah elektrik bergantung kepada ketinggian kekuatan dielektrik dan sifat penyejukkan minyak penebat untuk mengekalkan operasi normal. Secara statistik, kebanyakan kerosakan pengubah berlaku disebabkan oleh masalah penebat dielektrik. Kerosakan penebat dielektrik dipengaruhi oleh beberapa faktor seperti kelembapan, zarah tercemar, keasidan dan tekanan. Kekuatan elektrik minyak kering akan menurun disebabkan kehadiran air dalam minyak pengubah. Oleh itu, ciri-ciri penebat minyak pengubah adalah sangat penting untuk ditingkatkan. Baru-baru ini, cecair nano berasaskan minyak pengubah telah dikembangkan dengan menyebarkan nanopartikel ke dalam minyak. Ia telah terbukti bahawa sebahagian daripada cecair nano ini mempunyai kekuatan dielektrik yang lebih bagus atau keberaliran haba lebih daripada minyak pengubah asli. Nanopartikel telah mempengaruhi perubahan dalam sifat-sifat elektrik ketika tersebar dalam minyak penebat. Oleh itu, projek ini bertujuan untuk menyediakan cecair nano menggunakan minyak mineral dengan menyuraikan Fe_3O_4 nanopartikel konduktor kedalamnya. Kemudian satu persediaan peralatan Voltan Tinggi (HV) untuk ujian ketahanan tembus mengikut piawain IEC 156 akan disediakan. Seterusnya, cecair nano akan diuji untuk menentukan ciri-ciri elektrik di bawah kesan kelembapan mereka iaitu ujian ketahanan tembus. Minyak mineral sebagai minyak asas dibandingkan dengan peratusan kehadiran air di nanofluid Fe_3O_4 itu. Projek ini dijangka memberi manfaat kepada penjanaan elektrik, penghantaran dan sistem pengagihan rangkaian dengan meningkatkan ketahanan voltan cecair nano berasaskan minyak pengubah. Ini kerana nanopartikel tersebar dalam minyak penebat menjanjikan kepada peningkatan AC ketahanan voltan.

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LIST OF ABBREVIATIONS

HV	-	High Voltage
IEC	-	International Eletrotechnical Comission
AC	-	Alternating Current
DC	-	Direct Current
EHV	-	Extra High Voltage
nm	-	nanometer
BDV	-	Breakdown voltage
PVD	-	Physical Vapor Diposition
g	-	gram
kV	-	kilovolt
mm	-	milimeter
l	-	liter
kPa	-	kilopascal
MF	-	Mass fraction
M	-	Mass
PFAE	-	Palm Fatty Acid Easter

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will discuss about research background, problem statement, project objectives, scopes of project and contribution of project. Background of the project will explain the purpose, motivation and significance of the project. Problem statement is a short brief of the issues that need to be avoided and solve. While the objectives and scope will explain the purpose and goals of the project. Lastly, project contribution is the expected improvements to be achieved after this project is complete.

1.2 Research Background

Power transformer is a very important apparatus and it is the most costly part of the electrical generation, transmission and network of distribution system. Power transformer depends on high dielectric strength and the cooling properties of insulating oil to maintain normal operation [1]. It is so significant to improve the insulating properties of transformer oil because the possible Extra High Voltage (EHV) power transformer failures were due to dielectric insulation problems [2]. Recently, transformer oil based nanofluids have been developed by dispersing nanoparticles in the oil. It has been shown that some of these nanofluids have greater dielectric breakdown strength or thermal conductivities than the host transformer oil [3]. Nanoparticles have affected changes in electrical properties when dispersed in insulating oil. Thus, this project aim is to prepare nanofluids using mineral oil

by dispersing it with conducting nanoparticles. Then, a High Voltage (HV) apparatus for breakdown voltage test will be prepared. Next, the nanofluids will be tested to determine their electrical characteristic which is Alternating Current (AC) breakdown voltage. It is expected that by dispersing nanoparticles into mineral oil, it will improve the AC breakdown voltage of the insulating oil.

1.3 Problem Statement

Transformer damage can cause interruption of power system operation and income losses because power transformer is a very important and costly part of the electrical generation, transmission and distribution system network. Statistically, most of the transformer damages occur due to the dielectric insulation problems. The dielectric insulation problems affected by several factors, such as moisture, suspended particles, acidity, and pressure [4]. The electrical strength can be decreased to 20% of the dry oil value due to the presence of 0.01% water in the transformer oil [5]. Hence, it is important to improve the electrical characteristics of the transformer oil. Thus, this project will focus on improving the AC breakdown voltage of mineral oil by dispersing it with conductive nanoparticles and and test it under the influence of moisture.

1.4 Objectives

The objectives of this project are:

i. To prepare nanofluids by dispersing conductive nanoparticles into mineral oil.
ii. To prepare a liquid insulation's Breakdown Voltage Test set.
iii. To determine the conductive nanofluids AC breakdown voltage level under moisture effect.

1.5 Scope of Research

The scope of research are:

i. Prepare nanofluids by dispersing the conductive nanoparticles (Iron Oxide, Fe_3O_4) into mineral oil.
ii. Mineral oil that is used in this project is HYRAX HYPERTRANS transformer oils manufactured by Malaysia company as a base oil.
iii. AC Breakdown Voltage Test (Megger Oil Test Set OTS60PB) according to IEC 156.

1.6 Contribution of Research

This research gives benefit to electrical generation, transmission and distribution system network by improving the breakdown voltage of transformer oil based nanofluids. This is because of nanoparticles dispersed in insulating oil are expected to enhance the breakdown voltage.

1.7 Report Outlines

This thesis is covered with five chapters. Chapter 1 is explained about the research background, problem statements, project objectives and scopes of project. Chapter 2 will describes the theory or general concept that related to the project and review the previous research works. It will more focus on the performances of the insulation oil that has been dispersed with nanoparticles. Then, Chapter 3 will illustrated methodology applied in order to get the required output. The flow of project development will be explained by a flow chart. Chapter 4 interpreted and explained the result by presents the tables and graph. Analysis and discussion on the problem issued were discussed. Lastly, Chapter 5 is about the conclusions and recommendations should be made through out this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter contains of review of some of previous studies that relate to this project. There are some previous studies on the theory and basic principle, electrical properties of transformer oil, application and uses of nanoparticles. Principles of the methods or techniques used in the previous work also provided in this chapter.

2.2 Theory and Basic Principles

This project is based on nanotechnology studies because nanoparticles are the main material that use to determine the breakdown voltage of nanofluids when it's dispersed into insulating oil. Nanotechnology offers a new innovative process and produce extremely small things about 1 nm to 100 nm [6]. Fluids dispersed with nanoparticles are called nanofluids. Nanofluids are a new generation of heat transfer fluids due to enhancement of heat transfer performance. Nanofluids have a good cooling properties compared to conventional heat transfer fluids [7]. From the literature review, there are two theories to explain on how nanoparticles can improve the AC breakdown voltage level which is nanoparticles relation times and electron trapping and de-trapping process.

2.2.1 Nanoparticles Relaxation Times

The fundamental electrodynamic processes are the basic principles that show why a transformer oil based nanofluids indicates the different characteristics of electrical breakdown of pure oil. The charge relaxation time constant of nanoparticles in liquid modified has an influence on the extent to which electrodynamic process. If the nanoparticles charge relaxation time constant shows that a short relative to the timescales of interest for a streamergrowth, indirectly it's present in the oil may change the electrodynamics. Otherwise, if the nanoparticles relaxation time constant is long relative to the timescales of interest for streamer growth, the presence of nanoparticles will less effects on the electrodynamics process[8].

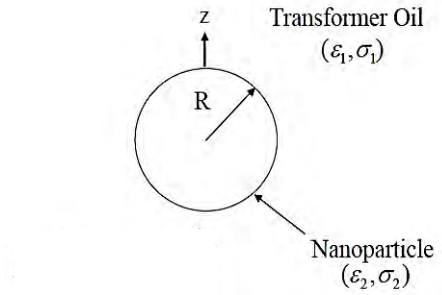

Figure 2.1: Material of nanoparticles in transformer oil [8]

Figure 2.1 shows a material of nanoparticle in transformer oil instead of calculate the relaxation time constant. Where ε1 and σ1 are respectively the permittivity and conductivity of the mineral oil, and ε2 and σ2 are the corresponding quantities for the nanoparticles. Below is the equation of the charge relaxation time constant τ_r of nanoparticles dispersed in transformer oil is [8]:

$$\tau_r = \frac{2\varepsilon 1 + \varepsilon 2}{2\sigma 1 + \sigma 2} \tag{2.1}$$

If the equation of relaxation time constant of the nanoparticles is shorter than a few microseconds, which is the time scale that involved in the development of the streamer in mineral oil, the polarized nanoparticles will capture fast electrons and effectively reduce their mobility. Otherwise, if the nanoparticle relaxation time is much longer than the

streamer development time scale, the nanoparticles will have less effect on the high electron mobility [9].

2.2.2 Electron Trapping and De-trapping Process

Based on the previous research, the space charge characteristics of nanofluid semiconductive nanoparticles found that it can produce many electron shallower traps in nanofluid. The shallower traps could capture the mobile electrons and release them rapidly. When moving from high electric field to the lower field, the electrons can transform from fast electrons to the slow electrons by repeats the trapping and de-trapping process in the oil. It is the high shallow traps that contribute to the rapid charge dissipation and result in the improvement of breakdown performance [10].

The trap features of the nanofluid modified by insulating nanoparticles and pure oil, demonstrates that adding insulating nanoparticles in the oil produce shallower traps, which is consistent with the research of oil modified by semi-conductive nanoparticles [10]. In the transformer oil, conductive nanoparticles with extremely low charge relaxation time constant could capture the fast electrons and convert them into the low mobility that negatively charged nanoparticles. Such a change, in the oil it can modify the electrodynamics and the propagation of streamers can be slows. Therefore, the dielectric performance of the oil adding the conductive nanoparticles is enhanced. Adding semi-conductive nanoparticles and insulating nanoparticles can both produce shallower traps in the oil. These shallower traps could capture mobile electrons and release them rapidly. During this process, the speed of the electrons is reduced [11].

2.3 Review of Previous Related Works

Review from the previous related works shows there are some research, investigation, case study and analysis that have been done related with nanofluids, mineral

oil, insulation in power transformer and others. All the information gets from books, journals and articles that are useful to support the approach that has been made.

2.3.1 Electrical Properties of Transformer Oil

Transformer oil is also known as insulating oil. It is produced by the fractional distillation process and treatment of crude petroleum. Figure 2.2 shows the transformer oil. The transformer oil performs two important functions. First, to create an insulation resistance level in the combination of the insulating materials that used in the coils and conductor. Then, serves as a coolant to remove heat from the core and the windings of the transformer. Additionally, this oil have two other functions which is to maintain the core and winding as it was sunk in the oil and other functions are preventing direct contact of atmospheric oxygen with cellulose made paper insulation of windings that susceptible to oxidation [12].

Figure 2.2: Insulating oil in an electrical power transformer [13]

The electrical properties of the transformer have two which is an electrical breakdown voltage strength and resistivity. Under a prescribed condition the voltage breakdown occurs between the two electrodes when the oil was subjected to an electrical field, it is known as the breakdown voltage (BDV) of transformer oil. The breakdown voltage was measured by a BDV testing instrument shown in Figure 2.3 [13]. The electrical breakdown strength is used as a basic parameter for insulating system design of the transformer. The breakdown voltage strength of transformer oil should be high. If the

transformer has a lower strength it shows that the presence of the impurities agents such as moisture, fibrous materials, carbon particles, precipitable sludge a sediment. The breakdown voltage of the new sample of transformer oil is 30kV. While for a sample after filtration, it must has BDV of 60kV [13].

Figure 2.3: BDV testing instrument [13]

The resistivity is also equivalent to the resistance that occurs between opposite faces of a centimeter cube of the liquid. The insulation resistance of the windings depends on the insulation of the oil. To have a good transformer oil, the resistivity should be high and the low resistivity of transformer oil shows that the presence of moisture and conductive impurities agents [12].

2.3.1.1 Mineral Oil

Petroleum oil has been utilized as transformer oil since 1891 which is discovered by Sebastian de Ferranti. There are two methods for a creation process for petroleum oil which is crude petroleum and refining petroleum. Initially, petroleum oil comes from the extraction source namely crude petroleum. Hydrocarbons are a main content in this oil and also contains a little portion of sulfur and nitrogen. Fundamentally, hydrocarbon molecule can be isolated into three groups which are paraffin, naphthenes and aromatics [14]. The quality of oil is very important to reduce the failure of transformer