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Breakdown Characteristic of Palm and Coconut Oil with Different Moisture

N. A. M.Jamail[1], N. A. Azali[2], E.Sulaiman[3], Q.E.Kamarudin[4], S.M.N.S.Othman[5,] M.S.Kamarudin[6]
[1,2,3,6]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[4]Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[3,5]Research Centre for Applied Electromagnetics, Universiti Tun Hussein Onn Malaysia 86400 Parit Raja, Batu Pahat, Johor, Malaysia

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ABSTRACT

Oils acts as insulation and cooling agent in the transformer. Petroleum-based oils are widely used in transformers due to their qualified properties as good insulation materials. Unfortunately, the used of petroleum-based oils has adverse effects on environment in the event of any failure to transformers such as tank leakage or explosions. Therefore, researchers have been studied and have found environmentally friendly oil that is suitable as substitutes in transformer. Thus, breakdown voltage tests using direct current and alternating current with the addition of different water content were performed to identify the potential of palm oil and coconut oil in the transformer isolation system. Refined, Bleached and Deodorized oil (RBDPO) and coconut oil samples were selected to be test in this study. The oil samples were test by varies the gap distance of test cell electrode and the level of water content. As a conclusion, RBDPO oil has greater breakdown voltage test under DC breakdown voltage test in term of increment of the gap distance.

Corresponding Author:

N. A. M.Jamail
Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia 86400 Parit Raja,
Batu Pahat, Johor, Malaysia.
E-mail: norakmal@uthm.edu.my

1. INTRODUCTION

In high voltage system such as power transformers, the insulating liquid is commonly used as it caters electrical insulation, reduces corona and serves as a coolant to avoid the transformer from overheating. Good insulating liquid must have high breakdown voltage, good chemical stability, low dielectric dissipation factor, reasonable economical price and act excellent cooling medium. Petroleum-based mineral oils fit almost all the factor as the good insulating oil; therefore, it has been used as liquid insulator for a long time.

Recently, researches try to seek the substitutes of liquid insulating material in transformer due to the hazardous mineral oil to the environment. Biodegradable insulating oils made from vegetable oils are gaining wide usage in power transformers because when compared to the commonly used petroleum based mineral oils, they are environmentally safer, healthier and found to have better dielectric properties like breakdown voltage [1]. Vegetable oils are natural products available in plenty. They are used mostly for edible purposes, but special oils are used for drying and cutting. Palm based oils are one type of vegetable oil stock that have found potential use as insulating liquids in power transformers [2]. The abundant production of palm oil and its derivatives encourages the study of making such insulating liquids more available and affordable for power transformers [3]. Coconut oil also included as one of vegetable oils which is a colorless to pale

brownish-yellow liquid. In mild climates, it appears as greasy, somewhat crystalline, and white to yellowish solid fat. Coconut oil is extensively used for edible and industrial purposes. Products derived from coconut oil and its fatty acids find numerous applications in food, soap, textile and synthetic resin industries, and recently even as an auto lubricant [4].

Huge problem in power systems usually cause by many factors which occurs due to the transformer failures. This failures costs fortune to the utilities companies in maintenance expenses. Insulation deterioration is caused by four factors; pyrolosis (heat), oxidation, acidity, and moisture. But moisture is reported separately [5]. Despite the low percentage of failure caused by moisture, the transformer operation still can be affected, and maintenance costs will also increase. There are several categories of moisture that caused transformer failures including bushings or fittings failures due to water entering the tanks, and other forms of oil contamination. Many insulating liquids are insulating oil, which include petroleum, vegetable and synthetic oil. Mineral oil is widely used as the transformer liquid insulation due to its present availability and the low cost. Nowadays, environmental friendly oil like vegetables oil being used as alternative to the hazardous mineral oils.

Palm oil is extracted from the mesocarp of the fruit of an oil palm species called Elaeis guineensis. In Malaysia, the high yielding tenera, which is a cross between dura and pisifera species, is the most commonly cultivated palm tree. The Malaysian palm oil contributes to about 13% of total vegetable oil production in the world in 2011 [6]. Compared with other types of vegetable oils, palm-based oils have a large composition of fatty acids that consist of different types of carbon. This carbon composition contributes to the good oxidation stability [7-8]. Coconut oil is a colorless to pale brownish-yellow liquid. In temperate climates, it appears as greasy, somewhat crystalline and white to yellowish solid fat [9]. Studies on physical properties, chemical composition and electrical properties of coconut oil have been carried out by some researchers, and studies on using purified coconut oil as insulation have also been carried out. The important properties considered are the dielectric strength and the pour point [10].

In general, there were higher breakdown voltages of most vegetable oils compared to mineral oils. Dielectric strength of insulating material depends on the dielectric stress developed subject to high voltage. There is some factor that affects the dielectric breakdown strength such as temperature, impurity in dielectric substance and humidity [11]. AC breakdown voltage is high for new oils because after ageing, the breakdown voltage could be decreased due to the appearance of contaminants such as ageing by-product [12]. A previous paper [13] stated that water can be presence in some different states within the transformer. The increasing of moisture content in insulating liquid will reduce the dielectric breakdown voltage.

The presence of moisture in insulation oils is one of the leading causes of electrical breakdown because it increases the ionic conductivity of the oil hence lowering the breakdown voltage. Water is a substance that undesirable and should be avoided. Thus, this study has focused on how the breakdown characteristics in palm oil and coconut oil changes under AC and DC voltage when the moisture rate is changing. The analysis and discussion on effect of water content towards the breakdown was done to see the performance of oils.

2. RESEARCH METHOD

This project focused on the breakdown voltage test for HVAC and HVDC which are purpose to identify the breakdown strength of palm oil and coconut oil under AC and DC voltage. Distilled water was added into oil sample by using 3 ml syringe. Distilled water has been added into the oil at 0.5, 1.0, 1.5, and 2.0 ml per sample prepared. A hotplate magnetic stirrer being used to stir the mixture of water and oil for 3 hours [14] as shown in Figure 1 to ensure the water and oil were mixing properly.

Oil sample of 400 ml was filled in the test cell. The electrode gap in the test cell was adjusted to 2.5, 3.0, 3.5, 4.0, and 4.5 mm for each sample of oil sample that were tested in this experiment as shown in Figure 2. Figure 3 shows the circuit connection for HVAC breakdown test and Figure 4 shows circuit connection setup for HVDC breakdown test. Both experiments circuit are connected in series.The silicon rectifier act as the converter to convert alternating current to direct current in circuit connection for HVDC experiment test. Meanwhile, charging resistor being used to add the time delay between the flashover to ensure the reading of this project more accurate. Coconut oil and RBDPO has been used as oil sample for the breakdown test in this project.

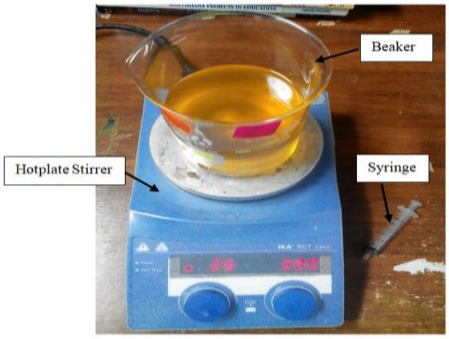


Figure 1. Mixing water with oil using hotplate stirrer

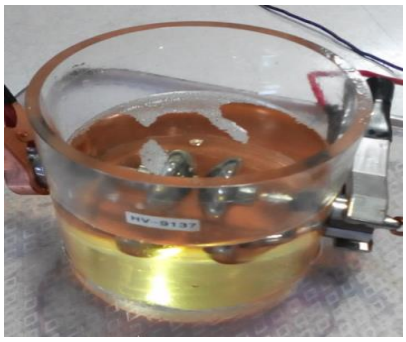


Figure 2. Test cell filled with oil

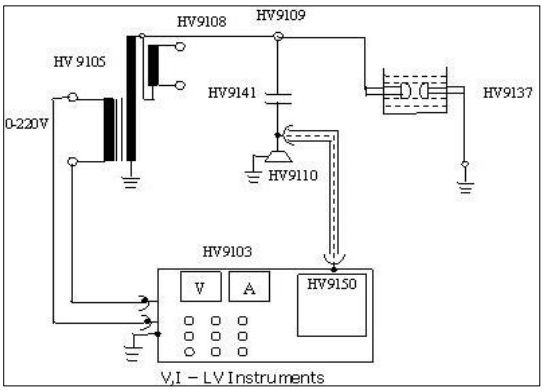


Figure 3. Circuit connection for HVAC experiment

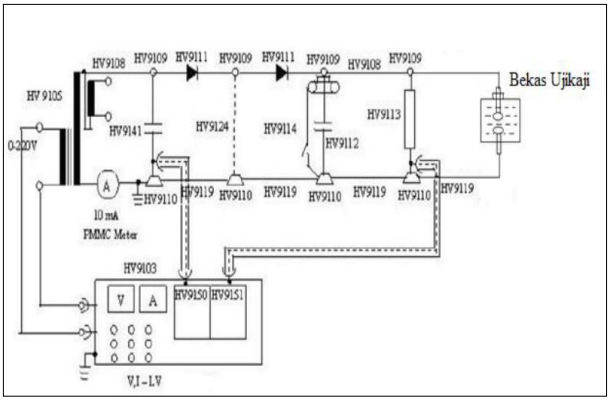


Figure 4. Circuit connection for HVDC experiment

3. AC AND DC BREAKDOWN VOLTAGE

Figure 5 shows AC Breakdown voltage of RBDPO Oil when added with water. The test cell electrode was adjusted to 2.5mm. From the results, it shows that the highest maximum breakdown voltage for normal RBDPO oil without any addition of water was 16.31 kV while the mean breakdown voltage was 15.35 kV. The flow was expectedly decreased after the addition of water was increased. The lowest breakdown voltage was 14.27 kV for maximum breakdown voltage line and the mean breakdown voltage slightly lower at 14.23 kV after the addition of 2.0 ml water.

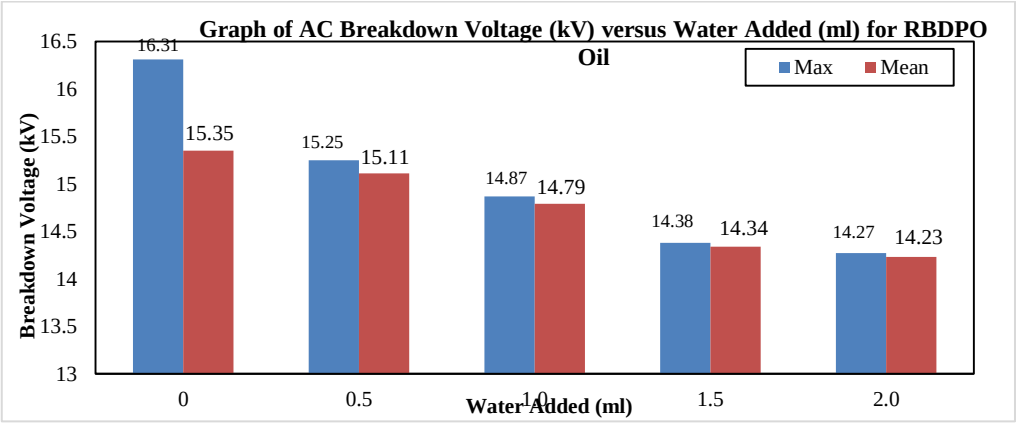


Figure 5. AC Breakdown voltage of RBDPO Oil when added with water

The result for Coconut Oil is shown in Figure 6. It can be seen that for normal Coconut Oil, the maximum breakdown voltage was 12.26 kV while the mean breakdown voltage was 11.93 kV. As soon as the level of water addition increased, the breakdown voltage also decreased. The lowest breakdown voltage for maximum trend for coconut oil when 1.5 ml water was added in the oil was 11.35 kV whereas the mean breakdown voltage value was slightly different with 11.16 kV.

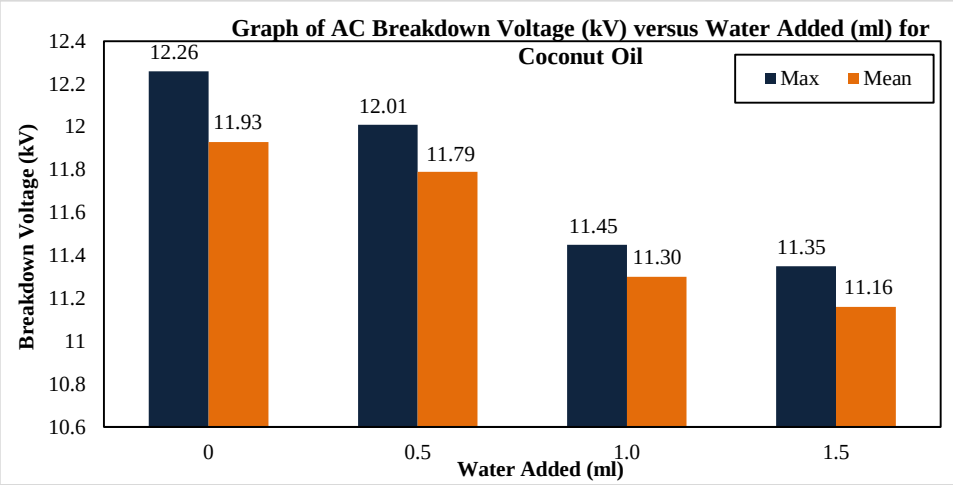


Figure 6. AC Breakdown voltage of Coconut Oil when added with water

The result for DC breakdown voltage for RBDPO oil is shown in Figure 7. From the graph, the maximum breakdown voltage was 18.91 kV and the mean breakdown voltage was 18.42 kV. This value was the normal RBDPO oil without any addition of water. The breakdown voltage decreased at the same time when the level water addition increased. The lowest value for maximum breakdown voltage was 11.20 kV and the mean breakdown voltage was 10.77 kV.

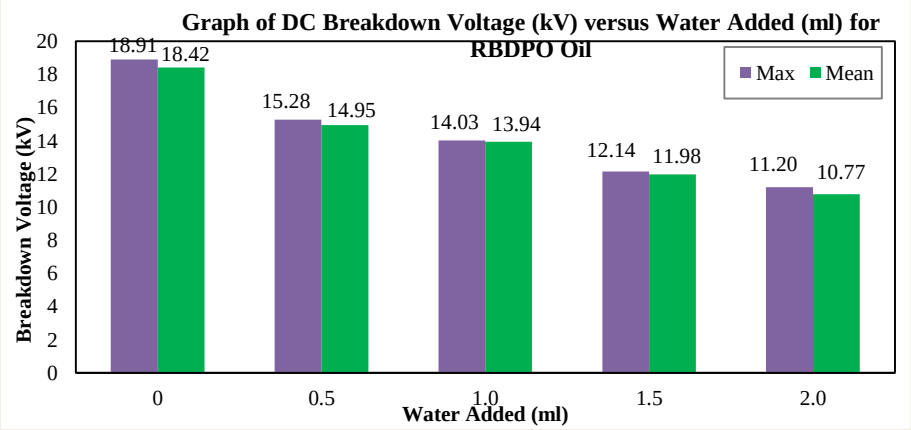


Figure 7. DC breakdown voltage for RBDPO oil when added with water

Referring to Figure 8, the maximum and mean breakdown voltage of Coconut Oil only has small variation. At the maximum line, the maximum breakdown voltage was 15.48 kV and the mean breakdown voltage was 15.06 kV when the oil free from any presence of water. At the same time when the water addition in the oil increased, the maximum breakdown voltage decreased to 7.75 kV while the mean breakdown voltage fallen to 7.58 kV.

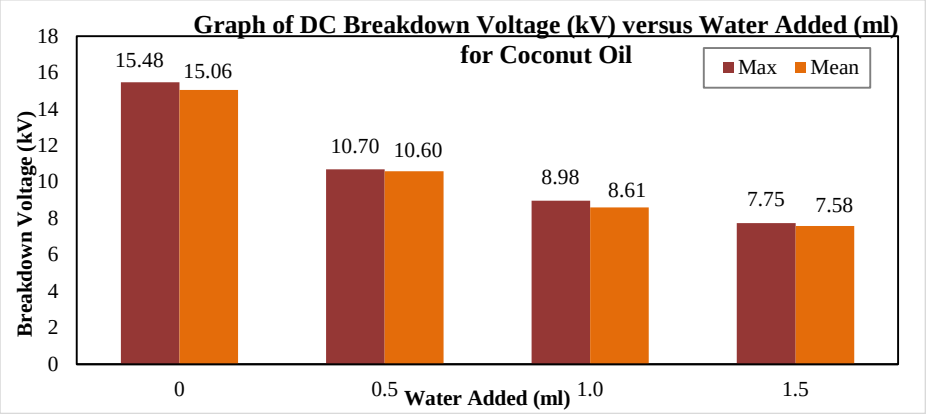


Figure 8. DC breakdown voltage of Coconut Oil when added with water

3.1. Comparison for Breakdown Voltage

Figure 9 shows the comparison for breakdown voltage between RBDPO oil and coconut oil under AC and DC voltage. Both oils breakdown voltage was analyzed by manipulate the water content and the electrode gap.

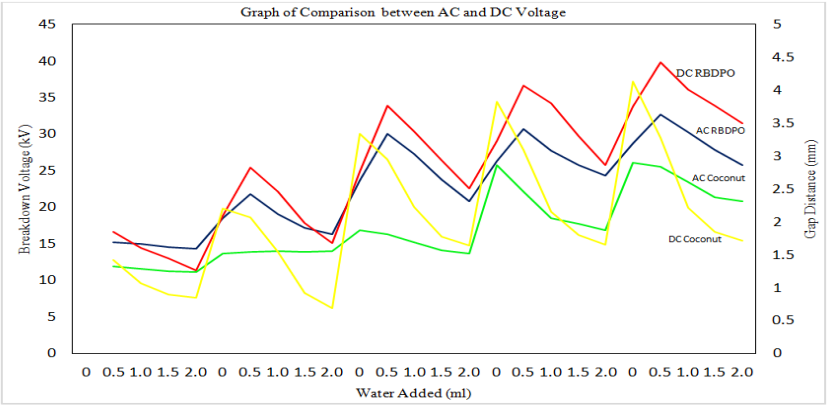


Figure 9. Comparison of AC and DC Breakdown Voltage

The graph showed that when the water addition in the oil increased, the breakdown voltage slightly decreased for both RBDPO oil and coconut oil under AC voltage. While, the breakdown voltage unexpectedly decreased under DC voltage for both type of oils. As for AC voltage, the breakdown voltage decreases firmly with water content and stay almost stable at a water addition beyond 1.0 ml. In addition, the trendline for DC breakdown voltage clearly seen the decreasing when the water addition in the oil increasing. This is due to the DC voltage stressing the insulation elements and affected by degradation of dielectric strength in the oil due to the water presence.

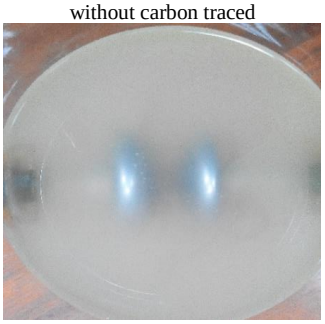
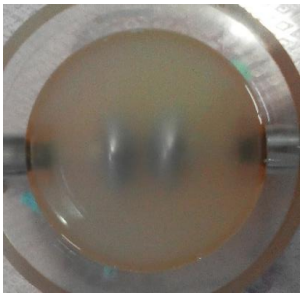
The trend line showed the increasing of breakdown voltage after the addition of electrode gap. Obviously, the AC breakdown voltage line was less compared to DC breakdown voltage. For both RBDPO oil and coconut oil, the DC breakdown voltages were greater than in AC breakdown voltages. The breakdown voltage increased along with the increasing of gap distance. From the graph, we can assume that under DC breakdown voltage test, when the gap distance increased, the oils sample withstand field strength for a lengthy time thus resulting the increasing in breakdown voltage. The gap distance has stronger effect in DC breakdown voltage compared to AC breakdown voltage due the caused that in AC breakdown voltage depends quite on the electrode geometry.

While conducting the experiment, some bubble and pop sound were produced by the oil sample when undergoes DC breakdown voltage test. As for AC breakdown voltage test, there was spark visible when the breakdown occurred. For both breakdown voltages testing, the increasing of gap distance and water added in oil resulting with the decreasing of the breakdown voltage.

3.2. Physical Change

Table 1 shows the physical changes in both RBDPO oil and coconut oil after the breakdown occurred. There was carbon traced appeared in the oil after the breakdown especially within the electrode.

Table 1. Physical change before and after breakdown occurred

Oil type	Before	After
RBDPO	 without carbon traced	 A little darker and with carbon traced
Coconut	 Cloudy without carbon traced	 Darker cloudy and with carbon traced

As reported by Nur Syamimi [15] the breakdown strength of oil insulation deteriorates when the water was added. Clearly, in this experiment the breakdown strength of both type of oils reduced when the samples were added with water even though the gap distance of the electrode were increased.

4. CONCLUSION

Breakdown voltage of RBDPO oil was higher than coconut oil in normal condition. However, when the water in oil increased the breakdown voltage hugely decreased due to the physical stability of RBDPO oil that highly affected with the presence of water in the sample. RBDPO oil breakdown voltage under AC breakdown test decreased slightly and remains almost stable compared to the same type of oil but undergoes DC breakdown test. From both type of breakdown test, RBDPO oil has better breakdown voltage compare to coconut oil. Compared to AC breakdown voltage test, RBDPO oil has greater breakdown voltage test under DC breakdown voltage test in term of increment of the gap distance. This is due the gap spacing has strongly affect under DC voltage rather than AC voltage that depends much on the electrode geometry. The result of this experiment shows that RBDPO and coconut oil have wide potential as insulating liquid in transformer in future.

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