Analysis of Dielectric Strength of Virgin Coconut Oil as an Alternative Transformer Liquid insulation

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Abstract. This paper presents the experimental results of a study, which has been carried out to analyze dielectric strength of virgin coconut oil in order to check the suitability as liquid insulation in power transformers. In this study dielectric strength response measurements after five times breakdown voltage test both mushroom electrode and spherical electrode slightly decreased, but the value of breakdown voltage is still high enough. While the measurement of the water content decrease is not stable, viscosity increase almost linear, the same thing also happened linear increase in measurement of flash point.

Keywords: transformer oil, liquid insulation, vegetable oil, virgin coconut oil, dielectric strength, water content, viscosity and flash point

1. Introduction

Power transformers consisting of oil/paper/pressboard insulation are considered as one of the main components in a power system. However, during service, their insulation gets deteriorated due to applied stresses such as thermal, electrical, mechanical, etc., so that majority of failure are caused by the failures of their insulation. In addition to the insulation, the oil is not only used as a liquid insulation but also as a coolant the transformer. The mineral oil extracted from crude oil, because of its better performance, has been used as the liquid insulation of more than 70 years. However, due to its poor biodegradability and future scarcity.

Currently scientists are looking for alternatives for these nonrenewable sources, which are also environmentally friendly. Some countries use sunflower oil, and possibilities of using soybean-based oil are being explored. Presently there are more than 10,000 transformers in service all around the world, which uses vegetable oil for insulations.

Among the many vegetable oils studied are palm and coconut oil. Since palm and coconut oil, which biodegrades quickly and completely without toxic, has preferable environmental properties in addition to its widely available in Indonesia it can be used as an alternative to transformer oil.

Some researchers have already examined physical, chemical composition and the electrical properties of coconut oil and have studied the possibility of using heating the oil sample to over 100°. with sufficient surface area exposed to the atmosphere to allow the moisture to escape from the oil sample. Dielectric breakdown voltage of the sample at room temperature was 20 kV and the sample was heated using a domestic heater of 500 W. The test result show that breakdown voltage increases gradually up to 60 kV.

The other researchers conducted a study of VCO by heating VCO from 30° C up to 80° with interval 5° C. In case of the test under varied temperatures, the VCO is being heated by heater until a certain value of temperature, and then the applied voltage is increased until a breakdown occurs.

If on samples oil there are nanoparticles for example TiO2 (Titanium Dioxide), it causes breakdown voltage reduce initially with addition of 0.001% of TiO2. The breakdown voltage of oil start to increase after addition of 0.025% of TiO2. [5].

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Several important properties, specified in transformer oil standards were compared with the relative values of coconut oil in Table 1[3].

| Property                   | Coconut oil | Standard oil (IEC 296) |
|----------------------------|-------------|------------------------|
| Dielectric Strength (kV)   | 60          | 50                     |
| Pour Point (° C)           | 20          | -40                    |
| Flash Point (° C)          | 225         | 154                    |
| Moisture Content (mg/kg)   | 1.0         | 1.5                    |
| Viscosity (cSt) at 40°C    | 29          | 13                     |
| Density (kg/dm³) at 20°C   | 0.917       | 0.895                  |

And according to for IEC 60422 standard for new oil insulation such as Table 2 below [6].

| Test Parameters | Limits                      |
|-----------------|-----------------------------|
| Breakdown Voltage | > 30 kV/2.5mm               |
| Viscosity at 40°C   | < 12 cSt                    |
| Flash Point          | > 140 °C                    |
| Water Content        | < 30 ppm                    |
| Sediment             | < 0.02%                     |
| Color                | < 2                         |
| Acidity              | < 0.01 m KOH/kg             |
| Interface Voltage    | > 40 dyne/m                 |
| Pour point           | < 40 °C                     |
| Tan δ                | < 0.0005                    |

In this paper, an examination on the dielectric strength of virgin coconut oil is carried out. Samples are tested for are breakdown voltage, water content, viscosity, and flash point. Is carried out based on experimental test results. In this study VCO samples was tested to five times the breakdown voltage test with interval of 10 to 15 minutes.

2. Experiment setup

2.1. Experimental setup and measurement method

Figure 1. presents the experimental for breakdown voltage tester. The breakdown voltage measurement was carried out IEC 60156 by an automatic oil breakdown test set Megger OTS100AF. The test was carried out using IEC, spherical electrode with diameter of 12.7 mm and mushroom electrode 36 mm facing each other at a gap distance of 2.5 mm. Voltage rate was set to 2 kV/s. The volume of the oil in the cell is around 400 ml. The time interval for between each breakdown was set to 5 minutes[8].
The measurement of breakdown voltage is carried out in the following manner, first sample once breakdown, second sampel twice breakdown, third sample three times breakdown, fourth sample four times breakdown and fifth sample five times breakdown. After all the samples have been tested breakdown voltage, then the samples will be tested water content, viscosity, and flash point. Measurement instruments used for water content is Megger Karl Fischer KF figure 3, for Flash point is Koehler –PMCC Kf6200 figure 4, and viscosity is Koehler type KV 3000 figure 5 and Glass capillary kinematic viscosity figure 6. The instruments used is shown in the following figures below.
2.2. Oil sample preparation procedures

Samples used are virgin coconut oil without processed before being used for breakdown voltage testing. The number of samples of virgin coconut oil used is five liters. Each breakdown voltage test is required as much as 400 ml.

3. Results and discussion

3.1. Breakdown Voltage

The breakdown voltage for all samples can be seen in table 3. It can be seen that the value of breakdown voltage spherical is higher than that of the mushroom electrode. After the VCO samples in the tested in the one test to five times breakdown, it is seen that the value of breakdown voltage decreased, but in the fifth test there was an increase compared to the fourth test for both types of electrodes. The graph of the BDV relationship with the number of breakdown test is shown in the figure 8. below.
Table 3. Breakdown voltage (kV)

| Test  | Breakdown voltage (kV) |
|-------|------------------------|
|       | Mushroom electrode | Spherical electrode |
| 1 x BDV | 33.98                | 44.96                |
| 2 x BDV | 25.57                | 32.00                |
| 3 x BDV | 18.13                | 27.60                |
| 4 x BDV | 18.25                | 26.75                |
| 5 x BDV | 20.80                | 30.00                |

Graph relationship between testing the breakdown voltage with the number of breakdown voltage shown in figure 8. Below

![Graph relationship between testing the breakdown voltage with the number of breakdown voltage](figure)

Figure 8. BDV Vs number of BDV test

3.2 Water Content

Table 4. Water content (ppm)

| Test  | Water content (ppm) |
|-------|---------------------|
|       | Mushroom electrode | Spherical electrode |
| 1 x BDV | 8700                | 9900                |
| 2 x BDV | 7800                | 6300                |
| 3 x BDV | 7800                | 22400               |
| 4 x BDV | 12200               | 16800               |
| 5 x BDV | 100                 | 7200                |
Water content test results after each BDV test are shown in table 4, and illustrated in figure 9, above. From the results shown in table 4, and figure 9, it is seen that the change in water content value is relatively very high, but after the breakdown voltage test fifth time seen a considerable decrease, this decrease caused the increase of breakdown voltage.

3.3 Viscosity
The viscosity test results are relatively stable, i.e the lowest value 26.09 and highest 26.43 cSt.

Table 5. Viscosity (cSt)

| Test   | Viscosity (cSt) | Mushroom Electrode | Spherical Electrode |
|--------|-----------------|---------------------|---------------------|
| 1 x BDV| 26.09           | 26.09               |                     |
| 2 x BDV| 26.13           | 26.22               |                     |
| 3 x BDV| 26.19           | 26.30               |                     |
| 4 x BDV| 26.22           | 26.35               |                     |
| 5 x BDV| 26.27           | 26.43               |                     |
3.4. Flash point
The test results of the flash point after each test the breakdown voltage increased linearly, as shown in the table 6 and figure 11, below. i.e for the mushroom electrode 122 °C to 133 °C, while for the spherical electrode 124 °C to 135 °C.

| Test  | Flash point (°C) |
|-------|-----------------|
|       | Mushroom Electrode | Spherical Electrode |
| 1 x BDV | 122              | 124                   |
| 2 x BDV | 125              | 127                   |
| 3 x BDV | 127              | 128                   |
| 4 x BDV | 130              | 131                   |
| 5 x BDV | 133              | 135                   |

**Figure 10.** Viscosity Vs number of BDV test
4. Conclusions
Based on the results of this study found that the value of BDV down to the fourth test, then on fifth test the increase in BDV. This is due to a considerable decrease in water content and increase in flash point. This can be seen in table 4, table 6, and figure 9, figure 11.

The BDV value on the first test produced meets the IEC standard, while the water content value is still very high in contrast to the viscosity and flash point is still below the standard value.

The results of this study showed that virgin coconut oil will be an alternative to transformer oil. Then the future research to be virgin coconut oil must be processed first in order to improve the characteristics cococut oil breakdown voltage and other characteristics such as water content, viscosity and flash point etc.

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