ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika

ISSN(p): 2338-8323 | ISSN(e): 2459-9638 | Vol. 12 | No. 3 | Halaman 701 - 715
DOI : http://dx.doi.org/10.26760/elkomika.v12i3.701 Juli 2024

The Influence of Olive Oil Additive on Sunflower Seed Oil to Improve The Breakdown Voltage of Insulation Oil

CHRISTIONO[1], MIFTAHUL FIKRI[2], IWA GARNIWA MULYANA [3], SYAMSIR ABDUH, KARTIKA TRESYA MAURIRAYA[5], MUHAMMAD FAHRI[6]

[1,2,3,4,5,6]Fakultas Ketenagalistrikan dan Energi Terbarukan, Institut Teknologi PLN, Jakarta
[1,3]Departmen Teknik Elektro, Universitas Indonesia, Depok
Email: miftahul@itpln.ac.id, christiono@itpln.ac.id

Received 5 February 2024 **|** Revised 7 May 2024 **|** Accepted 12 June 2024

ABSTRAK

Tegangan tembus isolasi minyak yang baru adalah sebesar ≥30kV/2,5mm. Sesuai dengan standar IEC 601-56:2018. Minyak biji bunga matahari dipilih sebagai alternatif karena harganya terjangkau dan mudah diperoleh, akan tetapi minyak biji bunga matahari murni belum memenuhi standar IEC 61099:2010, dalam memenuhi standart tersebut dibutuhkan zat adiftif untuk meningkatkan nilai tegangan tembus isolasinya. Tujuan dari penelitian ini adalah untuk meningkatkan tegangan tembus isolasi minyak bunga matahari setelah ditambahkan aditive minyak zaitun untuk meningkatkan kemampuan isolasi, mengikuti standar IEC 61099:2010. Hasil penelitian menunjukkan bahwa minyak biji bunga matahari mempunyai nilai tegangan tembus sebesar 30,9 kV. Namun, setelah ditambahkan aditif minyak zaitun dengan perbandingan 60:40, nilai tegangan tembus meningkat menjadi 50,3 kV. Sehingga hasil pengujian minyak biji bunga matahari yang ditambahkan minyak zaitun memenuhi standar tersebut.

Kata kunci*: Minyak Isolasi, Minyak Bunga matahari, aditif, Tegangan Tembus*

ABSTRACT

The new oil insulation breakdown voltage is ≥30kV/2.5mm. Compliant with IEC 601-56:2018 standards. Sunflower seed oil was chosen as an alternative because it is affordable and easy to obtain, however, pure sunflower seed oil does not meet the IEC 61099:2010 standard, to meet these standards additives are needed to increase the value of the insulation breakdown voltage. This research aims to increase the insulation breakdown voltage of sunflower oil after adding olive oil additives to increase its insulating ability, following the IEC 61099:2010 standard. The research results show that sunflower seed oil has a breakdown voltage value of 30.9 kV. However, after adding olive oil additives in a ratio of 60:40, the breakdown voltage value increased to 50.3 kV. So that the test results for sunflower seed oil added with olive oil meet the standards outlined.

Keywords: *Insulation Oil, Sunflower Seed Oil, additive, Breakdown Voltage*

1. INTRODUCTION

A transformer is an electrical equipment that is used as a large voltage converter and voltage transfer from the primary side to the secondary side equipped with insulation materials, The breakdown voltage specification for the new oil insulation is 30kV/2.5mm. Following the IEC standard 601-56:2018 **(Christiono et al., 2022)(Fikri et al., 2022)(Kamilatin et al., 2021)**. In transformers, oil insulators are used to separate between two conductors with a voltage to prevent jumps or electric sparks. Transformers generally use mineral oil insulation, which is a derivative of fossil fuel, because of its ability as insulation and coolant.

The continuous application of mineral oil as transformer insulation, however, harms the amount of fossil fuel production because fossil fuel has non-renewable properties. Data released by Indonesia’s Central Statistics Agency shows that petroleum production in Indonesia per year in 2014 was 287,902 million barrels, which decreased to 273,494 million barrels per year in 2019 **(Bukit, 2021)**. Even with relatively lower oil prices, extraction and exploration companies have been highly profitable. At the same time, perhaps in recognition of a less buoyant future, they have reduced their investment. Production in oil fields and the number of wells is declining, and reserve depletion is rapid. The drop in both capital expenditure and replacement of oil reserves has persisted since 2014 (Duttagupta et al.). To avoid the scarcity of mineral oil, many studies have been conducted on vegetable oils as an alternative for transformer oil insulation. In this study, the test sample is a mixture of vegetable oils, namely sunflower seed oil and olive oil**(Christiono et al., 2022)**. These two oils were chosen as the object of study because of their abundant availability, easy to obtain, and renewable. Moreover, Olive oil is added because it has an unsaturated fatty acid content of 84.2%, which is dominated by oleic acid, which will reduce the saturated acid content found in sunflower seed oil **(Romadhona et al., 2021)**.

IEC 61099: 2010 is used as a reference standard for vegetable oil insulation characteristics, including the physical condition of insulation, namely color and appearance, density value, kinematic viscosity value, flash point, combustion point, pour point, crystallization, water content, acidity or neutrality value, oxidation resistance, test breakdown stress value, dielectric leakage factor, and resistivity value. Based on the parameters of vegetable oil isolation in IEC 61099: 2010, tests were carried out on pure oil-type sunflower seed oil and sunflower seed with olive oil mixtures, to see the effect on these parameters.

Sunflower seed oil still has several shortcomings, one of which is its dielectric characteristics which are still low based on IEC 61099:2010 standards **(Sulemani et al., 2018)**. This research aims to analyze the effect of mixing olive oil additives with sunflower seed oil on increasing the dielectric ability of vegetable oil insulators as an alternative to transformer oil insulation.

1.1 Transformer Insulation

Electrical power transmission commonly uses High Voltage Alternating Current for several reasons. The usage of high voltage allows for the reduction of transmission losses, by reducing the amount of current transferred **(Fikri et al., 2023)**. It’s also more efficient, by making use of transformers to step up the voltage of transmission or step it down for distribution. High-voltage transmission also allows for better voltage regulation along the transmission line, by changing the taps of transformers installed along the line. HVAC remains the preferred choice for most transmission applications, and transformers are a critical part of HVAC transmission **(Fikri et al., 2023)**.

The transformer is the equipment used in the electrical world to flow (move) and convert electrical energy from one circuit to another. Transformers utilize the principle of electromagnetic induction to transfer electrical energy from the primary coil to the secondary coil **(Siburian, 2019)**.

The transformer has a construction consisting of a core made of iron with a multi-layered arrangement, a primary coil, and a secondary coil, made of wire made of copper which is then wound around the transformer core. Transformers are divided into 2 types based on the form of construction, namely core-type transformers and shell-type transformers. At high voltages, liquid insulation is used as a separator for two or more conductors of electricity in a voltage state so that between these conductors there are no failures such as sparks or sparkover and voltage breakdowns. Liquid insulation is used because it has a density of 1000 times compared to gas insulation, can fill gaps or spaces to be insulated well, and also self-repair when charge-discharge occurs. Generally, liquid insulators are classified into 3 types, namely mineral oil isolation, vegetable oil isolation, and synthesis oil isolation. In practice, mineral oil insulation is most often used as a coolant or as insulation in transformers.

Oil isolation in transformers is a coolant in transformers because transformers that work at high voltage require cooling components. If a transformer does not have cooling components, the iron core, windings, and other parts can be damaged **(Puteri, 2018)**.

Some factors can affect the chemical structure in transformer oil including temperature, air bubbles, and catalyst.Transformer oil in its use is divided into two, namely transformer oil in a new state and transformer oil in a state that has been used or used. According to IEC 60296, new transformer oil is insulating oil that has never been used has never been in direct contact with electrical equipment or other equipment, and is not used during the manufacturing, storage, or transportation process. Whereas used transformer oil is insulating oil that is being used or has been used as an insulating or cooling medium in transformers.

As an insulating material, the breakdown voltage is key in figuring out the quality of transformer oil insulation. Breakdown voltage is an occurrence where magnetic field conditions progressively intensify, resulting in the ionization of atoms and pushing the tested insulator to its voltage-withstanding limit **(Fikri et al., 2023)**. Consequently, the insulator undergoes a transformative shift from being non-conductive (insulator) to conductive (conductor)**(Fikri et al., 2022)**. The purpose of conducting breakdown voltage testing is to identify the critical point of transformer oil insulation. By measuring this voltage, we can determine the minimum threshold at which increased conductivity arises, potentially leading to insulation failure. A low breakdown voltage is indicative of contamination within the insulator, such as water, impurities, or conductive particles, thereby highlighting the presence of undesirable substances in the tested insulator. This research paper explores the significance of breakdown voltage testing in evaluating the integrity and effectiveness of transformer oil insulation.

According to SPLN 49-1:1982, the standard breakdown voltage value of new insulating oil is 30 kV/2.5mm, and for used or used oil is 50 kV/2.5mm. Meanwhile, according to IEC 61099: 2010 **(PLN, 1982)** the standard breakdown voltage value for vegetable insulation oil is 45 kV / 2.5mm. Factors that can affect the value of the breakdown voltage of transformer oil insulation are the electrode surface area, the distance between electrodes, cooling, and the dielectric strength of the transformer oil insulation **(Puteri, 2018) (Aperti, 2018)**. Viscosity or viscosity influences the purity of liquid insulation **(Aperti, 2018)**. The lower the viscosity value in a transformer oil insulation, the better it will be, because this will make it difficult for the transformer oil insulation to be contaminated with other substances that can cause deterioration of the quality of the transformer oil insulator. It also relates to the dielectric strength of the oil insulation tested, because there are contaminants attached to the oil **(Rafiq et al., 2015)**. Viscosity is an obstacle to fluid flow against friction between molecules with one another. Viscosity is a characteristic of fluids that are closely related to the resistance to flow due to pressure or voltage, in this case, the higher the viscosity value, the greater the resistance. A low viscosity value fluid, when placed in a vessel, can flow easily following the shape of the vessel, and vice versa **(Winanta et al., 2019)**.

1.2 Dielectric Leakage

A high dielectric leakage factor value indicates contamination or damage that can be caused by several factors, such as water, oxidation products, alkali metals, and others **(APERTI, 2018) (Fikri et al., 2023)**. This dielectric leakage factor test was carried out at a temperature of 900C and a frequency of 50 Hz, following 60247 method standards. Based on IEC 61099: 2010 reference for vegetable oil insulation, the maximum limit of the dielectric leakage factor value in test oil is 0.03, while in SPLN 49-1: 1982 the standard value of the dielectric leakage factor for new insulating oil is a maximum of 0.05 **(PLN, 1982)**.

2. METHOD

2.1 Experimental Trials

In the context of evaluating sunflower seed oil for its suitability as transformer oil insulation, several tests are essential. Firstly, the water content, acid content, flash point, and pour point tests are conducted on pure sunflower seed oil. These tests aim to assess the oil's moisture level, acidity, temperature stability, and flow characteristics, respectively. These parameters are crucial in determining the effectiveness of sunflower seed oil as an insulating medium.

Moreover, additional testing is conducted to investigate the impact of incorporating olive oil additives into sunflower seed oil. The kinematic viscosity, density, and breakdown stress values are measured for both pure sunflower seed oil and mixtures containing different ratios of sunflower seed oil to olive oil (90%:10%, 80%:20%, 70%:30%, and 60%:40%). These tests aim to understand how the presence of olive oil affects the viscosity, density, and breakdown strength of the oil mixture. This information is important for evaluating the performance and potential synergistic effects of incorporating olive oil additives into sunflower seed oil as a potential transformer oil insulation blend.

Through these comprehensive tests, a thorough understanding of the properties and performance of sunflower seed oil, both as a standalone insulating medium and in combination with olive oil, can be gained. This knowledge is vital in assessing the feasibility and effectiveness of sunflower seed oil and oil blends for transformer oil insulation applications.

2.2 Experimental

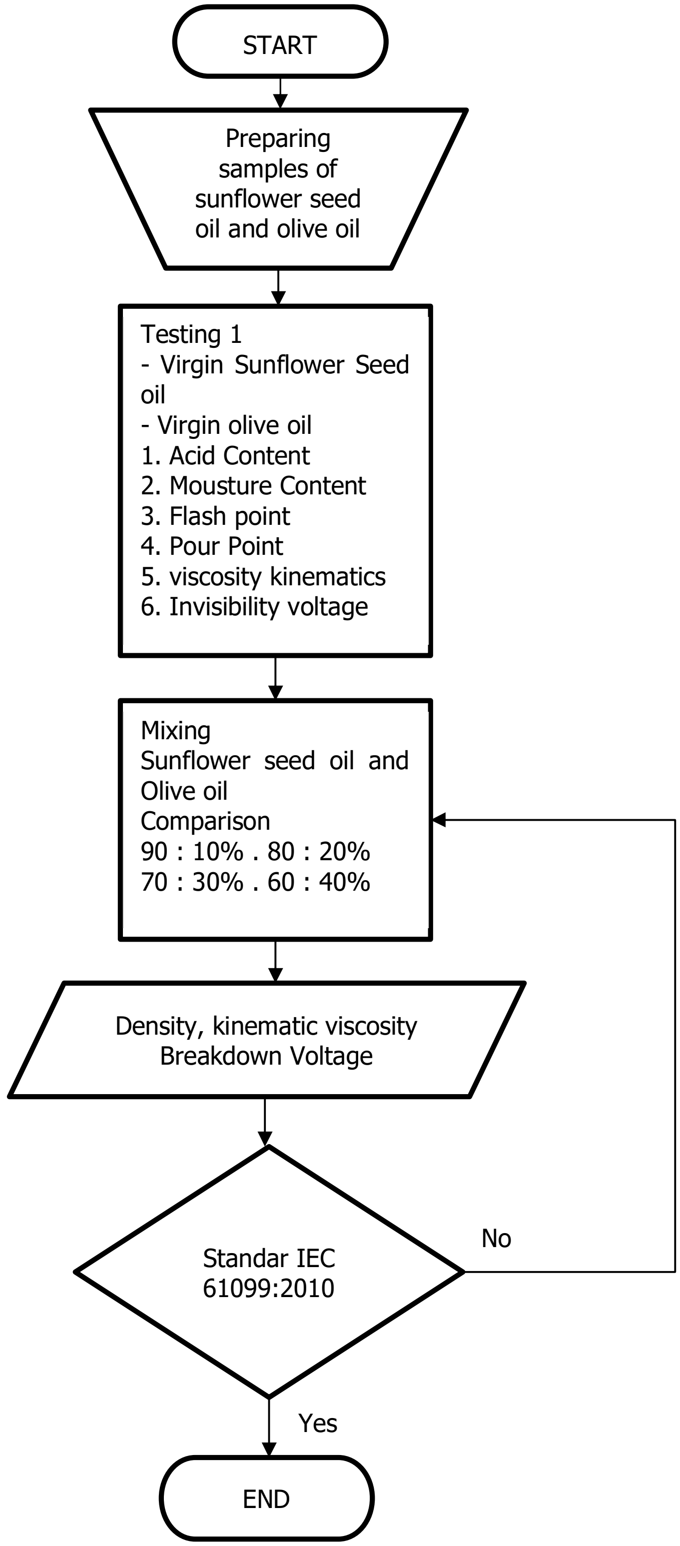

Figure 1. Experimental Flow

Various tests are conducted to assess sunflower seed oil's suitability as transformer oil insulation. Here is a simplified explanation of each test:

a. Acid content testing determines the amount of acid present in pure sunflower seed oil. Higher acid content indicates poorer oil quality.
b. Moisture content testing aims to measure the water content in the insulating oil. Higher water content is undesirable as it can affect insulation performance **(Arsad et al., 2023)**. As water poses a significant risk to the insulation system of power transformers, accurately determining the water content is crucial for ensuring stable operation and preventing potential damage to the transformer **(Safariansyah et al., 2021)**.
c. Flash point measurement determines the oil's resistance to heat. It assesses if the oil can withstand high temperatures in the transformer without catching fire.
d. Pour point testing identifies the temperature at which the oil starts to flow after freezing. It indicates how effective the oil is in resuming its insulation properties after freezing.
e. Density testing determines the density of the oil. Oil typically has a lower density than water, so it separates from water in a vessel. It is measured using a device called a pycnometer.
f. Kinematic viscosity testing measures the oil's ability to flow effectively in a working transformer or when exposed to heat. It helps determine if the oil can serve as an efficient coolant.
g. Breakdown voltage (BDV) testing evaluates the oil's ability to withstand high-voltage events, such as sparkovers. A higher BDV indicates better insulation performance **(Rouabeh et al., 2019)**.

3. RESULTS AND DISCUSSION

3.1 Acid Content

The acid content of pure sunflower seed oil (100%) is tested without the presence of olive oil additives. The testing process involves using a burette to carefully dispense KOH liquid into the test sample container. After conducting the measurements, calculations are performed to determine the acid levels of the test sample using the equation provided below.

$$\text{TAN} = \frac{V_{KOH} \text{ x N KOH x mr KOH}}{m_{oil}} \quad (1)$$

and Equation

$$\text{TAN}_{avg} = \frac{\text{TAN 1 + TAN 2}}{2} \quad (2)$$

use the data from Table 1 as follows

Table 1. Acid Content Test Sample

Information	Data 1	Data 2
V_{KOH}	0,34 ml	0,32 ml
N_{KOH}	0,02 N	0,02 N
mr KOH	56,1	56,1
M_{oil}	5,0478	5,0464

This analysis provides valuable insights into the acid content of sunflower seed oil and its suitability for specific applications.

3.2 Moisture Content

The Moisture Content in transformer oil insulation is measured to determine the amount of water present. This testing is performed using the Aquamax KF Coulometric tool, which can detect water content in units of ppm or mg/l. The test is conducted twice, and the results are automatically generated by the tool. The purpose of conducting the test twice is to obtain the average value, which is then recorded as the final result of the water content test. According to IEC 61099:2010, the maximum allowable water content in transformer oil insulation is 200 mg/l **(IEC, 2010)**. The obtained test results are used to calculate the moisture content of 100% pure vegetable oil insulation using the equation provided below and data from Table 2.

$$\text{Water content}_{\text{Average}} = \frac{Water\ content\ 1 + Water\ content\ 2}{2} \tag{3}$$

Table 2. The result of Calculating the Moisture Content Value

Information	Result
Moisture Content 1	367
Moisture Content 2	342
Average moisture content	354,5

3.3 Flash Point

Flash point testing is conducted using a flash point device to assess the ability of a sample to withstand heat retention when subjected to elevated temperatures, such as those experienced during transformer operation or under increased load conditions. In this particular test, a 100% pure sunflower seed oil sample is examined. The objective is to determine the oil's durability in terms of heat resistance. According to IEC 61099, the pour point value for insulating vegetable oil is 25°C. To ascertain the flash point of the test oil sample, two tests are performed, and the average of the two measurements is calculated. The flashpoint device employed in this process heats the sample and measures the temperature at which the first flame occurs within the oil insulation being tested. The calculation is carried out using the equation below.

$$\text{Flash point}_{\text{avg}} = \frac{FlashPoin\quad 1 + FlashPoint\ 2}{2} \tag{4}$$

and the data from Table 3 are as follows.

Table 3. Flash Point Calculation Result of Test Sample

Information	Result (°C)
flashpoint 1	184
flashpoint 2	180
flashpoint Average	182

3.4 Pour Point

Pour point testing is carried out with the help of a pour point device, in this test the sample tested is a 100% pure sunflower seed oil sample to want to know the ability of oil insulation to return to a circulating state after freezing, so that when the transformer works it can quickly melt again and re-circulate. Based on IEC 61099 the pour point value of an insulating vegetable oil is -450C. The calculation is carried out using an equation.

$$\text{Pour point}_{avg} = \frac{PourPoint\ 1 + PourPoin\ \ 2}{2} \quad (5)$$

and the data from Table 4.

Table 4. Flash Point Calculation Result of Test Sample

Information	Result (°C)
flashpoint 1	-24
flashpoint 2	-25
flashpoint Average	-29,5

3.5 Pour Point

Density testing is conducted to determine the density value of transformer oil insulation. This test provides essential data for calculating the kinematic viscosity values. To perform the density test, a pycnometer, and a balance device are utilized. The pycnometer is used to measure the weight of distilled water and the weight of the oil samples being examined. The samples subjected to this test include 100% sunflower seed oil, 100% olive oil, and sunflower seed oil blended with olive oil additives in ratios of 90:10, 80:20, 70:30, and 60:40. By analyzing the density values, we can derive valuable insights into the characteristics and behavior of these oil mixtures in transformer applications. Based on the results of measurements that have been made, calculations will be carried out using the formula in the equation.

$$\rho\ \text{Sample} = \frac{\text{Sample period}}{\text{Water period}} \times \rho \quad (6)$$

referring to the data in tables 5 to table 6 with the calculation results obtained.

Table 5. Water Weight Measurement And 100% Pure Sunflower Seed Oil

Information	100 % Sunflower	100% virgin olive oil
Empty pycnometer weights	23 g	23 g
Empty pycnometer weight + distilled water	71,9 g	71,9 g
Empty pycnometer weight + test sample	68,2 g	68 g
Distilled water weight	48,9 g	48,9 g
Test sample weight	45,2 g	45,0 g
ρ Distilled water	998 kg/m3	998 kg/m3

Table 6. Water Weight Measurement

Information	Ratio Between Sunflower Seed Oil And Olive Oil			
	90%:10%	80%:20%	70%:30%	60%:40%
Empty pycnometer weights	23 g	23 g	23 g	23 g
Empty pycnometer weight + distilled water	71,9 g	71,9 g	71,9 g	71,9 g
Empty pycnometer weight + test sample	67,1 g	66,9 g	66,7 g	66,5 g
Distilled water weight	48,9 g	48,9 g	48,9 g	48,9 g
Test sample weight	44,1 g	43,9 g	43,7 g	43,5 g
ρ Distilled water	998 kg/m3	998 kg/m3	998 kg/m3	998 kg/m3

3.6 Kinematic Viscosity

Kinematic viscosity is a measure of viscosity that is determined by dividing the dynamic viscosity by the density of a substance. To obtain the kinematic viscosity value, the dynamic viscosity value must be known beforehand. Dynamic viscosity represents the internal friction and resistance to the flow of a substance **(Rafiq et al., 2015)**. In this research, the dynamic viscosity values are determined using the Oswald viscometer, which serves as a container for the test samples to flow and calculates the flow rate time using a stopwatch. Based on these measurements, the dynamic viscosity values can be calculated using Dynamic viscosity equations

$$(\eta)\ \eta\ \text{sample} = \frac{\rho\ sample\ x\ t\ sample}{\rho\ water\ x\ t\ water}\ x\ \eta\ water \quad (7)$$

$$\text{and Kinematic Viscosity Calculation } (v),\ v = \frac{\eta\ \text{sample}}{\rho\ \text{sample}} \quad (8)$$

using data from Table 7 to 17 as follows.

Table 7. Kinematic Viscosity Measurement Data 100% Pure Sunflower Seed Oil

Information	Result
η Distilled water	0,818 cps
ρ Distilled water	998 kg/m3
ρ Test sample	922 kg/m3

Table 8. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	126
2nd recurrence	2,89	130
3rd recurrence	2,98	132
Average	2,86	129,3

Table 9. Kinematic Viscosity Measurement Data 100% Virgin Olive Oil

Information	Result
η Distilled water	0,818 cps
ρ Distilled water	998 kg/m3
ρ Test sample	918 kg/m3

Table 10. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	123
2nd recurrence	2,89	124
3rd recurrence	2,98	122
Average	2,86	123

Table 11. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	120
2nd recurrence	2,89	117
3rd recurrence	2,98	110
Average	2,86	115.6

Table 12. Kinematic Viscosity Measurement Data Ratio Between Sunflower Seed Oil And Olive Oil Is 80%:20%

Information	Result
η Distilled water	0,818 cps
ρ Distilled water	998 kg/m3
ρ Test sample	896 kg/m3

Table 13. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	120
2nd recurrence	2,89	108
3rd recurrence	2,98	114
Average	2,86	114

Table 14. Kinematic Viscosity Measurement Data Ratio Between Sunflower Seed Oil And Olive Oil Is 70%:30%

Information	Result
η Distilled water	0,818 cps
ρ Distilled water	998 kg/m3
ρ Test sample	892 kg/m3

Table 15. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	109
2nd recurrence	2,89	112
3rd recurrence	2,98	110
Average	2,86	110.3

Table 16. Kinematic Viscosity Measurement Data Ratio Between Sunflower Seed Oil And Olive Oil Is 60%:40%

Information	Result
η Distilled water	0,818 cps
ρ Distilled water	998 kg/m3
ρ Test sample	887 kg/m3

Table 17. Flow Rate Time

Flow Rate Time	Distilled Water(s)	Test Sample(s)
1st repetition	2,73	110
2nd recurrence	2,89	106
3rd recurrence	2,98	107
Average	2,86	107.6

Based on the test results obtained from each sample, including pure sunflower seed oil (100%), pure olive oil (100%), and sunflower seed oil with olive oil additives in ratios of 90:10, 80:20, 70:30, and 60:40, it is necessary to calculate the average value to determine the breakdown stress value of the samples. Calculations use data from table 18 to table 19.

Table 18. Translucent Voltage Measurement Data

Information	Distilled Water(s)	
	100% pure sunflower seed oil	100% virgin olive oil
Measurement 1	31,3 kV	33,8 kV
Measurement 2	30,3 kV	30,3 kV
Measurement 3	28,4 kV	28,5 kV
Measurement 4	29,1 kV	27,5 kV
Measurement 5	32,1 kV	32,3 kV
Measurement 6	33,0 kV	33,2 kV
Distance (d)	2,5 mm	2,5 mm

Table 19. Translucent Voltage Measurement Data Ratio Between Sunflower Seed Oil And Olive Oil

Information	Distilled Water(s)			
	90%:10%	80%:20%	70%:30%	60%:40%
Measurement 1	34,2 kV	38,1 kV	48,5 kV	49,5 kV
Measurement 2	36,8 kV	41,5 kV	46,2 kV	52,9 kV
Measurement 3	35,4 kV	39,8 kV	44,1 kV	52,8 kV
Measurement 4	35,1 kV	42,8 kV	48,4 kV	47,9 kV
Measurement 5	36,4 kV	39,8 kV	47,2 kV	50,2 kV
Measurement 6	35,5 kV	38,6 kV	49,3 kV	48,6 kV
Distance (d)	2,5 mm	2,5 mm	2,5 mm	2,5 mm

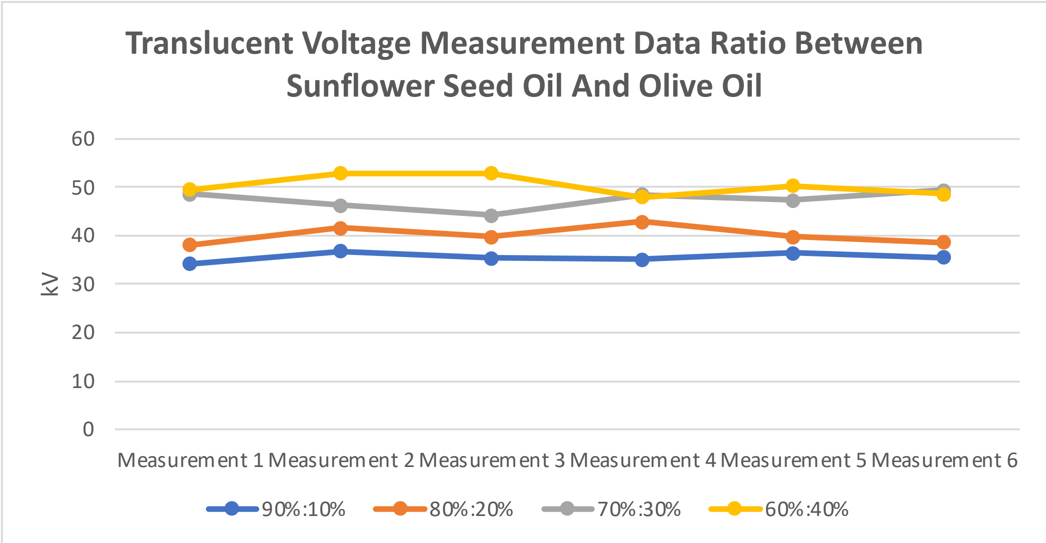

Figure 2. Graphic Translucent Voltage Measurement Data Ratio Between Sunflower Seed Oil and Olive Oil

Table 20. Comparison of Characteristic Values of Test Oils

Test Samples	Density	Kinematic Viscosity	Breakdown Voltage
MB 100%	922	37	30,7
MZ 100%	918	35,2	30,9
MB 90%:10% MZ	900	33,1	35,5
MB 80%:20% MZ	896	32,6	40,1
MB 70%:30% MZ	892	31,6	47,2
MB 60%:40% MZ	887	30,8	50,3

Table 21. Testing of Sunflower Seed Isolation

Experimental	Method	Standard IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Acid Content	IEC 296	≥ 0,03	≤ 0,03	0,0733 mgKOH/g	Poor
Moisture Content	IEC 814	≥ 200	≤ 200	354,5 mg/l	Poor
Flash Point	ISO 2719	≤ 250	≥ 250	182oC	Poor
Pour Point	ISO 3016	≥ -45	≤ -45	-19,5oC	Excellent
Density	ISO 3675	≥ 1.000	≤ 1.000	922 kg/m3	Poor
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	37 cSt	Poor
Dielectric Strength	IEC 156	≤ 45	≥ 45	30,7 kV	Poor

Table 22. Testing of Olive Oil Isolation

Experimental	Method	Standard IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Density	ISO 3675	≥ 1.000	≤ 1.000	918 kg/m3	Poor
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	35,2 cSt	Poor
Dielectric Strength	IEC 156	≤ 45	≥ 45	30,9 kV	Poor

Table 23. Testing of Sunflower Seed and Olive Oil Isolation (90:10 ratio)

Experimental	Method	Standard IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Density	ISO 3675	≥ 1.000	≤ 1.000	900 kg/m3	Poor
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	33,1 cSt	Poor
Dielectric Strength	IEC 156	≤ 45	≥ 45	35,5 kV	Poor

Table 24. Testing of Sunflower Seed and Olive Oil Isolation (80:20 ratio)

Experimental	Method	Standard IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Density	ISO 3675	≥ 1.000	≤ 1.000	896 kg/m3	Poor
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	32,6 cSt	Poor
Dielectric Strength	IEC 156	≤ 45	≥ 45	40,1 kV	Poor

Table 25. Testing of Sunflower Seed and Olive Oil Isolation (70:30 ratio)

Experimental	Method	Standar IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Density	ISO 3675	≥ 1.000	≤ 1.000	892 kg/m3	Poor
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	31,6 cSt	Poor
Dielectric Strength	IEC 156	≤ 45	≥ 45	47,2 kV	Poor

Table 26. Testing of Sunflower Seed and Olive Oil Isolation (60:40 ratio)

Experimental	Method	Standard IEC 61099:2010		Result	Abstract
		Poor	Excellent		
Density	ISO 3675	≥ 1.000	≤ 1.000	887 kg/m3	Excellent
Kinematic Viscosity	ISO 3104	≥ 35	≤ 35	30,8 cSt	Excellent
Dielectric Strength	IEC 156	≤ 45	≥ 45	50,3 kV	Excellent

Based on the test results obtained from the samples above, including pure sunflower seed oil (100%), pure olive oil (100%), and sunflower seed oil with olive oil additives in ratios of 90:10, 80:20, 70:30, and 60:40, it is necessary to calculate the average value to determine the breakdown stress value of the samples. Calculations use data in Table 20-26.

4. CONCLUSION

The result of the research conducted, it has been determined that the best oil for use as an alternative insulation oil in transformers is a mixture of sunflower seed oil and olive oil additives in a ratio of 60% sunflower seed oil and 40% olive oil. This ratio aligns with the characteristics specified in the IEC standard 61099:2010. The resulting values for this mixture are a density of 887 kg/m3, a kinematic viscosity of 30.8 cSt, and a penetrating voltage of 50.3 kV. These values are expected to enhance transformer reliability. However, certain parameters did not meet the IEC 61099:2010 standard. The water content, acidity level, kinematic viscosity, flash point, pour point, and breakdown voltage values of the insulation oil were found to deviate from the standard. The water content was measured at 354.5 mg/l, acidity level at 0.0733 mgKOH/g, kinematic viscosity at 37 CST, flash point at 182°C, pour point at -19.5°C, and breakdown voltage at 30.9 kV.The addition of olive oil additives to the sunflower seed oil improved the density, kinematic viscosity, and breakdown voltage values. The optimal density of 887 kg/m3 was achieved in the sunflower seed oil with a 60%:40% ratio of olive oil additives. The best viscosity value of 30.8 cSt was obtained in the same ratio. Furthermore, the highest breakdown voltage value of 50.3 kV was observed in the sunflower seed oil with the 60%:40% olive oil additive ratio. However, it is important to note that pure sunflower seed oil did not meet the standards set by IEC 61099:2010 for insulation oil in transformers. The parameters such as acid content, moisture content, flash point, pour point, kinematic viscosity, and breakdown voltage values did not align with the standard. Thus, further improvements or alternative solutions may be necessary before considering sunflower seed oil as a viable insulation option for transformers.

REFERENCE

APERTI, A. (2018). Analisis Efek Viskositas Terhadap Tegangan Tembus Minyak Transformator. *Jurnal Teknologia, 1*(1), 15-20.

Arsad, S. R., Ker, P. J., Jamaludin, M. Z., Choong, P. Y., Lee, H. J., Thiviyanathan, V. A., & Yang Ghazali, Y. Z. (2023). Water Content in Transformer Insulation System: A Review on the Detection and Quantification Methods. *Energies, 16*(4), 1920.

Bukit, F. R. A. (2021). Analisis Kekuatan Dielektrik Minyak Campuran Metil Ester Bunga Matahari Sebagai Isolasi Cair Pada Transformator. *Journal of Energy and Electrical Engineering (JEEE), 3*(1).

Christiono, R., Garniwa, I., Fikri, M., & Thahara, A. A. (2022). Reliability Evaluation of Transformer Oil Insulation with H2O Water and Super O2 Water Contaminants Disaster Mitigation Electrical Engineering. *International Journal of Engineering Continuity, 1*(2), 137-146.

Duttagupta, R., Pazarbasioglu, C., O'Neill, J., Arezki, R., Nysveen, P. M., Dollar, D., . . . Kalemli-Özcan, Ş. WHAT NEXT FOR EMERGING MARKETS?

Fikri, M., & Abdul-Malek, Z. (2023). Partial discharge diagnosis and remaining useful lifetime in XLPE extruded power cables under DC voltage: a review. *Electrical Engineering, 105*(6), 4195-4212.

Fikri, M., & Christiono, C. (2022). Clustering Fenomena Corona Discharge berdasarkan Suara menggunakan Metode LPC dan Euclidean Distance. *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, 10*(3), 689.

Fikri, M., Christiono, C., Mauriraya, K. T., Pasra, N., Samsurizal, S., Romadhoni, M. L., & Thahara, A. A. (2023). Clustering Suara Corona Discharge berdasarkan Tegangan menggunakan Metode Fuzzy C-Mean. *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, 11*(3), 609.

Fikri, M., Damiri, D. J., Safariansyah, M. R., Pratiwi, S., & Hidayat, M. R. (2022). Pengaruh Kontaminan Air terhadap Tegangan Tembus Isolasi Cair Minyak Mineral dan Nabati sebagai Alternatif Isolasi Minyak Transformator. *Jurnal Teknik: Media Pengembangan Ilmu dan Aplikasi Teknik, 21*(1), 42-51.

IEC, I. (2010). 61099 Insulating liquids-Specifications for unused synthetic organic esters for electrical purposes. In: Geneve.

Kamilatin, J., Warindi, W., & Nrartha, I. M. A. (2021). Uji Kelayakan Minyak Biji Ketapang Sebagai Bahan Isolasi Cair Transformator. *DIELEKTRIKA, 8*(1), 21-30.

PLN. (1982). *SPLN 49-1:1982 Minyak Isolasi Bagian 1: Pedoman penerapan spesifikasi dan pemeliharaan minyak isolasi*: Departemen Pertambangan Dan Energi Perusahaan Umum Listrik Negara.

Puteri, A. (2018). *Pengaruh Suhu Terhadap Tegangan Tembus Minyak Transformator Jenis Mineral.* UNIVERSITAS NEGERI JAKARTA,

Rafiq, M., Lv, Y., Zhou, Y., Ma, K., Wang, W., Li, C., & Wang, Q. (2015). Use of vegetable oils as transformer oils–a review. *Renewable and sustainable energy reviews, 52*, 308-324.

Romadhona, G., Wibowo, K., & Royan, R. (2021). *Study of extra virgin olive oil as liquid insulation in transformer.* Paper presented at the IOP Conference Series: Earth and Environmental Science.

Rouabeh, J., M'barki, L., Hammami, A., Jallouli, I., & Driss, A. (2019). Studies of different types of insulating oils and their mixtures as an alternative to mineral oil for cooling power transformers. *Heliyon, 5*(3).

Safariansyah, M., Christiono, C., & Koerniawan, T. (2021). *Analisis Korelasi Perubahan Temperatur Terhadap Densitas, Viskositas, dan Pengaruh Kontaminan Air Pada Pengujian Tegangan Tembus Isolasi Minyak Jenis Nabati.* INSTITUT TEKNOLOGI PLN,

Siburian, J. (2019). Karakteristik transformator. *Jurnal Teknologi Energi Uda: Jurnal Teknik Elektro, 8*(01), 21-28.

Sulemani, M., Majid, A., Khan, F., Ahmad, N., Abid, M., & Khan, I. (2018). *Effect of nanoparticles on breakdown, aging and other properties of vegetable oil.* Paper presented at the 2018 1st international conference on power, energy and smart grid (ICPESG).

Winanta, I. N. O., Agung, A., Amrita, N., & Ariastina, W. (2019). Studi Tegangan Tembus Minyak Transformator. *Jurnal SPEKTRUM, 6*(3).