Dielectric Strength of Some Vegetable Oils and Vegetable-based mixtures

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Abstract - This article deals with the comparison of the dielectric strength of mixtures in variable percentages of the five vegetable oils (Olive, Sesame, Almond, Cactus, and castor) and mineral oil. All tests were carried out according to the standard: IEC 60156, 'Insulating liquids - Determination of the breakdown voltage at power frequency - Test method'. The objective of this study is to verify whether a vegetable/mineral mixture can constitute an alternative to mineral oil. The results obtained show that a mineral oil and castor oil mixture could be seen as a potential fluid for the insulation of power equipment and in particular power transformers.

Keywords - Dielectric, vegetable oils, breakdown voltage, a mineral oil.

I. INTRODUCTION

Mineral oils have been used for the insulation of electrical equipment since the end of the 19th century[1]. These oils are in great demand in electrical installations and in power transformers for their good dielectric properties and heat transfer, their good compatibility with cellulosic insulation and their low cost (these transformers can contain between 40,000 and 80,000 liters of oil) [2]. Apart from distribution transformers subject to special operating constraints, power transformers are generally filled with mineral oil. The oil not only acts as an electrical insulator but also as a coolant.

However, mineral oil is derived from petroleum and therefore from a non-renewable source. In addition, it is non-biodegradable and can have a negative impact on the environment (contamination of soil and water)[3]. It is therefore imperative to find other replacement oils in power transformers. For twenty years, research has focused on vegetable oils from rapeseed and sunflower seeds, grape seeds, soybeans, palm and others to replace mineral oil in transformers.

Among these oils, BIOTEMP ®, a fluid derived from oils rich in oleic acid, patented in the United States by ABB in September 1999. This fluid is currently used in some distribution and network transformers in critical areas[4, 5] . Another soy-based fluid patented in the United States in September 1999 by Waverly Light & Power in Iowa [6] is also used to fill certain units.

Most current vegetable oils are derived from food products [3-10] , so it is necessary to find other fluids with less or no impact on food resources. In this article, we are mainly interested in the dielectric strength of some vegetable oils and mineral/vegetable mixtures. The tests are carried out in the electrical engineering laboratory (LGEO) at the University of Science and Technology of Oran (USTO).

II. EXPERIMENTAL PROCEDURE

The experimental device TUR is an apparatus used for the determination of the breakdown voltage of liquid insulators (Fig.1). The cell is made of porcelain

filled with 500 ml of oil. It is possible to close the cell with a sealed cover to prevent the entry of humidity during the test. Inside the cell are two hemispherical copper electrodes. The dimensions of the electrodes are given in figure 2.

An alternating voltage generator having a voltage of 60 kV was used to cause the arcs inside the oil. This voltage is supplied by a step-up transformer and increased automatically and therefore uniformly, in steps of 2.0 kV /s.

Before causing the second arc, the gas bubbles between the electrodes caused by the first arc are eliminated. After each test, the cell should be flushed with dry solvent and distilled water and heated to evaporate the moisture before use. It is very important to avoid touching the electrodes or the inside of the cell after cleaning.

Fig. 1. TUR experimental device

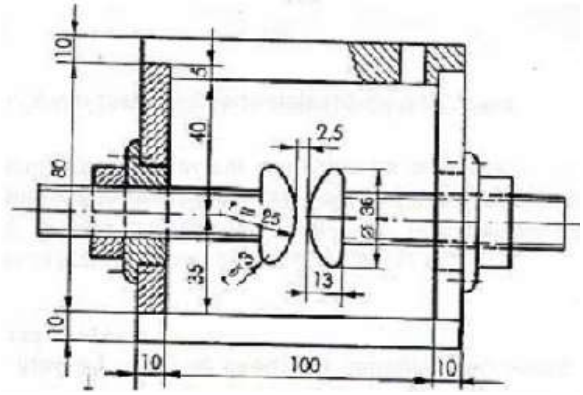

Fig. 2. Cell with hemispherical electrodes.

The breakdown voltage was measured for five vegetable oils (Olive, Sesame, Almond, Cactus, and Castor) and one mineral oil. According to an experimental study carried out in the biology laboratory at USTO. The yield of these oils is very important after the extraction stage[11].

We also measured the breakdown voltage for mixtures between vegetable oil and mineral oil. All the tests are carried out at ambient temperature and under atmospheric pressure.

For each vegetable oil sample, 3 consecutive arcs were elicited with an interval of two minutes between the arcs. For the mixtures we provoked six ars, three after 5 minutes of agitation and three trials after 10 minutes of agitation, a hot plate magnetic stirrer is used to mix the oils (Fig. 3). Breakdown voltage results are almost the same.

Fig. 3. Hot plate stirrer.

The breakdown voltage is the average value of measurements taken, it is calculated by the following equation (1):

$$U = \sum_{m=1}^{n} \frac{U_m}{n} \quad (1)$$

Where U: Average breakdown voltage.
U_m: Voltage measured.
n: Number of repeated measurements.

Mineral oil is indicated by the letter M , vegetable oil is indicated by the letter V.
The different percentages of these mixtures are presented in Table 1, the law of mixtures must be verified to achieve these mixtures [12].

Table 1. Percentage of mixtures.

	Sample 1	Sample 2	Sample 3
M (%)	20	50	80
V (%)	80	50	20

III. Results and Discussions

A) Breakdown voltage of vegetable oils and mineral oil

Figure 4 shows the variation of the breakdown voltage of the five vegetable oils and mineral oil. In this figure we notice that the breakdown voltage of some vegetable oils is lower than mineral oil, especially for cactus oil. In the case of cactus oil, the breakdown voltage exceeded 60 KV. Oil viscosity affects breakdown voltage [12].

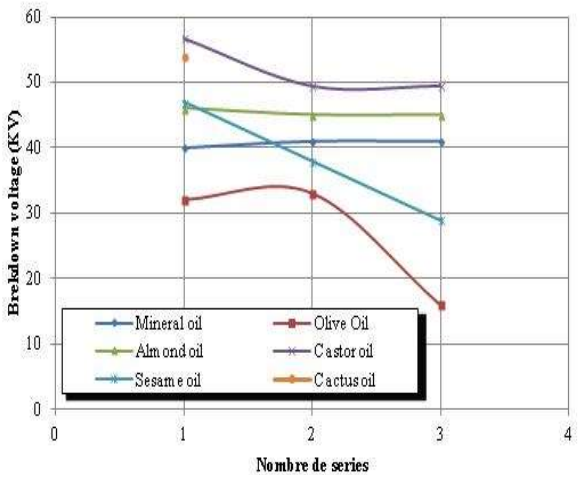

Fig. 4. Breakdown voltage variation.

B) Breakdown voltage of mixtures

Figures 5, 6, 7, 8 and 9 present the average breakdown voltage for the mixtures for the vegetable oils used in this study, namely olive oil, almond oil, castor oil, l sesame oil cactus oil.

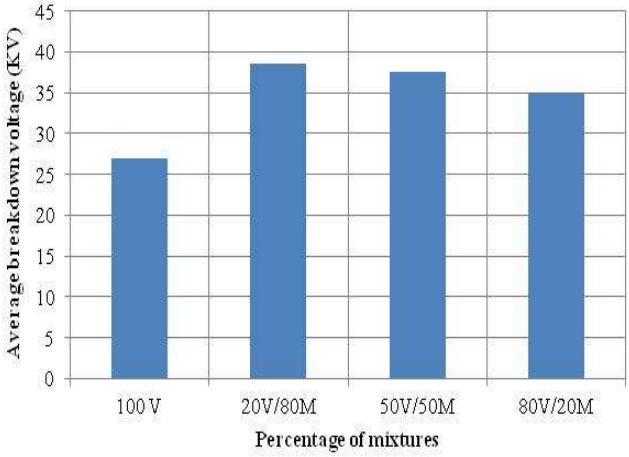

Fig. 5. Variation of average breakdown voltage (Olive oil).

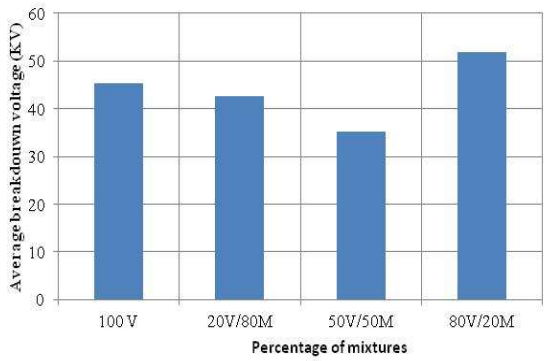

Fig. 6. Variation of average breakdown voltage (Almond oil).

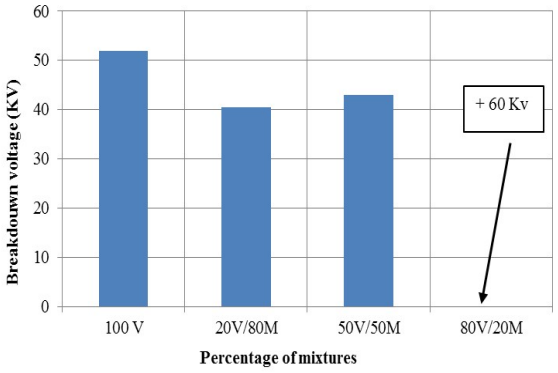

Fig. 7. Variation of average breakdown voltage (Castor oil).

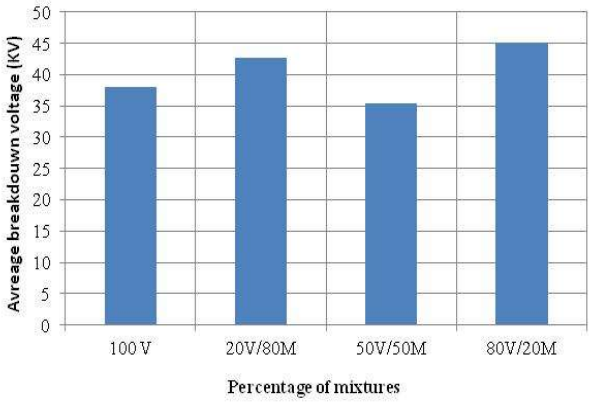

Fig. 8. Variation of average breakdown voltage (Sesame oil).

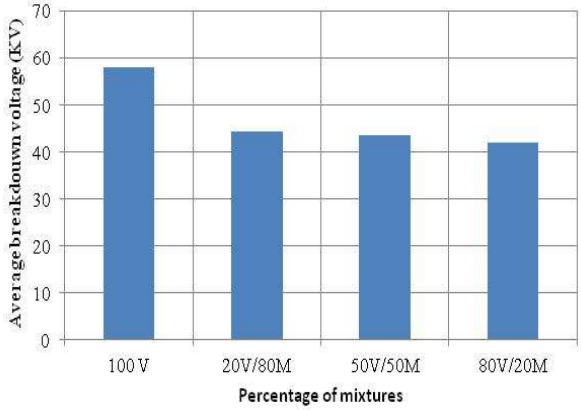

Fig. 9. Variation of average breakdown voltage (Cactus oil).

These results (Figures 5, 6, 7, 8 and 9) show that the breakdown voltage of the mixtures (20V: 80 M, 50V: 50M and 80V: 20 M) exceeds 30 kV.

According to standard IEC 60296:2020, entitled: "Fluids for electric applications - Mineral insulating oils for electrical equipment"[13], the breakdown voltage is between 30 kV and 70 kV for transformers and for low temperature switchgear.

For the mixture of 80% castor oil + 20% mineral oil, the breakdown voltage exceeded 60 kV. 60 kV is the maximum value indicated by the device, beyond this voltage a short circuit is caused and the value cannot be read.

In most cases mixing the oils improved the breakdown voltage. In most vegetable oils studied in this experimental study, the breakdown voltage of vegetable oil is higher than the breakdown voltage of mineral oil.

Figure 10 shows the breakdown voltage comparison between oil blends. We have presented in this figure the highest breakdown voltage for each type of vegetable oil.

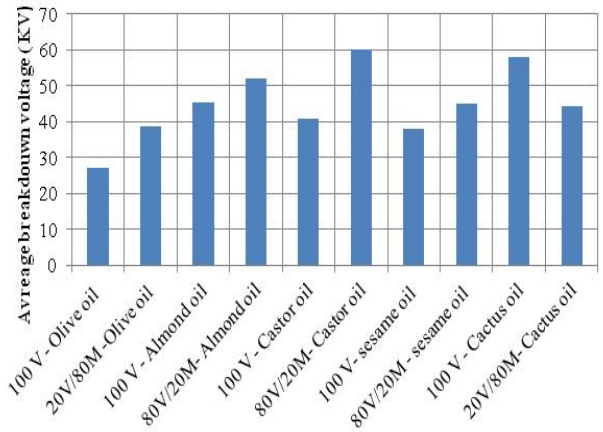

Fig. 10. Average breakdown voltage for oil mixtures.

It can be seen in this figure that the oils: Cactus, Castor and Almond have a significantly higher breakdown voltage than the other two vegetable oils. The mixture (80% castor oil, 20% mineral oil) has the highest breakdown voltage, compared to mineral oil . These results confirm the work carried out by Fofana et al. on mixtures of mineral oil and a synthetic ester liquid[14]. The lowest breakdown voltage is found for olive oil and sesame, which indicates that these oils have a higher amount of impurities than other oils. Among the most important influencing factors on the breakdown voltage: the impurities and gases dissolved in the liquid, the hydrostatic pressure, the configuration of the electrodes, the temperature, and the duration of application of the voltage [15-17].

IV. CONCLUSION

The use of vegetable oil in power transformers is not always possible and requires numerous studies, in particular on breakdown voltage, aging and oxidation stability. The results obtained show that:

The breakdown voltage of some vegetable oils exceeds 30 kV.

-Vegetable oils such as castor, almond and cactus have higher breakdown voltages than mineral oil.

-The breakdown voltage of the mixtures is very important. In the future, vegetable oils can be used as an additive to increase the breakdown voltage of mineral oil.

V. REFERENCES

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