Suitability Analysis of Non-conventional Oils for High Voltage Applications in Rural Areas

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Abstract: ***In high voltage transformers, the liquid insulations are used as the insulating medium as well as cooling medium. For the past several decades, the mineral based transformer oil is used traditionally for the purpose of liquid insulations. In the environmental aspect there are several disadvantages in the mineral oil even though it has better insulating properties. By considering the environmental aspect and insulating properties, the researchers tend to find the alternate insulating fluids for the high voltage applications. Increasing power demand forces the development of the high-rated power transformers. In a transformer, petroleum-based mineral oil is used as insulation, currently Transformer oil produces environmental and health issues because it is non-biodegradable. Thus it has been thought that why not to use vegetable oils if found suitable. The present work investigates breakdown voltage, flash point & fire point of three different vegetable oils and result is tabulated. Results obtained from experiments are validated with benchmark results and are found to be in good agreement. The results are reported in dimensional form and presented graphically. The results provide a substantial insight in understanding the behavior of vegetable oil for high voltage applications.***

Keywords: breakdown voltage; flash point; fire point; transformer oil.

1. Introduction

Based on recent research and development as coconut oil was used in Sri Lanka as alternate insulating oil for power transformers[1]. In this paper, three samples of vegetable oils which are namely linseed and fortune sunlite oil are tested for Breakdown Voltage by standard process and result is compared as per IS-335:1993

The power transformers are generally subjected to sudden loading which results in high current which results in I^2R loss in the transformers, because of which temperature of the winding increases and heat is transferred to insulating oil, thus flash point and fire point of the oil must be high enough. Thus above three samples were also tested for flash and fire point by using pensky martens apparatus and result is compared as per IS standards.

Experimental setup:

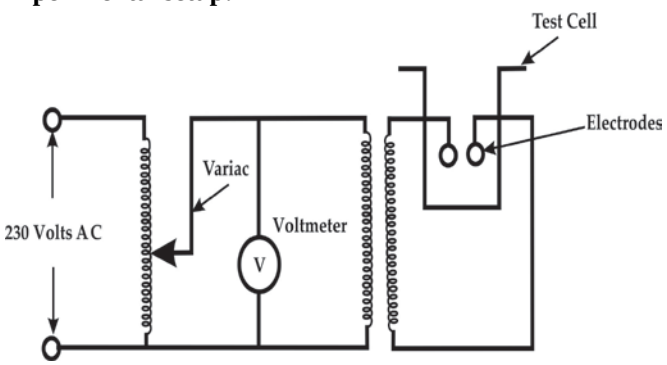

Figure 1: Block diagram of experimental setup for breakdown voltage (0-80 kV)

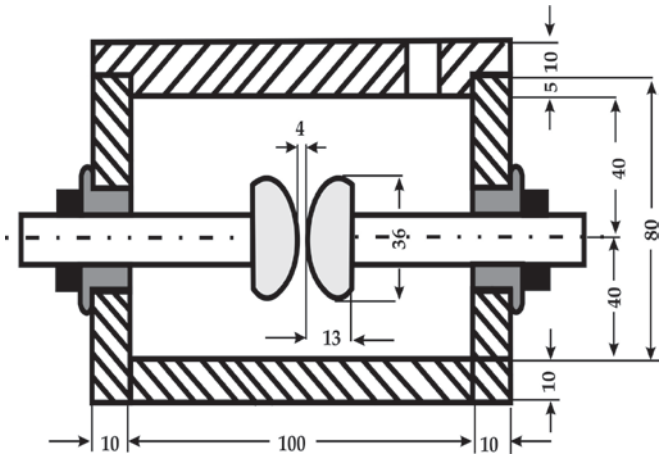

Figure 2: Details of electrode with all dimensions in mm

The above figures show the basic circuit setup for the Breakdown Voltage testing. The whole setup is encased inside a Motorized Oil testing Kit. The kit consists of a test cell in which electrodes are placed and the oil is filled. The other major components are:
1) AC Power Source, 2) Single Phase Variac, 3) A high voltage transformer, 4) Voltmeter, 5) Test cell 6) Electrodes

The supply of 230V is used as an input, the output of this unit is 0 to 80kV, is applied to electrodes that are open and placed inside a test cell. The whole setup is governed by safety devices and there is a voltmeter provided to monitor the voltage at every moment. Pensky martens apparatus is used for flash and fire point testing of oils, the result so obtained are also verified by Infrared Thermometer.

2. Testing procedure:

2.1 Breakdown voltage (BDV) testing procedure

To assess the insulating property of dielectric transformer oil, a sample of the transformer oil is taken and its breakdown voltage is measured.

- The transformer oil is filled in the vessel of the testing device. Two standard-compliant test electrodes with a typical clearance of 4 mm are surrounded by the dielectric oil.
- A test voltage is applied to the electrodes and is continuously increased up to the breakdown voltage with a constant, standard-compliant slew rate of e.g. 2kV/s.
- At a certain voltage level breakdown occurs in form of an electric arc, leading to a collapse of the test voltage.
- An instant after ignition of the arc, the test voltage is switched off automatically by the testing device. Ultra fast switch off is highly desirable, as the carbonization due to the electric arc must be limited to keep the additional pollution as low as possible.
- The transformer oil testing device measures and reports the root mean square value of the breakdown voltage.
- After the transformer oil test is completed, the insulation oil is stirred and the test sequence is performed repeatedly. (Typically 5 repetitions, depending on the standard)
- As a result the breakdown voltage is calculated as mean value of the individual measurements.

2.2 Flash point & Fire point

Flash point is the lowest temperature at which the lubricating oil gives off enough vapors that ignite for a moment when tiny flame is brought near it. Fire point is the lowest temperature at which the vapors of the oil burn continuously for at least five seconds when a tiny flame is brought near it.

Pensky martens testing Procedure:

1. Clean and dry all parts of the apparatus with the help of suitable solvent e.g. CCl4, ether, petroleum spirit or benzene and dry it to remove any traces of solvent.
2. Fill the oil cup with the test oil up to the mark.
3. Fix the lids on the top through which are inserted a thermometer and a stirrer. Ensure that the flame exposure device is fixed on the top.
4. Light the test flame and adjust it to about 4 mm in diameter.
5. Heat the apparatus as temperature of oil increases by 5 to 60˚ per minute as stirrer is continuously rotated.
6. At every 10° C rise of temperature Introduce test flame into the oil vapor. This is done by operating the shutter. On moving knob of shutter, test flame is lowered in oil vapors through opening.
7. When test flame causes a distinct flame in interior cup, note down the temperature which represent the flash point.
8. Further heat the oil at the rate of 10°C/ min. and continue applying the test flame as before.
9. The temperature at which the vapors of the oil give a clear and distinct blue flash for five seconds is recorded as the fire point of the oil.

3. Results:

3.1 Breakdown Voltage Test Results:

The results are tabulated and shown graphically below

Table 1 Mean B reakdown Voltages

Break down trials	Fortune sunlite Oil Sample			Linseed Oil Sample		
	BDV in kV (27◦C)	BDV in kV (30◦C)	Mean BDV (kV)	BDV in kV (27◦C)	BDV in kV (30◦C)	Mean BDV (kV)
BDT1	15	13	14	30	28	29
BDT2	15	14	14.5	30	28	29
BDT3	16	14	15	30	28	29
BDT4	16	13	14.5	32	28	30
BDT5	16	13	14.5	32	30	31

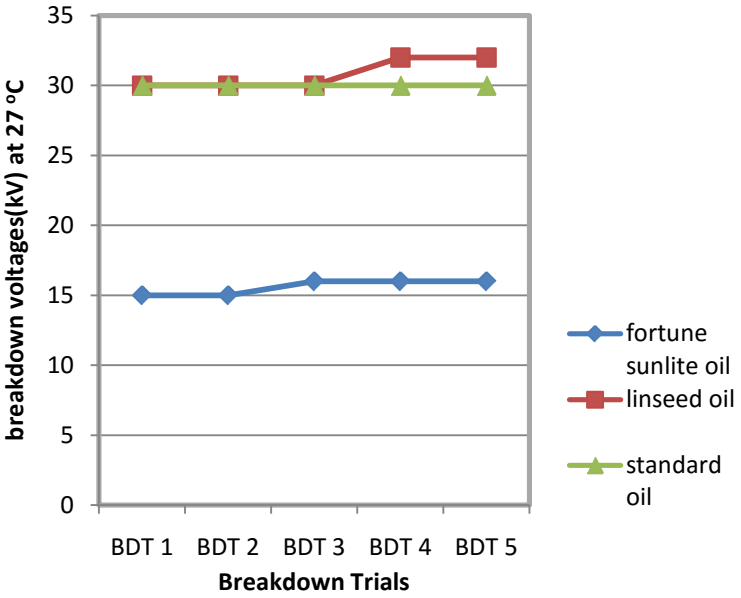

Figure 3: Mean breakdown voltages of oil for different trials

The final results including (**Flash point & Fire point)** can be put in the form of the following table:

Table 2 Comparison of different oils

Vegetable Oil	Average Breakdown voltage(kV)	Flash Point (°C)	Fire Point (°C)
Linseed Oil	29.6	218	229
Fortune sunlite Oil	14.5	332	348
coconut Oil	60	225	236

4. Conclusion:

This study was undertaken to find out the breakdown voltages of common non conventional oils in order to determine their suitability as insulating oil in various high voltage applications. From the results obtained, the following conclusions can be made.

(i) As pr IS-335:1993,linseed oil can be used as an alternate insulating oil after some processing as it is having flash point of 218°C (the min requirement is 140°C),and breakdown voltage of 29.6kV(the min requirement is 30kV).
(ii) The mean breakdown voltage of 29.6 kV was obtained for the Linseed Oil and 14.5kV was obtained for Sunlite fortune oil.
(iii) The Flash Point testing of the oils reveal that the flash point of Linseed Oil and fortune sunlite Oil are about 218˚C and 332˚C respectively.
(iv) The breakdown voltage measurement was slightly influenced by temperature in Linseed oil and fortune sunlite oil didn't show much variation.
(v) The findings present a data sheet of breakdown voltage as well as the flash point measurement of the three non-conventional oils viz. Linseed Oil, fortune sunlite oil and coconut oil.

Thus we propose these results for the technological development of liquids as insulating material in power industry, due to the higher flash point & fire point these oils can also be used commercially.

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