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Suitability Analysis and Comparison of Sunflower, Til and Mustered Oils for High Voltage Applications

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Abstract: In high voltage applications, the liquid insulating oils are used as the insulating medium as well as cooling medium. For the past several decades, the mineral based transformer oil which are extracted from petroleum crude oil is used traditionally for the purpose of liquid insulations. In the environmental aspect, there are several disadvantages of 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 devices such as Transformers Circuit Breakers etc. 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 namely Sunflower (Sweekar Brand), Til (Tilsona Brand) and Mustered (Fortune Brand) 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 (BDV), Breakdown Trials (BDT), Flash point, Fire point.

I. INTRODUCTION

Based on recent research and development as coconut oil was used in Shri-Lanka as alternate insulating oil for power transformers. A coconut oil filled sealed type distribution transformer had been installed in the Wathara area in Kesbewa, Sri Lanka in 2001 January. Its name plate parameters were three phase, 160 kV, 33 kV/400 V, 50 Hz, etc. This transformer has been supplying a 35 kVA bulk consumer (rubber factory) through a 400 V feeder and domestic consumers through another two 400 V feeders for the last 11 years. During its service, the transformer has been feeding an average load of about 40% and exposed to outdoor tropical weather conditions. The transformer worked well without having any reported failures [1]. In this paper, three samples of Sunflower, Til(To), Mustered oils which are having brand names as Sweekar, Tilsona and Fortune 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 Marten's apparatus[7] and result is compared as per IS standards. Mineral oil [3] is mostly used in the transformers. Many research work have been done in this field to investigate[5] the properties of vegetable oils [8, 10] such as coconut oil [1], olive oil[2], rapeseed oil [9, 11] etc. The properties of various oil can be further improved by using nano-particles of various materials[4,6].

II. EXPERIMENTAL SETUP

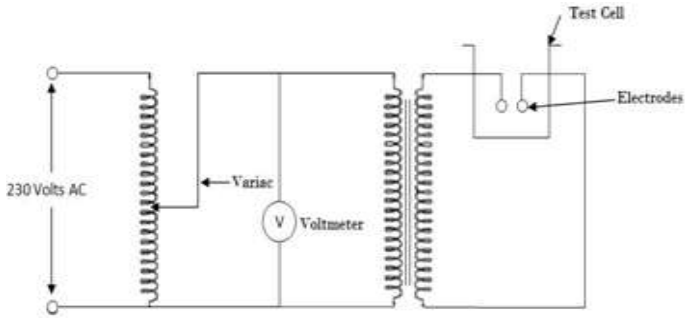

Figure 1. Block diagram of experimental setup for breakdown voltage (0-80 kV)

Figure 1 and 2 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

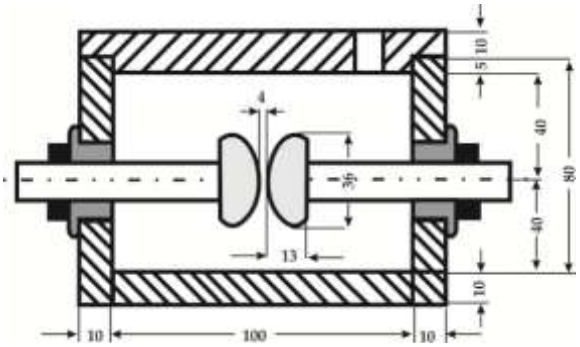

Figure 2. Detail of electrode with all dimensions in mm

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 marten's apparatus is used for flash and fire point testing of oils, the result so obtained are also verified by Infrared Thermometer.

III. TESTING PROCEDURE

1-Transformer oil testing (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. Flash point & Fire point test procedure:

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:

- 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.
- Fill the oil cup with the test oil up to the mark.
- 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.
- Light the test flame and adjust it to about 4 mm in diameter.
- Heat the apparatus as temperature of oil increases by 5˚ to 60˚ per minute as stirrer is continuously rotated.
- 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.
- When test flame causes a distinct flame in interior cup, note down the temperature which represent the flash point.
- Further heat the oil at the rate of 10°C/ min. and continue applying the test flame as before.
- 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.

IV. RESULTS

Breakdown Voltage Test Results

Dielectric breakdown voltage is the measurement of electrical stress that insulating oil can withstand without breakdown. This voltage is usually indicative of the amount of pollutant in the dielectric (usually moisture) The samples of oils were taken and placed in air tight containers.

- S1 sample consisted of Sunflower (Sweekar Brand) Oil
- S2 sample consisted of Til(To) (Tilsona Brand) Oil
- S3 sample consisted of Mustered (Fortune Brand) Oil
- Each sample was tested 5 times.

These experiments were replicated twice a day at different temperatures and the mean was taken.

The result of the experiments is tabulated in table 1 for specific brands of Sunflower, Til(To) and Mustered oils.

Table 1 Comparison of vegetable and mineral oil according to the BDVs.

Break down trials	Sunflower Oil (S1)			Til Oil (S2)			Mustered Oil (S3)		
	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)	BDV in KV (27°C)	BDV in KV (30°C)	Mean BDV (KV)
BDT1	57	58	57.5	58	56	57	59	58	58.5
BDT2	54	54	54	57	56	56.5	59	57	58
BDT3	53	54	53.5	56	55	55.5	58	58	58
BDT4	51	52	51.5	56	54	55	57	56	56.5
BDT5	49	48	48.5	55	53	54	57	55	56
Average BDV =53KV				Average BDV =55.6KV			Average BDV =57.4KV		

Table 2 is the comparison of different oils according to the cost analysis. Here cost of mineral oil has been compared with the other vegetable oils.

Table 2 cost analysis and comparison of vegetable and mineral oils.

Oils→	Mineral Oils	Sunflower Oil	Til(To) Oil	Mustered Oil
Cost in Rs./Kg	118/-	88/-	220/-	110/-
%Cost wrt Mineral oil	100%	75%	186%	93%

Figure 3 is the graph of breakdown voltages for various breakdown trials at room temperature.

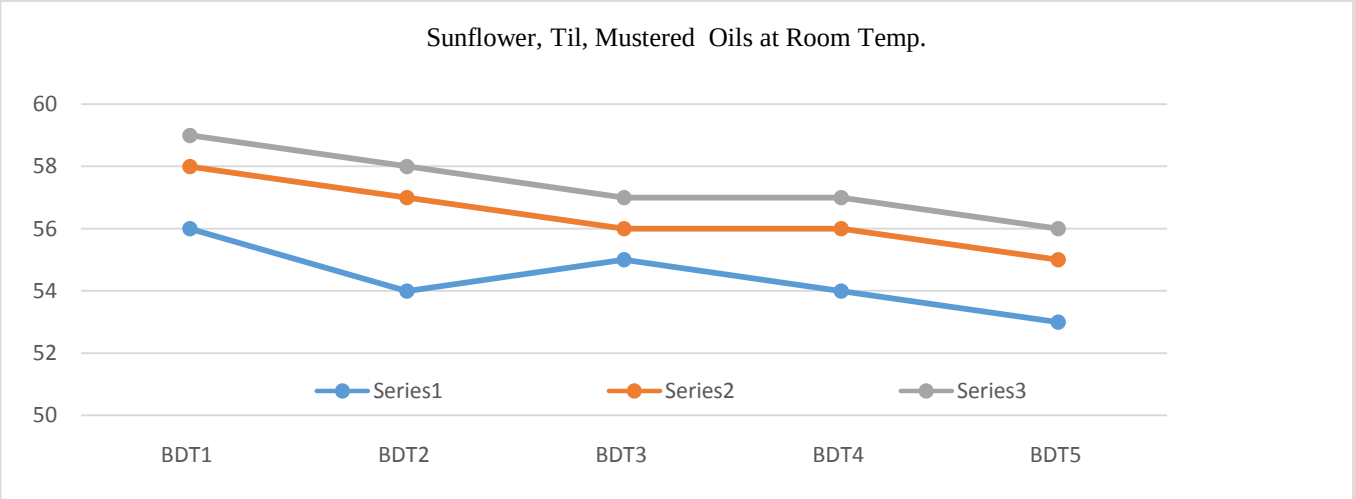

Figure 3. Breakdown voltages for various breakdown trials at room Temperature

The test results with temperature variation from 25 °C to 70 °C, for all above three vegetable oils are shown below.

Temp in °C	Breakdown Voltage in KV		
	Sunflower Oil	Til Oil	Mustered Oil
25	56	58	59
30	53	56	58
40	35	46	55
50	30	42	56
60	38	40	53
70	39	39	51

V. CONCLUSION

This study was undertaken to find out the breakdown voltages of three different vegetable oils(Sunflower, Til (To) and Mustered 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

1. The breakdown voltage measurement was influenced by temperature, in Sunflower as well as in Til(To) Oils while the Breakdown voltages of the Mustered oils didn't show much variation.

2. The mean breakdown voltage of 53KV was obtained for Sunflower oil, 55.6KV was obtained for the Til(To) Oil and 57.4KVwas obtained for Mustered oil at room temperature.

3. The Flash Point testing of the oils reveal that the flash point of Sunflower Oil is about 329˚C while those of Til(To) Oil and Mustered Oil are about 318˚C and 335˚C respectively.

4. As per IS 335-1993, The BDV Required for Transformer oil is 30KV.Thus this three oils can be used as an alternate for insulating oil in the Transformers and other electrical equipment's which are subjected to high voltage applications.

5. As per IS 335-1993, The Flash/Fire point Required for Transformer oil must be above 140°C. Thus all above Brands of mustered oils can be used according to Indian standards.

6. The cost of Mustered oil is comparable while Sunflower oil is 25% cheaper and Til oil cost is double as compared with traditional Mineral oils.

7. The findings present a data sheet of breakdown voltage as well as the flash point measurement of the three vegetable oils viz. Sunflower, Til(To) and Mustered oils.

The final conclusion can be put in the form of the following table:

Vegetable Oil Samples	Average Breakdown voltage (KV)	Flash Point (°C)	% Cost w.r.t. Mineral Oil
Sunflower Oil	53	319	75%
Til(To) Oil	55.6	315	186%
Mustered Oil	57.4	328	93%

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