Estimate the High Voltage Insulation Applications via Neem Oil with Its Physical Characteristics and Breakdown Strength

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Abstract— The success of any electrical system lies in its insulating system performance. Petroleum based mineral oils are the generally used fluids for electrical insulation and heat transfer. But they are non-biodegradable. Vegetable oils obtained from seeds, flowers and vegetables are biodegradable, non-toxic, environmental friendly and benign to aquatic or terrestrial. The objective of this project is to analyze the breakdown strength and physical characteristics of the neem oil under unaged and thermally aged conditions. In order to compare the results obtained for neem oil with castor oil, the same aging process and tests have been carried out on castor oil.

Key words: Vegetable Oils, Breakdown Voltage (BDV), Physical Characteristics, Viscosity, Flash Point, Fire Point

I. INTRODUCTION

Mineral oils are most commonly used for electrical insulation and cooling purpose electrical applications in power transformer. The major trouble faced with mineral oil is that it is poorly biodegradable and if any leakage occurs, it could lead to serious contamination of soil and waterways. Hence, it is necessary to carryout extensive studies in the development of new biodegradable insulating fluids. Neem oil is natural product and are plenty of Supply. The most attractive features of Neem oil is that they are biodegradable, non-toxic and most environmental friendly. Conventionally petroleum based mineral oils are used in high power apparatuses. Even though the mineral oils have excellent dielectric properties such as high electric field strength, low dielectric losses, good long-term performance and are obtained at reasonably low price, mineral oils or synthetic insulating liquids are usually non-biodegradable.

Extensive studies were carried out for the past two decades to find suitable alternate natural esters for electrical application. There is now considerable interest in understanding the thermal aging characteristics of Neem oil which is not yet well reported. Partial discharge (PD) due to electric field enhancement in a localized area of insulation accelerates the degradation and thermal aging of the insulating oil.

Hence it plays a major role in determining the insulation strength and life time of oil. Therefore, it is important to understand the PD characteristics of natural eaters before recommending them as an alternate of mineral oil for high voltage transformer applications. PD detection and analysis is now a well-recognized insulation monitoring method in determining the quality of insulation. However, the PD characteristics of natural esters such as neem oil and castor oil under un-aged and thermally aged conditions are investigated. For comparison purpose, the PD characteristics of mineral oil are also discussed.

II. INSULATING LIQUIDS USED IN THESIS

This work reports an investigation of the suitability of neem oil to replace conventional petroleum based mineral oil in large power transformers.

A. Neem oil

Neem oil is a vegetable oil pressed from the fruits and seeds of the neem an evergreen tree which is endemic to the Indian subcontinent and has been introduced to many other areas in the tropics. It is the most important of the commercially available products of neem for organic farming and medicines.

B. Composition of Neem oil

Neem oil varies in color. It can be golden yellow, yellowish brown, reddish brown, dark brown, greenish brown, or bright red. It has a rather strong odor that is said to combine the odours of peanut and garlic. It is composed mainly of triglycerides and contains many triterpenoid compounds, which are responsible for the bitter taste.

It is hydrophobic in nature in order to emulsify it in water for application purposes, it is formulated with surfactants. Azadirachtin is the most well-known and studied triterpenoid in neem oil. Nimbin is another triterpenoid which has been credited with some of neem oil's properties as an antiseptic, antifungal, antipyretic and antihistamine. Neem oil also contains several sterols, including (campesterol, beta-sitosterol, stigmasterol).

C. Castor oil

Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant (Ricinuscommunis). The common name "castor oil", from which the plant gets its name, probably comes from its use as a replacement for castoreum, a perfume base made from the dried perineal glands of the beaver (castor in Latin). Castor oil is a colorless to very pale yellow liquid with a distinct taste and odor once first ingested. Its boiling point is 313 °C (595 °F) and its density is 961 kg/m3. It is a triglyceride in which approximately 90 percent of fatty acid chains are ricinoleates. Oleate and linoleates are the other significant components.Castor oil and its derivatives are used in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold resistant plastics, waxes and polishes, nylon, pharmaceuticals and perfumes.

D. Composition of castor oil

The castor oil plant, Ricinus communis, is a species of flowering plant in the spurge family. Castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain 40% to 60% of oil. Castor oil is famous as a source of ricinoleic acid, a monounsaturated, 18-carbon fatty acid. Among the fatty acids, ricinoleic acid is unusual in that it has a hydroxyl functional group on the 12th carbon. This functional group causes ricinoleic acid (castor oil) to be more polar than most fats.

III. EXPERIMENTAL STUDIES

Fig. 3.1: Experimental Setup

A. Experimental Data

Measurements were carried out to determine the electric breakdown voltage of different samples of neem and castor oils: non-additive TR 30 oil, sunflower, corn and rapeseed oils. 436 M. Şerban, L. Sângeorzan and E. Helerea the Megger AF 60/2 equipment has been used. The electrodes of test vessel have different shapes: plane, sphere and semi-sphere, and could be set at different distances. A magnetic stirring could be produced by a rotating magnetic field, controlled by software. A thermometer of BK PRECISION 710 type measure the temperature of the oil and the ambient environment. Samples of oil have been subjected to increasing voltage up to breakdown of sample, with a rate of 2.5 kV/s and frequency of 61.8 Hz. A distance of 1 mm between electrodes for each type of electrodes - plane, calotte and sphere - has been fixed. The volume of oil used in each test subject to breakdown was 300 cm3. The temperature of oil and ambient environment was of 25-28°C. The results of breakdown voltage have been saved by a non-volatile memory.

B. Partial Discharge Test

A partial discharge in a high voltage transformer occurs when the electric field enhances in a localized area of insulation. Partial discharge detection is one of the most important diagnostic techniques used to assess condition of high voltage insulation in transformer. The most likely types of PDs in a transformer can be broken down into two categories such as corona discharges and surface discharges. Corona discharge may be due to any floating conducting particle in the insulating medium. Surface discharges in transformers mainly occur in the surface of pressboard layers.

In the present work, in order to simulate corona discharge, a needle-plane electrode configuration was used. Partial discharge measurement is carried out according to IEC 60270 test procedures. Figure shows the test cell with needle-plane electrode configuration. The tip of the needle has a curvature radius of 1.5µm. The test specimen is energized from a step up transformer which can supply voltage upto 100 kV. Primary side of the high voltage transformer is connected to a control panel and a 230 V AC supply.

The high voltage was connected to the needle electrode and the plane electrode was solidly grounded. Since it is difficult to get a stable PD source from the needle-plane electrode configuration, a 3 mm thick pressboard was used upon the ground electrode. The gap distance between the needle and ground electrode was maintained at 5 mm. PD signals were picked by connecting a high frequency current transformer (HFCT) around the ground connection of the test cell. HFCT is a clip on device clamped around the ground lead and it has a 50 MHz frequency bandwidth which is sufficient to cover the entire range of PD. Output of the HFCT is connected to the PD detector. Partial discharges were detected through a large bandwidth system.

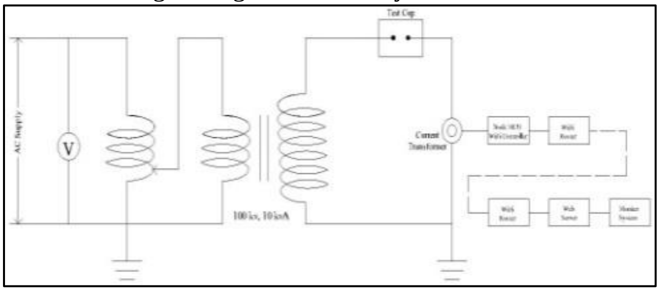

Fig 3.2 circuit diagram for pd test

C. Experimental Setup

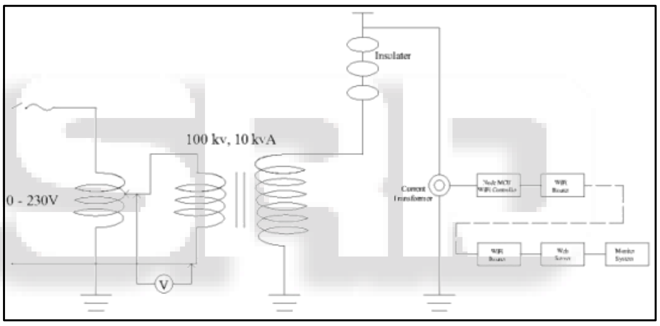

Fig 3.3 Experimental Diagram Circuit

When normal voltage is converted to High Voltage using transformer. The High Voltage is usually starting from KV. Normally the generator supply is not possible to convert from low voltage to high voltage. So while step up the voltage level safety precaution is needed. Initially the supply voltage is increased to KV level and this high voltage is passed through a vessel with two electrodes. This vessel is filled with oil and electrodes may be needle or plane electrodes. When insulation gets failure, the leakage current pass to Data Acquisition System through Current Transformer and PD waveform is analyzed using PD BASE II software.

The experimental setup of oil testing is shown in figure 3.3 it consists of transformer, vessel with electrode, current transformer, date acquisition system. Initially any oil is taken into test in test vessel with two electrodes called upper electrodes and bottom electrodes. The electrodes may be needle or plane electrodes. The two electrodes are separated by a small distance say some mm. while applying high voltage, the oil provides insulation between two electrodes at certain level. After Partial Discharge occurs, the insulation gets failure and leakage current is passed to Data Acquisition System (It is a PD base kit which is interconnected with computer to capture PD waveform).When voltage is increased, the dielectric strength of any type of oil gets varied. Care should be taken since high voltage is applied and voltage rises up to spark occurs between the electrodes. The PD waveform is shown in a fraction of seconds and we need to capture that waveform and stored in a computer for comparison and analysis.

IV. RESULT AND DISCUSSIONS

A. Phase Resolved Partial Discharge Pattern Analysis Rod-Plane Electrode Configuration

In the rod-plane electrode configuration, pressboard material is placed between the electrodes in order to simulate surface discharges. PD signals were recorded under constant electric stress and room temperature (30°C). In order to compare PD behaviour, all the oil specimens were tested under the same test voltage of 25 kV which is above the PD inception voltage of the tested oil specimens in this electrode configuration. The phase resolved partial discharge pattern shows the phase and amplitude of the whole amount of the acquired pulses during the test. In this study, the PD pattern of oils at 14 kV which is above the partial discharge inception voltage of all the nine samples is considered for comparison purpose. Figure 5.1 shows the PRPD pattern and time frequency map of virgin oils with plane needle electrode obtained at 14 kV applied voltage. Using the innovative PDBASE II instrument, it is feasible to analyze the captured PD signals result in different modes such as:

1) Complete PRPD pattern
2) Time frequency
3) PD pulse waveform
4) Pulse spectrum

The complete PD Characteristics is shown in the following figure,

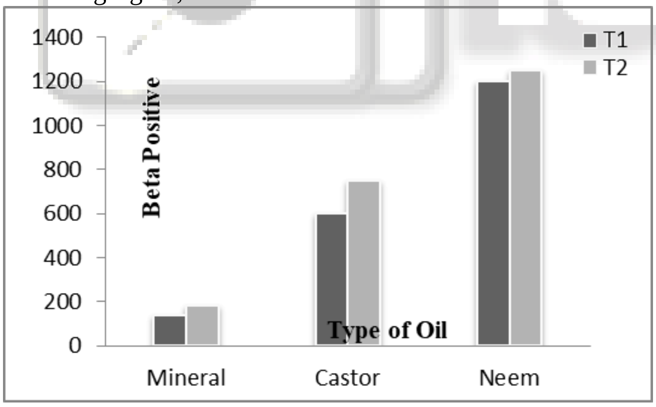

Fig. 4.1: PD Characteristics

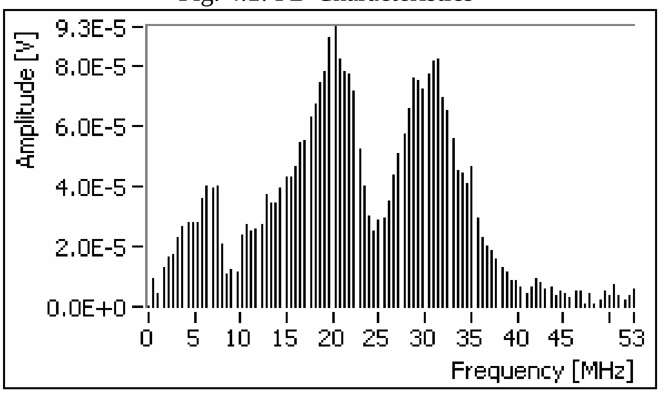

Fig. 4.2: variation of shape

Here the electrical breakdown voltage strength, physical characteristics such as viscosity, flash point and fire point of neem oil and castor oil under unaged and thermally aged conditions were analysed. The results show that the breakdown voltage of neem oil are higher than mineral oil even after aging. This is because of chemical changes takes place in neem oil during aging. The breakdown strength of castor oil thermally aged for 7 days is very high and after 30 days of aging no breakdown takes place up to 60kV for an electrode gap of 2.5mm. After 30 days of aging the viscosity of castor oil has become so high. Generally, there is no sludge formation with both oils, but there was some solid formation at the edges of oil. The viscosity of neem oil is much higher than Castor oil. So to reduce the viscosity of neem oil, chemical treatment is necessary. The flash point and fire point of virgin and aged neem oil are higher than castor oil. Therefore, neem oil and castor oil will have least problems arises due to low flash point and fire point. Even under higher thermal and loading conditions the neem oil will give smoother operations. The present work can also be extended for different high voltage insulation applications models for detecting the breakdown strength by different oils. Further the collected breakdown strength can be processes for the analysis.

A. Parameter beta positive of pd pattern at different aging conditions

The above fig 5.1 shows the minimum, maximum and mean values of skewness parameter, obtained with 95 percent confidence intervals from the PD amplitude distribution, at different aging conditions. It is observed that with increase in aging severity, the value of skewness considerably increases, which indicates the reduction in symmetry of the data at thermal aged conditions. In general, from the statistical analysis of PD pattern, it is observed that variation of shape parameter and skewness are closely related to the aging condition of the neem oil. The above reported PD characteristics of neem and castor oil clearly show that they have the ability to be considered as an alternate for mineral oils. Since PD in liquid dielectrics generates from any stress enhancement sites, its reproducibility in discharge measurements is practically difficult to achieve and hence it would be sensible to operate transformers below the PDIV level and thereby prevent possible molecular chain scission and chemical degradation of neem and castor oils in the reaction.

B. Viscosity

Viscosity is an important property and deciding parameter in the cooling capacity of a liquid insulator. The simple way of cooling system in transformer depends on the viscosity of the fluid, so the oil with low viscosity is desirable and it is important to analyze the viscosity of oil. As the long term thermal aging affects the viscosity of the oil samples, in this work the kinematic viscosity of 30 days thermally aged oils were determined by Redwood viscometer. For comparison purpose, the viscosities of virgin vegetable oils (neem oil and castor oil) are presented. The kinematic viscosity of oils with respect to temperature is shown in Figure 5.2. Viscosity of insulating oil decreases with increase in temperature, that is viscosity is inversely proportional to the temperature. This is because of reduction in intermolecular attraction. The change in viscosity with refer to temperature is less in mineral oil when compared to vegetable oils. Especially the viscosity of castor oil at 30°C is very high value and it is not desirable. In case of cold countries, where the atmospheric temperature falls even below this, a doubt arises about function of castor oil as a cooling agent.

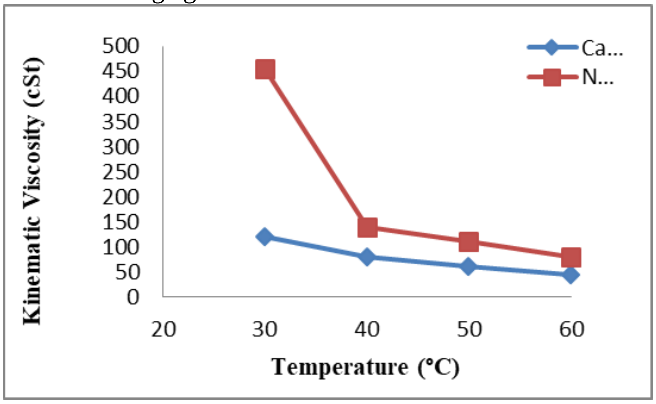

Fig. 4.1: Velocity vs Temperature

V. Conclusion

Hence a laboratory experiments were carried out to study the partial discharge characteristics of neem oil and castor oil for high voltage applications using with IoT. From this investigation, it appears that neem and castor oil have higher breakdown strength than mineral oil. The effect of thermal aging on breakdown strength seems much lower in natural ester fluids than in mineral oil. Lower PD activity is present in neem and castor oils with respect to mineral oil for un-aged specimens. However, with respect to corona discharges, steeper increase of PD pulses with aging time was noticed in neem oil than in mineral oil.The differences in terms of time and frequency domain analysis of partial on the above results, it can be speculated that neem oil have the required potential for electrical insulation applications. However, further research work is required to improve viscosity and long-term PD properties under the expected service stresses.

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