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Investigations on Partial Discharge Activity in Mineral & Eco Friendly Vegetable Oils

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***Abstract*—Partial discharge (PD) detection plays major role in the life time assessment of insulation system in the transformers. This paper investigates on the Partial Discharge activity and characteristics in mineral oil and ecofriendly vegetable oil (Rice bran and Sesame oil). Also the breakdown voltage measurement of ecofriendly oil and mineral oil were carried out. To develop the uniform and non-uniform electric field stress, plane-plane and point-plane electrode configuration were used. The phase resolved PD patterns of mineral oil, rice bran and sesame oil with pressboard were recorded and analyzed. From the findings, it can be seen that vegetable oils have a higher PD inception voltage than mineral oils. Also the two selected ecofriendly vegetable oils shows better PD characteristics hence they can be used for high voltage insulation applications. The electric field distributions in oil/pressboard during inception of PD activity were simulated using ANSYS software.**

***Index Terms*— Partial discharge, discharge power, events/sec, PD inception voltage.**

I. INTRODUCTION

High voltage transformers are the key component for reliable operation of power systems. Electricity supplies need to be secure and always available due to the rise in demand for electricity. Transformer malfunctions result in expensive repairs. Long-term thermal ageing stress and insulation system deterioration cause a significant portion of distribution transformer failures.[1]. Partial Discharges (PD) are one of the major causes for degradation of high voltage insulation systems. The condition of the insulating system is monitored using PD measurement as a diagnostic tool [2-4]. The key variables that need to be examined are the PD inception voltage, charge magnitude, number of discharge pulses, and their distribution.

Mineral oil is the commonly used insulating fluid in power apparatus which is poorly biodegradable and cause serious contamination of soil and water ways if spill occurs. Since petroleum goods will eventually run out, a shortage will result. Therefore, research must be done to create new environmentally acceptable, biodegradable insulating fluids. Vegetable seed oils are environmentally safe, non-toxic, and biodegradable [5–11]. Therefore, in-depth research was done to locate the best insulating oil for electrical purposes.

Partial discharge (PD) due to electric field enhancement in a localized area of insulation accelerates the degradation and thermal aging of insulating oil. The prolonged duration of PD activity leads to failure of insulation. Hence PD plays a major role in determining the insulation strength and life time of oil [12]. Therefore

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it is necessary to understand the PD characteristics of vegetable oil. Taking these facts into account, the primary goal of the current research project is to determine the typical PD patterns of two chosen vegetable seed oils in order to determine their feasibility for use in power apparatus applications. In this paper, Phase Resolved PD characteristics of rice bran and sesame oil with pressboard under uniform and non-uniform field stress are investigated. The PD characteristics of mineral oil are also examined for the purposes of comparison.

II. EXPERIMENTAL TEST SETUP

A. Breakdown Voltage Measurement

Breakdown voltage of a liquid dielectric is an important feature of its insulation strength. It is measured by applying a voltage to the liquid dielectric in a standard cell and increasing till the breakdown. The breakdown test of insulating oils is carried out as per Indian Standards (IS 6792/1992). The test set shown in figure-1 operates on 230V, 50Hz supply has High voltage transformer. The electrodes are mounted on horizontal axis with gap spacing of 2.5mm.

Figure 1: Experimental setup for Breakdown Voltage measurement

B. Partial Discharge Measurement setup

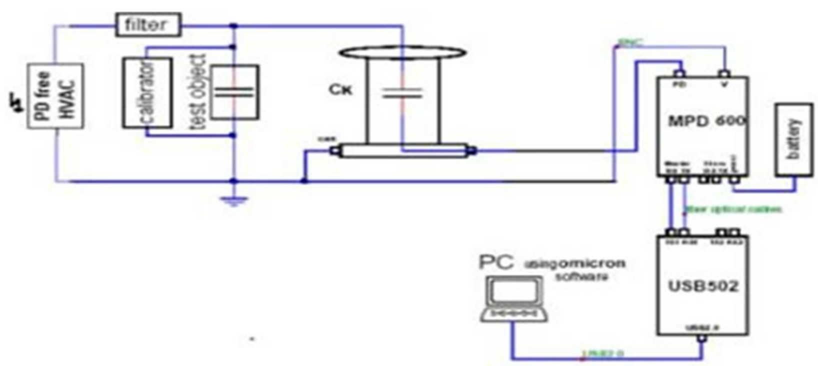


Figure 2: Circuit arrangement for PD measurement

The PD measurements are conducted using Omicron make MPD 600 digital PD detector. A 100kV PD free transformer is selected as the test source. As a coupling device, a 1000pF PD-free capacitor is used. The whole test setup is enclosed inside the Faraday's cage. To conduct PD measurement on oil/pressboard, Plane-plane and point-plane electrode arrangement are used. PD measurement is carried out according to the IEC 60270 test procedures. The circuit arrangement is as shown in figure-2.

III. EXPERIMENTAL RESULTS & DISCUSSIONS

A. Breakdown voltage

The average value of BDVs of mineral, rice bran and sesame oil are plotted as a function of temperature as shown in figure -3. It is observed that, there is improvement in BDV value of mineral oil in the temperature range of 30^0C to 70^0C. Since the operating temperature of transformers on loaded conditions are above 80^0C, mineral oil shows dip in BDV whereas rice bran and sesame oil shows continuous improvement in BDV in the temperature range of 30^0C to 90^0C.

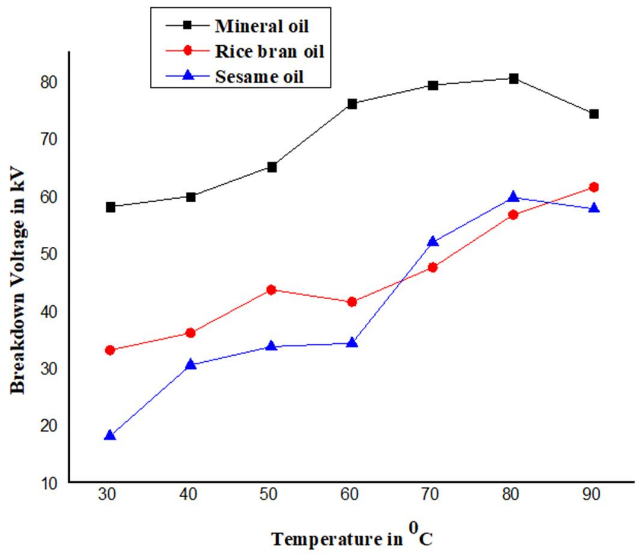


Figure -3: BDV as a function of temperature

B. Partial Discharge Measurements

Partial Discharge pattern identification and analysis have been proven tool for the diagnostics of the insulation status of the high voltage apparatus. PD takes place when the local electric field exceeds the threshold value and produces a partial breakdown of the surrounding insulating material. The electric field necessary to produce a partial discharge is obtained by utilizing Plane-Plane and Point- Plane electrode configurations. From the PD measurements- PD inception voltage (PDIV), Charge magnitude (q), phase of PD occurrence (Φ), number of PD events/sec (n), discharge current (I_{did}), discharge power (P_{dis}) and magnitude of peak charge (Q_{peak}) are measured. The PDIV is the lowest voltage at which detectable PD pulses can be seen on the PD detector.

C. PRPD pattern under uniform fields

A known voltage is applied to the test object in order to capture PRPD patterns. The test object consists of plane-plane electrodes, a 3mm pressboard placed between the electrodes and the insulating oil. The applied voltage is increased until the PD pulses starts to appear. Figure 4a- 4b, 5a-5b and 6a-6b represents the 2-D Φ-q pattern & 3-D Φ-q-n patterns of Mineral oil, Rice bran oil and Sesame oil respectively. Table-1 shows the PD characteristics at inception under uniform fields. From the results it is clear that the inception voltages of rice bran & sesame oil are almost same and it is 30% more than that of mineral oil. Also the phase of PD occurrence is only in positive half cycle indicates the surface discharge takes place in pressboard layer. In mineral oil, the number of PD events occurring is twice that of rice bran and sesame oil.

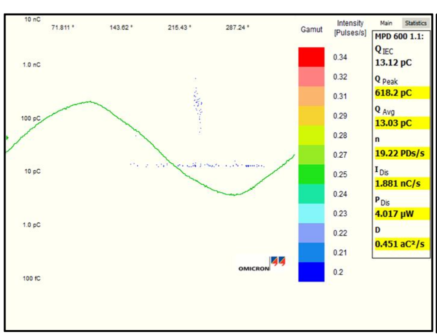


Figure-4a: 2-D Φ-q pattern of Mineral oil

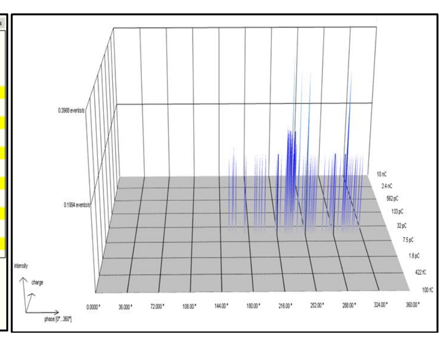
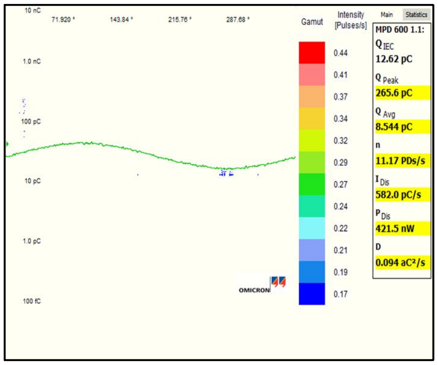


Figure-4b: 3-D Φ-q-n pattern of Mineral oil



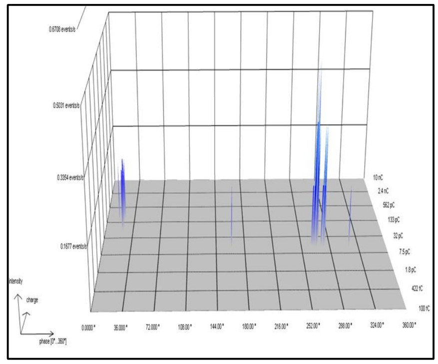
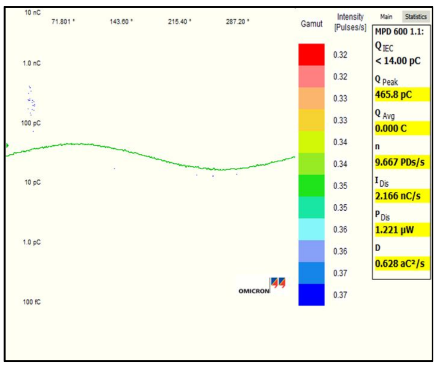


Figure-5a: 2-D Φ-q pattern of Rice bran oil

Figure-5b: 3-D Φ-q-n pattern of Rice bran oil



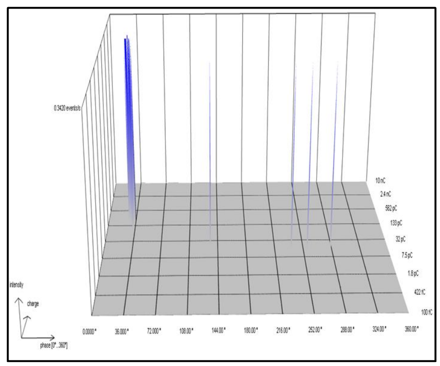


Figure-6a: 2-D Φ-q pattern of Sesame oil

Figure-6b: 3-D Φ-q-n pattern of Sesame oil

TABLE I: PARTIAL DISCHARGE CHARACTERISTICS AT INCEPTION UNDER UNIFORM FIELDS

PD Parameters	Mineral Oil 3mm Pressboard	Rice Bran Oil 3mm Pressboard	Sesame Oil 3mm Pressboard
PDIV in kV	0.922	1.31	1.11
Peak Charge (Q_{Peak})	618.2pC	265.6pC	465.8pC
Number of PD events/sec	19.22	11.1	9.66
Phase angle	200^0-300^0	0^0-40^0 & 270^0	0^0-45^0
Discharge current	1.881nC/s	582pC/s	2.16nC/s
Discharge Power	4.01µW	421nW	1.22µW

D. PRPD pattern under non-uniform fields

In order to capture PRPD patterns voltage is applied to the test object. The test object consists of point-plane electrodes, 3mm pressboard placed between the electrodes and the insulating oil. Figure 7a- 7b, 8a-8b and 9a-9b represents the 2-D Φ-q pattern & 3-D Φ-q-n patterns of Mineral oil, Rice bran oil and Sesame oil respectively. Table-2 shows the PD characteristics at inception under non-uniform fields. From the results it is evident that the inception voltages of rice bran & sesame oil are almost same and it is 30% more than that of mineral oil. Also the phase of PD occurrence is only in negative half cycle indicates the corona discharge due to non-uniform electric field stress. In mineral oil, the PD occurrence is more than that of rice bran and sesame oil.

Figure-10 shows the variation of PD inception voltage of Mineral oil, Rice bran oil and Sesame oil with pressboard under uniform and non-uniform electric field. The inception voltage of all the three oil samples is slightly less than in uniform field because the pressboard surface is completely covered with the plane electrodes.

IV. ELECTRIC FIELD DISTRIBUTION

The Ansys software is used study the electric field distribution in oil/pressboard interface under uniform and non-uniform field stress at the inception of partial discharge activity. Figure 11a, 11b, 12a, 12b and 13a, 13b shows the modeling of test object and electric field distribution for Mineral oil, Rice bran oil and Sesame oil

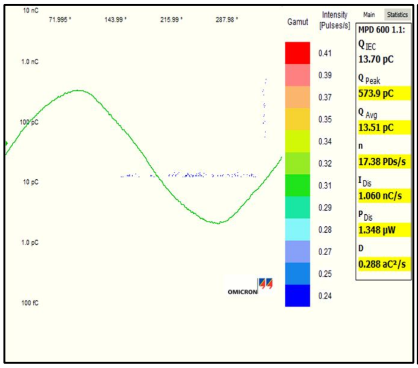


Figure-7a: 2-D Φ-q pattern of Mineral oil

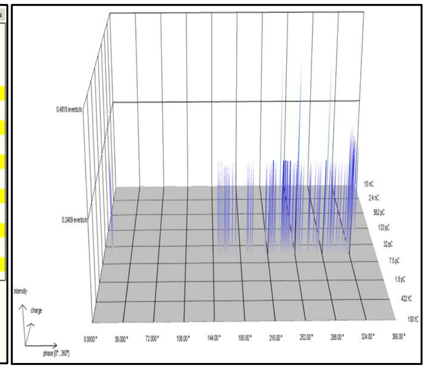


Figure-7b: 3-D Φ-q-n pattern of Mineral oil

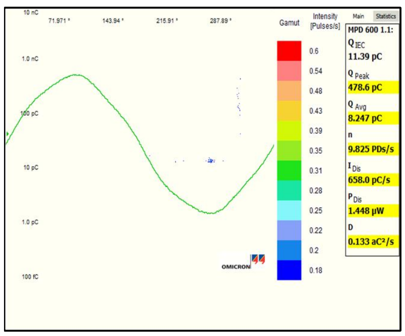


Figure-8a: 2-D Φ-q pattern of Rice bran oil

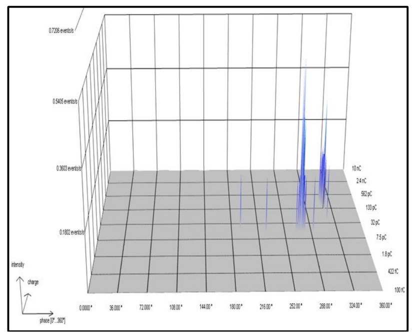


Figure-8b: 3-D Φ-q-n pattern of Rice bran oil

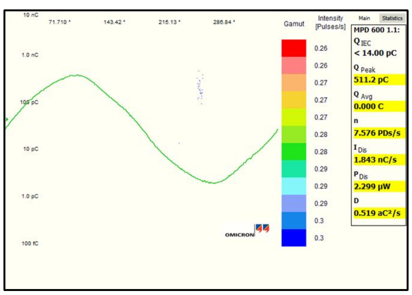


Figure-9a: 2-D Φ-q pattern of Sesame oil

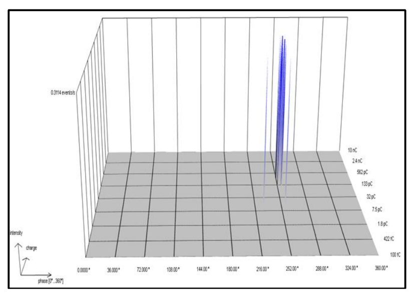


Figure-9b: 3-D Φ-q-n pattern of Sesame oil

TABLE II: PARTIAL DISCHARGE CHARACTERISTICS AT INCEPTION UNDER NON-UNIFORM FIELDS

PD Parameters	Mineral Oil 3mm Pressboard	Rice Bran Oil 3mm Pressboard	Sesame Oil 3mm Pressboard
PDIV in kV	1.04	1.46	1.2
Peak Charge (Q_{Peak})	573.9pC	478.6pC	511.2pC
Number of PD events/sec	17.38	9.825	7.57
Phase angle	140^0-360^0	270^0-300^0	270^0
Discharge current	1.06nC/s	658pC/s	1.84nC/s
Discharge Power	1.348µW	1.448µW	2.29µW

with pressboards under uniform and non-uniform electrode configurations respectively. From the simulated results it is evident that, the electric stress is more at the surface of pressboards in mineral oil under uniform fields whereas in rice bran oil and sesame oil stress is at the edges of pressboard. In non-uniform fields, the stress is more at sharp edge of point electrode & pressboard surface. Since the inception voltage of mineral oil, rice bran and sesame oils are different, the maximum electric stress values shown in simulated results are different.

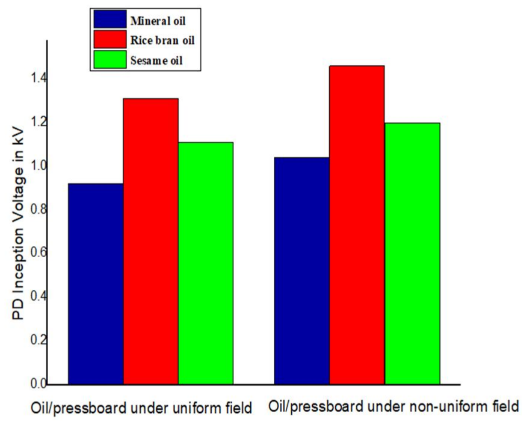


Figure-10: Variation of PDIV

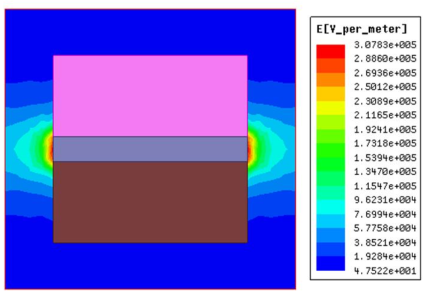


Figure-11a: Field distribution in Mineral oil/ Pressboard under uniform field

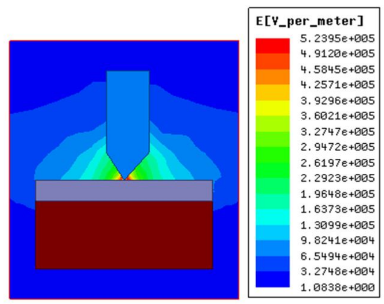


Figure-11b: Field distribution in Mineral oil /Pressboard under non-uniform field

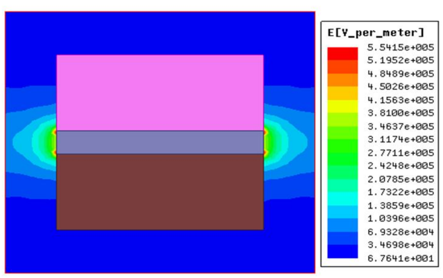


Figure-12a: Field distribution in Rice bran oil/Pressboard under uniform field

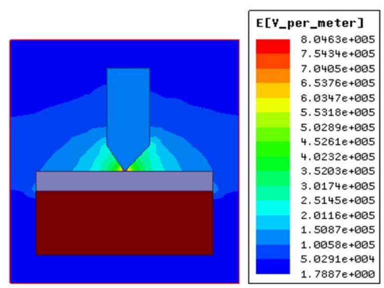


Figure-12b: Field distribution in Rice bran oil/ Pressboard under non-uniform field

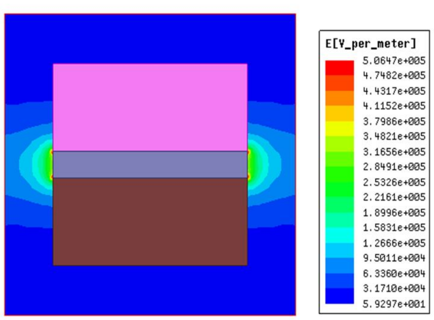


Figure-13a: Field distribution in Sesame oil/ Pressboard under uniform field

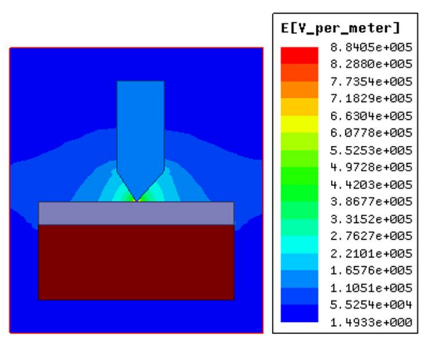


Figure-13b: Field distribution in Sesame oil/Pressboard under non-uniform field

V. CONCLUSION

Mineral oil used as liquid insulation in transformers is non-biodegradable and carcinogenic. Due to environmental concerns, biodegradable oil is increasing being used as replacement for mineral oil in transformers. Therefore it is necessary to compare their PD activity. The PD inception voltage of rice bran and sesame are higher than of mineral oil. For the plane-plane and point- plane testing, peak PD magnitude, number of PD events/sec, discharge power of rice bran and sesame oil are lesser than that of mineral oil. The experimental results show that both selected ecofriendly vegetable oils has the required potential to be used as liquid insulation in transformers.

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