Breakdown Voltage and Resistivity of MO and RBDPO mixture as potential Liquid Insulation at Ambient Temperature of Transformers

M.Y. Yusnida, Ahmad Farid Abidin, Mohd Abdul Talib Mat Yusoh

***Abstract*— The paper presents an investigation based on an experimental work of the dielectric behavior for transformer oil with palm oil at different mixture and temperature. The basic properties of transformers mineral insulating oil should be introduced to have a better understanding of dielectric strength of oil mixture. The author has highlighted oil resistivity and breakdown voltage (BDV) during the experimental work of Deodorized Palm Oil (RBDPO) mixed with transformer oil namely mineral oil (MO) at 40°C to 60°C. Testing was made at 40°C to 60°C according to IEC 156 standard by using AC Modul System circuit of Hivolt Power Diagnostic and MegaOhm 1KV 3005A megger was used to evaluate the resistivity. The highest breakdown strength is achieved 44kv at 80% of RBDPO content. The result of resistivity that was influenced by temperature also presented.**

***Index Terms*— Refined Bleached Deodorized Palm Oil; Mineral Oil; Insulation; Breakdown Voltage; Resistivity**

I. INTRODUCTION

Transformers demand better quality of oil since it is well known operating at high voltages and heavy duty. Although at low voltages, lightly operates, transformer demand for high quality oil is not critical but compulsory [1]. Mineral oils as a part of petroleum source are so demanding in today's world. Transformers use small fraction of the total mineral oil consumption as insulation, yet this fraction is almost not irreplaceable since it was non-renewable source. However, spillage or drainage leakage of this insulation oil could reflect toward environmental problems such as contamination of water supply, air and toxicity of soil[2].·

Palm oil a category of vegetables oil is a biodegradable oil and environmental friendly. Researchers found that palm oil as new alternative insulation for transformer oil[1,2,3]. It was reported that palm oil has excellent breakdown voltage, high flash point and fire point compared to mineral oil at low and medium temperatures[4,5,6,7]. Refined, Bleached and Deodorized Palm Oil (RBDPO) was found that has good potential to be used as transformer insulating fluid[8].

To enhance of previous research, it is essential to investigate and identify the electrical characteristic of the mixture of RBDPO with mineral oil (MO), since MO has been use as good insulating fluid in transformer for many years. Hence, the work which has been conducted in this study are focusing on the investigation on breakdown voltage characteristics of RBDPO with MO mixture at 40˚C to 60˚C and the relation of resistivity factor of RBDPO and MO mixture with the breakdown voltage. The optimum characteristics from the finding is based on the comparing the result with the standard [1, 2, 3, 16].

II. EXPERIMENTAL

The framework to start an experimental lab work is shown in Fig. 1. Samples were prepared as Fig 2. Experimental of breakdown voltge test (Fig 3 & 4) and resistivity test (Fig.5) were conducted at ambient temperatures of transformers (40˚C-60 ˚C) in High Voltage lab. Thus, the data collection of this experiments were repeated until 6 times where it is vital to verify the experimental results..

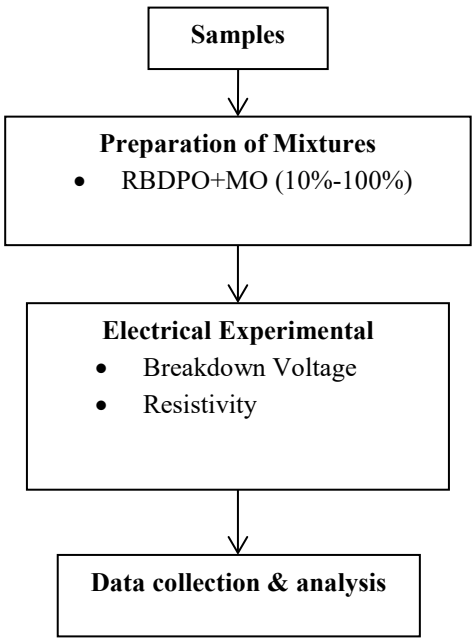

Fig.1 Framework an experimental lab work

This manuscript is submitted on 21st January 2019 and accepted on 2nd April 2019. Yusnida Mohd Yusof is Masters student of Electrical Power Engineering; of Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam Selangor (e-mail: yusnida_tiq@yahoo.com).

Ahmad Farid Abidin is Head of Director, Communities of Research (CoRe), Director of Advanced Computing & Communication Communities of Research, and lecturer for Electrical Power Engineering and Power system of Faculty of Electrical Engineering, Universiti Teknologi MARA 40450 Shah Alam Selangor (Email: ahmad924@salam.uitm.edu.my).

Mohd Abdul Talib Mat Yusoh is with Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia. (Email: mohd.abdul.talib@gmail.com)

A. Samples Preparation

Firstly, the experimental was started with providing the sample, where it is the mixture of RBDPO with MO. RBDPO and MO are mixed from 10 % to 100% ratio. Which is 10% means 10% RBDPO/MO 90%, 100%RBDPO/MO 0% means pure RBDPO without MO . Figure 2 shows the mixture of RBDPO with MO varies from 10 % to 100% mixtures. Each bottle contains 400ml samples .

Fig. 2 Mixture of RBDPO with MO varies from 10% to 100% of RBDPO content

B. Breakdown Voltage Measurement

Figure 3 shows AC Modul System circuit of High volt Power Diagnostic fully semi-automatic breakdown voltage test set is capable of supplying up to 100kV of breakdown voltage test with the diagram at Figure 4. The test cell has a volume capacity of 400ml consists of VDE electrodes with the gap of 2.5mm was rinsed by same samples mixture before filled with the 400ml oil mixture until the electrodes completely dipped .The experiment constructed as electrical diagram in Figure 4. The measurements considered automatically started 5 minutes after start button was pressed from main control panel as Operator Devices BG 5 illustrated in Figure 4. The voltage was rise automatically in the rate of 2kVs-1 until breakdown occurs. The breakdown voltage results were recorded at six measurements per test with 2 minutes gap between consecutive breakdowns. The results were taken in average of six measurements. The experiment was conducted with varied temperature from 40˚C to 60˚C.

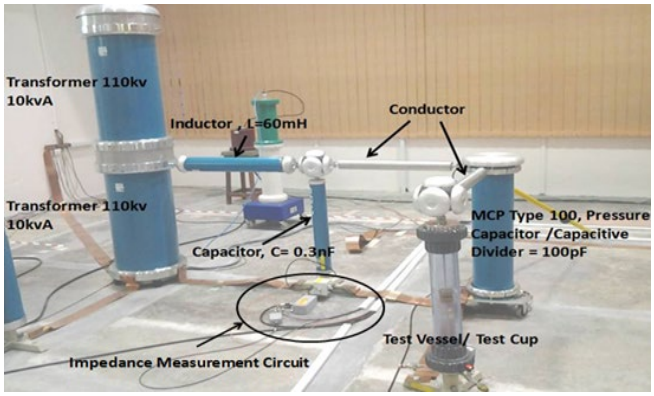

Fig. 3 The AC Modul System circuit of Hivolt Power Diagnostic fully semi-automatic breakdown voltage test set

Figure 3 shows the diagram of test cell with the AC Modul System circuit test set configuration was used to evaluate the breakdown voltage up to 100kV according IEC 156.

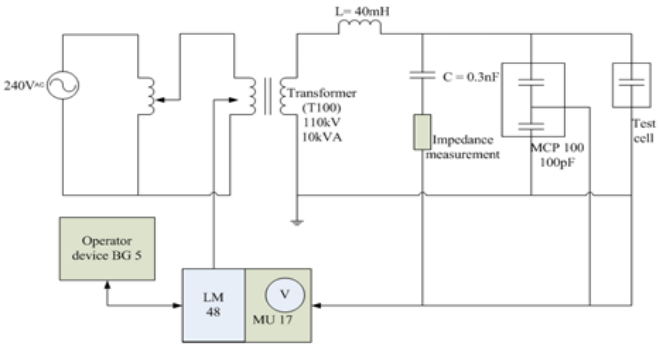

Fig. 4 Diagram of AC Modul System circuit with test-cell configuration

C. Resistivity measurement

Fig. 5 show the MegaOhm 1KV 3005A construct with oil test cell used in this experiment. The test cell has a volume capacity of 400ml, consists of (VDE) electrodes with the gap of 2.5mm was heated with 400ml sample of oil on hot plate for 5 to 10 minutes at the same time stirred thoroughly to ensure the temperature equilibrium in the test cell. The resistivity test of each oil mixture was conducted by apply 1KV injected into the samples average six times under the temperature of 40°C to 60°C .The temperatures were confirmed by Digital Thermocouple.The results appears on the panel were recorded manually.

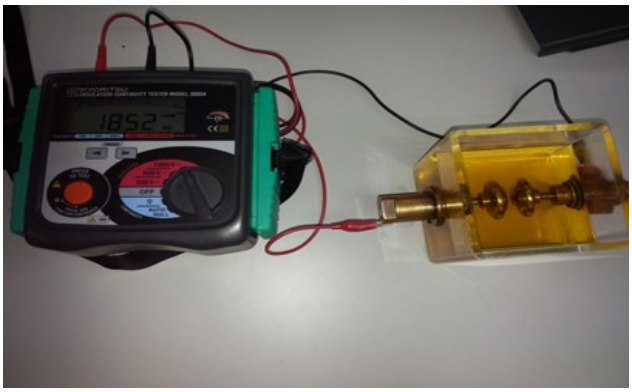

Figure 5: MegaOhm 1KV 3005A with oil test cell

The electrical resistivity ρ (rho) can also be given by equation and can be determined by using the following formula:

$$\rho = \frac{RA}{\lambda} \quad (1)$$

The cross section area of electrode,A is given as follow:

$$A = \lambda W \quad (2)$$

Where λ and W are length and width of electrode, and R is resistance. In this experiment, the gap of electrode is set 2.5mm. Based on the equation (1), the unit of electrical resistivity ρ (rho) is Ωmm.

III. RESULT AND DISCUSSION

A. Breakdown Voltage Characteristic

Figure 6 shows the breakdown voltage dependence on the RBDPO/MO mixture for 40˚C, 50˚C and 60˚C. MO 100% as plotted at 0%-The result depicts that the breakdown voltage abruptly decline at 10% RBDPO, when the MO 70% is mixed with 30% of RBDPO, there is an increasing result at all temperatures. The highest reading of breakdown voltage shows the mixture of 80% RBDPO with 20% MO at (1) 40˚C, (2) 50˚C and (3) 60˚C

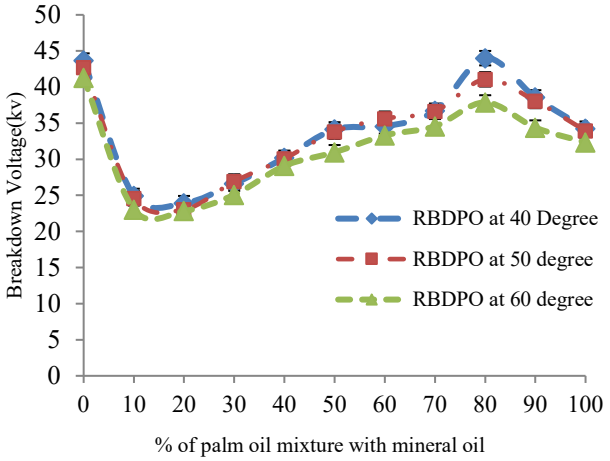

Fig 6. Breakdown (Y-Axis) dependence on percentage of RBDPO with MO mixture (X-Axis) at 40°C, 50°C, and 60°C

The breakdown occurs rapidly might due to moisture, oxidation products and other contaminants [9]. The moisture level of the insulating liquid is depended on the type of insulating liquid, its chemical composition and also its molar weight, means RBDPO's moisture level might be high. However, the higher breakdown strength of the RBDPO with MO mixture fulfilled and maintains the characteristic of the desired properties as insulation oil [10, 11]. At 80% RBDPO with 20% MO mixture, it can be related with suspended particles theory that is stated that slow movement rate of gas bubbles when high voltage injected through electrode and it is completely bridged the gap when achieved maximum strength that cause breakdown when the voltage achieved 44kV. Bridging process of the gas bubble can be explained when electric field is applied, the electrostatic repulsive forces between space charges of the oil molecules become sufficient to overcome the surface tension which produce the gas bubbles according to the suspended particle theory [9]

B. Resistivity Characteristic

Figure 7 shows the resistivity dependence on the RBDPO/MO mixture for 40˚C, 50˚C and 60˚C. Results show the resistivity dependence tends to decrease when the capacity % of RBDPO/MO mixtures are increased from 0% until 100%. It is seen that the resistivity dependence are influenced by capacity of fluid properties..

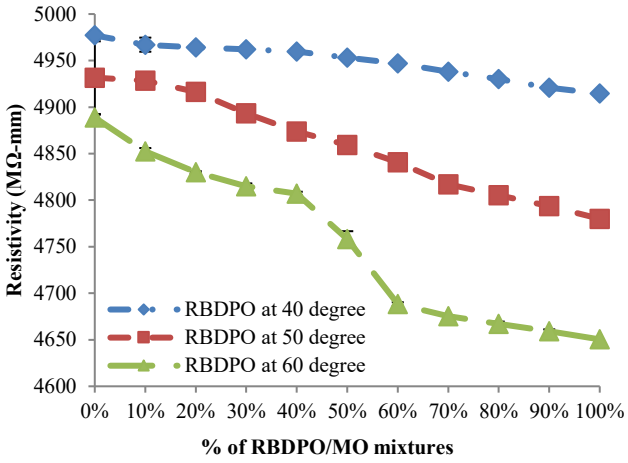

Fig.7. Resistivity dependence on RBDPO with MO mixture (Y-Axis) at temperature 40°C, 50°C, and 60°C (X-Axis)

Furthermore, results also show the RBDPO at 60 degree of temperature are the lowest resistivity value and then followed by the RBDPO at 50 and 40 degree of temparatures. In addtion, the RBDPO at 60 degree tends to decline fastest than RBDPO 50 and 40 degree. Thus, can be concluded that relation of resistivity between viscosity and temperature are related to the heat evaporation that is the energy to separate molecules of substance [15].

Investigations of the electrical resistivity of RBDPO with MO mixtures showed that, its resistivity is affected by temperature, and polar components properties such as water or moisture, fatty acid, and viscosity.[12-14]. Besides, if the temperature of oil increased, the resistivity would decreased logarithmically [15]. Mineral oil has highest resistivity (4977.08M-Ωmm) at 40˚C, lowest resistivity(4888.75MΩ-mm). Thus, it concluded that theresistivity of liquid insulation changes with changing the temperature. This corresponding is happen due to the effect of temperature changes and consequently the dimensions of the conductor in liquid will change as it expands or contracts. So far, MO given highest resistivity at all temperatures.

IV. CONCLUSION

A mixture at 80% RBDPO with 20%MO shows better result compare to others. The experiment of breakdown voltage and resistivity of RBDPO/MO mixture at 40°C to 60°C has been studied The breakdown voltage result shows slightly increased with the increasing percentage of the RBDPO mixture where at 80% RBDPO with 20%MO has achieved the highest breakdown voltage. The breakdown voltage of RBDPO/MO is affected by the temperature of material, density of ratio, chemical bonding of oil, and the viscosity ratio. High viscosity of this mixture ratio causes the increment of resistivity which slowing down the movement rate of gas bubbles to the electrode. All the breakdown voltage of RBDPO/MO was above 30kV which fulfilled the IEC standard while the result of resistivity of RBDPO/MO not achieved requirements as good insulation.

ACKNOWLEDGMENT

The author is deeply indebted to the Universiti Teknologi MARA for financially support this work under MOSTI sciencefund grant scheme

REFERENCES

[1] J R. Lucas, D. C. Abeysundara, C. Weerakoon, K. Perera, K. C. Obadage, and K. A. I. Gunatunga, "Coconut oil Insulated Distribution Transformer," 2001.
[2] T. V. Oommen, "Vegetable oils for liquid-filled transformers," Electrical Insulation Magazine, IEEE, vol. 18, pp. 6-11, 2002.
[3] U. U. Abdullahi, S. M. Bashi, R. Yunus, and H. A. Nurdin, "The potentials of palm oil as a dielectric fluid," 2004, pp. 224-228W.-K.Chen,*LinearNetworksandSystems*.Belmont, CA:Wadsworth, 1993, pp. 123–135.
[4] Kiasatina, K., Kamarol, M., Zulhilmey, M. & Arief, Y. A., "Breakdown characteristics of RBDPO and soybean oil mixture for transformer application", IEEE International Conference on Electrical, Control and Computer Engineering (INECCE), pp. 219-222, 21-22 June 2011,.
[5] Azmi, K., Jamil, M. K. M. & Ahmad, M. A., "Breakdown voltage characteristics of RBD Palm Olein and Envirotemp FR3 mixture under quasi-uniform electric field", *IEEE Colloquium on Humanities, Science and Engineering (CHUSER),* pp.421-424, 5-6 Dec. 2011.
[6] Azmi, K., Jamil, M. K. M. & Ahmad, M. A., "Characteristics of Breakdown Voltage of RBDP Olein and Envirotemp FR3 Mixtures Under AC Voltage". *International Review on Modelling and Simulations (IREMOS),* 5(2), 1107-1114, 2012
[7] T. Kanoh, H. Iwabuchi, Y. Hoshida, J. Yamada, T. Hikosaka, A. Yamazaki, Y. Hatta, and H. Koide, "Analyses of electro-chemical characteristics of Palm Fatty Acid Esters as insulating oil,", pp. 1-4,2008
[8] Rajab and S. Aminuddin, "Properties of RBDPO Oleum as a candidate of palm based-transformer insulating liquid,", pp. 548-552, 2009
[9] M. S. Naidu and V. Kamaraju, High voltage engineering: Tata McGraw-Hill Education, 2004.
[10] P. Boss and T. V. Oommen, "New insulating fluids for transformers based on biodegradable high oleic vegetable oil and ester fluid," 1999, pp. 7/1-710.
[11] H. Borsi, "Dielectric behavior of silicone and ester values fluids for use in distribution transformers," Electrical Insulation, IEEE Transactions on, vol. 26, pp. 755-762, 1991
[12] Tekin, A., and E.G. Hammond, Factors Affecting the Electrical Resistivity of Soybean Oil, *J. Am. Oil Chem. Soc*. *75*:737–740 (1998).
[13] Tagg, H.F., *The Practical Measurement of Insulation Resistance*, Newnes Books, Feltham, England, 1968, pp. 17–35.
[14] Lipscomb, T.G., II, Mineral Insulating Oil Manufacture and Safekeeping, in *Electrical Insulating Oils,* STP 998, edited by H.G.Erdman, American Society for Testing and Materials, Philadelphia,1988, pp. 5–24.
[15] Tekin, Aziz, and Earl G. Hammond. "Factors affecting the electrical resistivity of soybean oil methyl ester." *Journal of the American Oil Chemists' Society* 77.3 (2000): 281-283.
[16] British Standard (1979). Method for the Measurement of Relative Permittivity, Dielectric Dissipation Factor and DC Resistivity of Insulatin
[17] g Liquids. BS 5737

Yusnida Mohd Yusof was born in Malaysia, on Jan 13 1983. She received his Bachelor of Engineering in Electrical, from Universiti Kuala Lumpur (UNIKL-BMI). She is currently a student Masters of Electrical Power Engineering; Faculty of Electrical Engineering, Universiti Teknologi MARA. Her main research interest are in Electrical Power and Nano Technology.

Ahmad Farid Abidin was born in Malaysia, on Dec 25, 1978. He received his Bachelor of Engineering in Electrical, Electronic, and System Engineering from Universiti Kebangsaan Malaysia (UKM), M. Sc in Electrical Engineering from Universiti Teknologi MARA (UiTM), and Ph.D degree from Universiti Kebangsaan Malaysia (UKM), in 2000, 2005, and 2011, respectively. He is currently a lecturer and Head of Director, Communities of Research (CoRe), Director of Advanced Computing & Communication Communities of Research, and lecturer for Electrical Power Engineering and Power system of Faculty of Electrical Engineering. His main research interests are in power quality andpower system protection.

Mohd Abdul Talib Mat Yusoh was born in Malaysia, on August 24, 1988. He received Bachelor of electrical Engineering (Hons.) and Master of Electrical Engineering from Universiti Tun Hussein Onn Malaysia, (UTHM) in 2009 and 2012 respectively.He is currently enrolled as a PhD student at Universiti Teknologi MARA, (UiTM).