Study of Breakdown Voltage Characteristic of Blended-Insulating Oil: Mineral-Palm Fatty Acid Ester Oil

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ABSTRACT – Considering the environmental risk and lack of source of petroleum-based material in future, blended-insulating oil were introduced as an innovative approach to reduce and improve the performance of mineral insulating (MI) oils. In this study, the blended-insulating oils were prepared by mixing the MI oils and natural ester insulating (NEI) oils with aim to determine the optimum ratio of blended-insulating oil without reducing too much quantity of MI oils. The ratio of palm fatty acid ester (PFAE) oils were varied from 0 % to 50 % mixture with MI oils. The effect of ester-based contents were observed and analysed based on the AC breakdown voltage. The results show that the optimum ratio of blended-insulating oils that yields the highest AC breakdown voltage oil is 80 % MI oil and 20 % of PFAE oils.

1. INTRODUCTION

The ever-growing demand for electrical power today could lead to the shortage of petroleum-based material. Petroleum-based mineral insulating (MI) oils have been used as HV application insulation for over a century owing to its low price, low viscosity, good aging behaviour and ability to transfer heat [1]. However, for the future, researchers try to develop other alternative insulating oils to replace the MI oils due to its environmental issue and lack of crude materials.

Natural ester insulating (NEI) oil is an insulating oil that can fulfil that requirement since it is derived from renewable and sustainable source such as palm, rapeseed, sunflower and etc. This biodegradable insulating oil offers good fire safety, higher water solubility and can retard thermal aging progress [2]. However, NEI oils still facing low demand from industry due to its poor oxidation stability, higher pour point, viscosity level and costly price [2]. Blending of NEI oil with MI oil is observed as an innovative approach by considering the advantage and disadvantage of both insulating oil. Previous studies [3] have mentioned that blending of 10-25 % of synthetic ester-based oil with MI oil has improved the breakdown voltage and performance of MI oil but studies on blended NEI with MI oil is still lacking.

Therefore, in this study, the blended-insulating oils were prepared by blending the MI oil with NEI oil in order to obtain the best compromise. The amount of NEI to be blended with MI oil was varied from 0 % to 50 % with aim to determine the optimum ratio of blended-insulating oil without reducing too much quantity of MI oil. This is to enhance the properties of blended oil by taking into the pros and cons of both types of oils. Hotplate magnetic stirrer with stirring speed and temperature setting of 550 rpm and 90 °C was used as the method to mixture. The breakdown voltages of MI oil, NEI oil and blended of MI with PFAE oil are present in this work.

2. THE EXPERIMENT

A. Sample Preparation

In this work, blended-insulating oils were produced by mixing the MI (Nytro Libra) with NEI (Palm Fatty Acid Ester) at volume ratio of 0 % to 50 %. For pre-processing, the insulating liquid samples were firstly filtered through a quantitative filter paper (pore size: 0.02 μm) before the mixing process. The mixing process was conducted at stirring speed and temperature setting of 550rpm and 90°C [4] by using hot plate magnetic stirrer to ensure both insulation oils are well blended. 1 hour duration time was set to complete the mixing process. Each oil sample was prepared with total volume of 500 ml. After both insulation oils were well mixed, the samples were then left rest in bottles for at least 24 hours in room temperature before experiment is conducted. This purpose to observe the visual change of blended oil colour and miscibility level of oil sample after being blended together. The moisture contents of oil samples were measured before and after the mixture process before testing were conducted.

B. Breakdown Voltage

Breakdown voltage of insulating oil was measured in order to observe the oil samples ability to withstand electric stress without failure. Figure 1 shows the semi-sphere electrode configuration with gap distance of 1.0 mm. The AC breakdown voltage of the samples were measured using Megger OTS60PB portable oil test set which compiles with the ASTM D1816 standard test method. The breakdown voltage was recorded for 30 data for analysis purposes as well as for repeatability in obtaining the results.

Figure 1 Electrode configuration for breakdown test.

3. RESULTS AND DISCUSSION

The bar chart in Figure 2 summarizes the average breakdown voltage of oil samples. It is seen that the increase of PFAE ratio in the mixture yield to the lower breakdown voltage of MI-PFAE blend oil starting when the MI oils is mixed with 30% of PFAE. The breakdown voltage at ratio of 10% PFAE shows a decrease pattern when compared with the other ratio of blended oils. This might be due to the amount of PFAE and MI oil that does not enough to assist each other which makes this ratio of blended becomes the worst among others.

For commercial insulating oil, 100% PFAE shows more excellent dielectric strength with 32.47 kV compared to MI oil. The ratio of 80% MI/20% PFAE oil has shown the highest breakdown voltage with 33.57kV an increase of 22.52% the performance of MI oil alone (27.4kV). This enhancement may happen due to the excellent properties of ester-based oil which has better water solubility compared to MI oil, thus able to absorb moisture or water resident in the MI oils [3]. It is interesting to note that by adding 20 % of ester-based contents of PFAE oil can improve the dielectric strength of MI oils alone by considering the advantage and disadvantage of MI and NEI as dielectric.

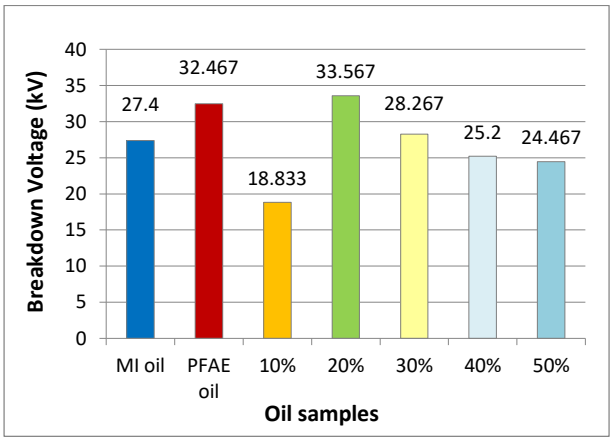

Figure 2 Average breakdown voltage ester contents.

4. CONCLUSION

Based on the experiment results, it can be concluded that the properties of mixture between MI oil and PFAE oil is significantly affected by the ester-based oil contents. The ratio of both insulating oil are very important in preparing the blended-insulating oil. Throughout the mixture process conducted in this study, the ratio of 80%MI/20%PFAE oil represents the best compromise of the blended-insulating oil between MI oil and NEI oil in which this ratio enable to enhance the breakdown voltage of both insulating oils. Thus, it fulfils the objective of this study, which is to produce the best ratio of the blended-insulating oil without reducing too much quantity of MI oil. This shows that blended-insulating oil can be capable as MI oil for transformer insulating oil.

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