Study of Dielectric Strength on a Blends of Mineral and Natural Ester Insulating Oil

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ABSTRACT: Up to now, the most common insulating oil used in oil-immersed transformers is mineral insulating (MI) oil, which is derived from petroleum. MI oils are not only non-renewable, but they are also non-biodegradable, where these oils are harmful to the environment in cases of oil spillage. Therefore, the aim of this study is to investigate the potential of mixing MI oil with natural ester insulating (NEI) oil in order to reduce the high dependency on MI oil for transformer applications. The MI and NEI oils were mixed with different mixing ratios. Dielectric strength was studied on the MI-NEI oil blends by using AC breakdown voltage test method which complied to ASTM D1816 standard. From the results, it is found that the following mixing ratios (70% of MI oil + 30% of NEI oil, 80% of MI oil + 20% of NEI oil) result in significant improvement in terms of the AC breakdown voltage compared with unused MI oil.

Keywords: *Mineral insulating oil, Natural Ester oil, Blend.*

1. INTRODUCTION

In the transmission and distribution system, the transformer plays a crucial role in maintaining a reliable and efficient supply of electricity. The transformer is the most crucial piece of equipment for high voltage equipment. The liquid used to fill electric transformers is both an electric insulator and a medium for cooling. Mineral insulating oil is usually one of the liquid insulations commonly used in transformers with high voltage due to inexpensive costs and outstanding features, including low dielectric loss, high electric field strength and long-term performance. However, mineral insulating oil has a limited shelf life when it comes to the environmental impact. The first is mineral insulating oil, which is notorious for being non-biodegradable and damaging soil and water in case of severe oil discharge. Consequently, mineral insulating oil is also non-renewable because petroleum is not renewable [1]. Therefore, since the mid-1990s, various researchers have been rapidly developing a totally biodegradable insulating liquid [2].

Natural ester insulating (NEI) oil has more advantages than mineral insulating (MI) oil in terms of fire protection, environmental friendliness, and ageing. NEI is non-toxic, biodegradable and less ignitable, making it better suited for use in insulation systems for transformers. [1, 3]. Malaysia is famous for its palm plantations, and the use of palm oil is diverse. Many researchers [4] are studying the feasibility of using palm oil as an alternate basis for transforming oil. Palm oil has various advantages, including maximum cooling stability and great oxidation stability. It has the potential to be utilised instead of mineral insulating oil because of the greater dielectric properties of palm oil. Since 2006, Palm Fatty Acid Ester (PFAE) has been developed by Lion Corporation as an insulating oil transformer. PFAE is an outstanding high voltage transformer isolator which is favourable to the environment [4,5].

In recent years, research has attracted the curiosity of numerous researchers towards mixed insulating oils comprising mineral insulating oil and natural ester oil. Fofana [6] proposes to combine its dielectric, flash point and thermal qualities in order to improve the insulating oil's stability. In addition to the reduction of the cost of transformers, mixed insulation oils consisting of mineral and ester oils have been shown to show higher thermal performance in terms of increase oxidation stability. As researchers have gained popularity in the production of mixed insulating oil, reports indicated that the best ratio of mixed insulating oil is 80 percent mineral insulating oil and 20 percent ester oil [7]. Therefore, in this article an attempt to determine the best mixing ratio for mineral and natural ester insulating (palm oil-based) oil blends is presented. The dielectric strength for the whole samples were measured by using AC breakdown voltage test method.

2. EXPERIMENTAL DESIGN

This project is divided into several stages, beginning with the selection of mineral insulating (MI) oil and natural ester insulating (NEI) oil and finally testing and analysis of the results. The MI oil used in this experiment is Nytro Libra from Nynas, and the NEI oil used is Palm Fatty Acid Ester oil from the Lion Corporation, Japan. Firstly, the MI and NEI oils are pre-processed to ensure that their properties are normalized prior to being used in the entire experiment. Eleven MI-NEI oil blends were prepared, each with a different composition, as listed in Table 1. The AC breakdown voltage (BdV) test was conducted on the MI and NEI oil samples using the Megger OTS60PB portable oil tester, which complies with the ASTM D1816 standard. Verband der Elektrotechnik (VDE) electrodes (Shape A) were chosen and the gap between the electrodes was set at 1 mm.

Table 1. Mixing ratios of the MI-NEI oil blends

Sample no.	Composition (by volume)
1	100% of MI oil
2	**90% of MI oil + 10% of NEI oil**
3	**80% of MI oil + 20% of NEI oil**
4	**70% of MI oil + 30% of NEI oil**
5	**60% of MI oil + 40% of NEI oil**
6	**50% of MI oil + 50% of NEI oil**
7	40% of MI oil + 60% of NEI oil
8	30% of MI oil + 70% of NEI oil
9	20% of MI oil + 80% of NEI oil
10	10% of MI oil + 90% of NEI oil
11	100% of NEI oil

3. RESULTS AND DISCUSSION

The AC BdV was used as the parameter to determine the best mixing ratio for the oil blends prepared in this study. Figure 1 shows the AC BdV of the oil blends. It can be seen that the mean AC BdV for Sample 1 (unused MI oil) is 24 kV. In contrast, Sample 11 (unused NEI oil) has a significantly higher AC BdV, with a mean of 34 kV. In general, both oils surpass the requirement stipulated in the ASTM D3487 and ASTM D6871 standards. Based on the test results, Sample 4 (30% of MI oil + 70% of NEI oil) has the highest AC BdV (34 kV) compared with all the oil blends tested in this study. In contrast, Sample 2 (90% of MI oil + 10% of NEI oil) has the lowest AC BdV (19 kV) among the oil blends. The results can be attributed to the higher water solubility of the NEI oil, which improves the AC BdV when NEI oil is mixed with MI oil. However, the focus of this study is to determine the best mixing ratio for the MI-NEI oil blends without significantly reducing the quantity of the MI oil. Thus, the following mixing ratio (50% of MI oil + 50% of NEI oil) was chosen as the reference. Samples 7–10 were not considered because they contained more than 50% of NEI oil. It can be observed that the mixing ratio for Sample 4 (70% of MI oil + 30% of NEI oil) and Sample 3 (80% of MI oil + 20% of NEI oil) have produced the highest AC BdV output for about 28 kV.

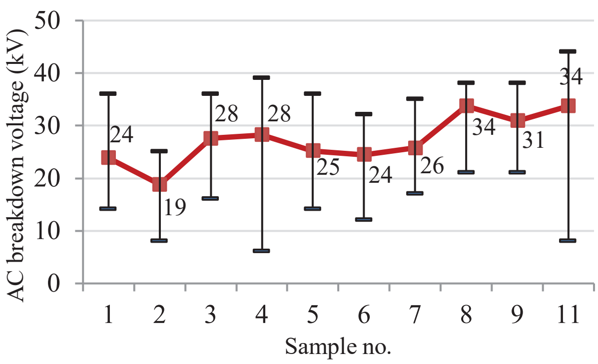

Figure 1. Breakdown voltage of differences ratio of concentration of mixed insulating oil

4. CONCLUSION

Based on the results, in terms of the AC BdV, Sample 4 (70% of MI oil + 30% of NEI oil) and Sample 3 (80% of MI oil + 20% of NEI oil) were found to be the best MI-NEI oil blends.

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REFERENCES

[1] R. Liao, J. Hao, G. Chen, Z. Ma, and L. Yang, "A Comparative Study of Physicochemical, Dielectric and Thermal Properties of Pressboard Insulation Impregnated with Natural Ester and Mineral insulating oil," IEEE Trans. Dielectr. Electr. Insul., vol. 18, no. 5, pp. 1626–1637, 2011.

[2] N. S. Murad, N. A. Muhamad, A. A. Suleiman, and N. A. M. Jamail, "A study on Palm Oil-Based Oil Moisture Absorption Level and Voltage Breakdown," in Annual Report - Conference on Electrical Insulation and Dielectric Phenomena, CEIDP, 2013, pp. 925–928.

[3] D. Martin and Z. D. Wang, "Statistical Analysis of the AC Breakdown Boltages of Ester Based Transformer Oils," IEEE Trans. Dielectr. Electr. Insul., vol. 15, no. 4, pp. 1044–1050, 2008.

[4] M. S. Mohamad, H. Zainuddin, S. Ab Ghani, and I. S. Chairul, "Comparative Study on the AC Breakdown Voltage of Palm Fatty Acid Ester Insulation Oils Mixed With Iron Oxide Nanoparticles," Int. J. Electr. Comput. Eng., vol. 6, no. 4, p. 1481, 2016.

[5] S. Ab Ghani, N. A. Muhamad, I. S. Chairul, and N. Jamri, "A Study of Moisture Effects on the Breakdown Voltage and Spectral Characteristics of Mineral and Palm Oil-Based Insulation Oils," ARPN J. Eng. Appl. Sci., vol. 11, no. 8, pp. 5012–5020, 2016.

[6] I. Fofana, "50 Years in the Development of Insulating Liquids," IEEE Electrical Insulation Magazine, vol. 29, no. 5, pp. 13–25, 2013.

[7] U. M. Rao, Y. R. Sood, and R. K. Jarial, "Oxidation stability enhancement of a blend of mineral and synthetic ester oils," *IEEE Electrical Insulation Magazine*, vol. 32, no. 2, 2016, doi: 10.1109/MEI.2016.7414230.