Influence of Moisture Content on Conductivity of Synthetic Ester

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***Abstract*-- Synthetic ester is gaining popularity as an eco-friendly replacement for mineral oil in power transformers. Hence, there is a necessity to adopt or develop techniques to monitor the condition of ester-based insulating liquids. Conductivity is one of the commonly used oil-quality indicators due to its sensitivity to contaminations in the liquid. This paper studies the conductivity of a synthetic ester and the impact of moisture content as the external influence factor. In general, the conductivity of the synthetic ester was higher than conventional mineral oil. Conductivity in ester increased with the moisture content in two different stages. At low moisture content up to about 400 ppm, the conductivity increase was much smaller compared to the conductivity increase above 400 ppm, which could be related to the microscopic state of water clusters in the ester.**

BACKGROUND & TEST SYSTEM DEVELOPMENT

Last few decades the global market has witnessed a rapid growth in the number of ester-based insulating liquid-filled transformers due to their environmentally friendly nature and better fire safety features compared to mineral oil. Ester liquids have been widely applied in distribution transformers, and in recent years there has been a rise in the number of transmission transformers built with esters.

Compared to mineral oil, developments in the condition assessment of synthetic ester are still in their infancy. Synthetic ester has a different molecular structure from that of mineral oil. Hence, some of its dielectric properties and behaviour differ from mineral oil. Therefore, the condition assessment criteria for mineral oil cannot be applied directly to synthetic ester without experimental verification and validation.

Conductivity is commonly used to assess the quality of insulating liquids because it is highly sensitive to impurities such as ionic impurities and moisture. Hence, the moisture content is usually recognized to be the influence factor affecting the conductivity of insulating liquids. An increasing oil conductivity could be found with moisture content due to the increased density of charge carriers from the dissociation of water molecules.

In this paper, the commercially available synthetic ester, MIDEL 7131 was selected for the study. Test cell, circuit, and sample preparation were followed by IEC 60247 [1]. A sample from the preprocessed oil was injected with deionised water to obtain synthetic ester saturated with water. The moisture content of the saturated liquid sample was ~3200 ppm. Ester liquid samples with intermediate moisture content between 100 and 3200 ppm were prepared by mixing dried liquid with saturated liquid in different ratios.

As shown in Fig.1, there are two distinct trends, one at moisture content below 400 ppm and the other at above 400 ppm. This phenomenon could be linked to the status of water molecules in the insulating liquid. At low moisture content levels, most of the water molecules in ester liquids are in the form of bound water which is physically bounded to the insulating liquid molecules. Synthetic esters have functional groups such as hydroxyl and carbonyl groups, those which can form hydrogen bonds with water. The initially bound water mainly consists of monomolecular water and the physical bound prevents water from dissociating into ions.

With further increase in the moisture content, the bound water accumulates resulting in the formation of water clusters. Such water clusters may have weakly bounded water molecules that could dissociate into hydrogen and hydroxide ions. This could rapidly increase the density of charge carriers in synthetic ester at high moisture content levels.

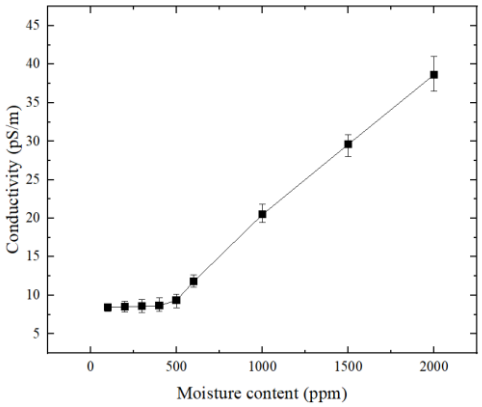

Fig. 1 Moisture effect on ester conductivity

CONCLUSION

This paper studies the impact of moisture content on the conductivity of a synthetic ester liquid. Synthetic ester in general showed a higher conductivity than typical mineral oils. The conductivity of the ester increased with the moisture content, and two development stages were discovered at around 400 ppm, this could be linked to the microscopic states of water content in the ester.

REFERENCES

[1] R. Yu, S.Y. Matharage, S.H. Shen, and Z.D. Wang, "Influence of Temperature and Moisture Content on Conductivity of Synthetic Ester," in 9th International Conference on Condition Monitoring and Diagnosis (CMD), 13-18. Nov. Kitakyushu, Japan, pp. 163-166, 2022