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Dielectric response change of pressboard immersed with mineral oil after replacing insulating liquid with synthetic ester

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Abstract The manufacturer of synthetic ester claims that replacing mineral oil with his product does not affect the work of the unit. Despite assurances, this information should be treated cautiously. Insulating liquid replacement, i.e. substitution of oil with ester, and especially intermediate stages of this process can cause problems while evaluating solid insulation moisture of the transformer done by means of the most commonly applied FDS indirect method. The article presents results of model investigations of the dielectric response of pressboard samples immersed with mineral oil, which was replaced with synthetic ester afterwards.

1. Introduction

One of the most important parameters of cellulose insulation of power transformers is its moisture. Moisture increase of insulation causes (among others) decrease of electric strength, initiation or intensification of partial discharges and increase of the risk of the bubble effect [1]. The most accurate and most reliable evaluation method of insulation moisture is the laboratory method of titration (Karl Fischer Titration, KFT). Unfortunately, it requires taking samples of transformer insulation, which most often is not possible. This is the reason why insulation moisture of these devices is evaluated by polarization methods. These include: dielectric spectroscopy in the frequency domain (FDS) [2], dielectric spectroscopy in the time domain (RVM) [3], and the measurement of polarization and depolarization current (PDC) [4].

In Poland evaluation of the transformer's solid insulation moisture is most often carried out using the method of dielectric spectroscopy in the frequency domain. It consists of the measurement of capacity C', C" or dielectric losses tg δ in the frequency range from 10⁻⁴ to 10³ Hz. The measurement results are matched with already possessed pattern characteristics of the dielectric response of model samples, of a known temperature and moisture. When the dielectric response of the model is the same as of the investigated object, it is assumed that their moisture is the same. The FDS method is based on the so-called XY model of insulation (Fig. 1) and a set of pattern characteristics obtained from samples of known cellulose parameters and a dielectric liquid by which it is immersed [5]. The accuracy of the determined insulation moisture depends on a number and quality of possessed moisture patterns.



Figure 1. Model XY of the transformer's insulation.

2. Research target

A manufacturer of one of synthetic esters claims that mineral oil can be replaced by their product without any harm to the transformer. Although cases of such an operation are already known, we should, however, analyse a number of effects accompanying the liquid replacement. Both the electroinsulating liquids have different properties, which generates many questions, especially for transformer designers, and to which we do not have a full answer. The measurement reconnaissance done by the author concerned dynamics of replacing mineral oil with synthetic ester process. This evaluation was based on dielectric spectroscopy in the frequency domain.

3. Research object

The research object was a pressboard sample of the moisture of 4.07% and density of 1.2g/cm³. This sample was initially immersed with mineral oil and next conditioned in a climatic chamber for three days. Moreover, both mineral oil and synthetic ester were used in the experiments. The synthetic ester used for the research was initially dried by covering with it paper rolls which had been dried in a vacuum chamber.

4. Research procedure

The investigated pressboard sample was placed between electrodes in a tight vessel filled with electroinsulating liquid (Fig. 2). This vessel was put in a thermal chamber at the constant temperature of 30°C during the whole period of the investigation (47 days). Between further FDS measurements, the electrodes were moved apart from each other in order to allow easier replacing mineral oil with synthetic ester inside the pressboard sample.





The experiment was carried out according to the following procedure:

- preparation of the pressboard samples and insulating liquids,
- conditioning the samples immersed in oil 3 days,
- determining the moisture of the pressboard sample using the KFT method,
- placing the pressboard sample at the research set-up,

- investigating the dielectric response of the pressboard immersed in mineral oil (according to the scheme of the measurement system presented in Figure 3),
- replacing mineral oil in vessel with synthetic ester,
- investigating the dielectric response of the sample repeatedly for a few days.



Figure 3. Measurement set-up.

5. Research results

Figure 4 presents obtained characteristics of the dielectric response (ε ' i ε ") of the insulating system of pressboard and liquid dielectric. These curves were generated on the basis of measurement results and just after changing the insulating liquid from mineral oil to synthetic ester.



Figure 4. The characteristics of ε ' and ε " pressboard immersed in oil (1) and immediately after changing the oil on synthetic ester (2).

We can see in the graphs that the dielectric response of the pressboard-mineral oil insulating system differs very slightly from the dielectric response of the pressboard-synthetic ester insulating system. It is natural because the synthetic ester had not been able to displace the mineral oil from the pressboard sample in a short time. Noticeable discrepancies in the research results occur only in the range of frequencies from 0.001 to 0.01 Hz, which should be interpreted as a result of the pressboard drying effect by the synthetic ester. Figures 5 and 6 contain graphs of the dielectric response of the paper-

synthetic ester insulating system as a function of time which passed from the moment of replacing mineral oil with synthetic ester. We can see in them a successive change of the curves: from a characteristic typical for the pressboard-mineral oil insulating system to a characteristic for the pressboard-synthetic ester insulating system. It results from the figures that after 47 days a full replacement of the dielectric liquid in pressboard still was not obtained. It should be noted, however, that obtaining a model dielectric response of the pressboard-synthetic ester insulating system is practically impossible because there is always a certain residual amount of mineral oil in the measurement vessel.



Figure 5. Characteristics ε' as a function of frequency for different times from the moment of replacing mineral oil with synthetic ester.



Figure 6. Characteristics ε " as a function of frequency for different times from the moment of replacing mineral oil with synthetic ester.

6. Conclusions

After replacing mineral oil with synthetic ester, characteristics of the dielectric response of the pressboard-dielectric liquid insulating system, taken at intervals, successively shift from a pattern characteristic of the cellulose-mineral oil type to a pattern characteristic of the cellulose-synthetic ester type. Replacing mineral oil with synthetic ester in pressboard is a long-lasting process: after 47 days, complete replacement of mineral oil with synthetic ester was not observed in the investigated sample. A reliable moisture assessment of the cellulose-synthetic ester insulating system after replacing mineral oil with synthetic ester (using the FDS method) is possible either right after the liquid replacement or after a few tens of days.

It should be also included in the further research on results of replacing mineral oil with synthetic ester that there is an effect of cellulose drying by synthetic ester, known from the literature.

7. References

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