СРЕДСТВА ИЗМЕРЕНИЙ

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MEASUREMENT STAND FOR STUDY PROPERTIES OF ISOLATION MATERIALS USING POLARIZATION METHOD

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The article presents measurement stand, which is used to measure polarization and depolarization currents, using PDC method, in wet transformer oil-impregnated cellulose isolation. Maximum resolution of measured currents reaches 10^{-15} A. The accuracy of thermal stabilization, in three-electrode capacitor system, comes to 0,001 °C.

Keywords: isolation material, polarization method, polarization current.

Introduction

Moisture of oil-impregnated cellulose insulation, used in constructions of electrotechnical devices, is one of the main factors affecting the lifetime of electrotechnical machines which use it. The analysis of moisture content in individual parts of energy devices proves, that the main place where molecules of water are accumulating, is oil impregnated transformer paper or pressboard isolation. Compared to transformer oil, wherein water molecules are sparingly soluble, moisture content, solid isolation made of cellulose is 1000 times bigger. Furthermore, according to standards used in the USA, it is assumed that increase of dampness above 2,5 % leads to rapid growth of isolation degradation.

A lot of transformers, especially those which are used in Eastern Europe, for economic reasons, are exploited much longer than it designers predictions would assume. The result of this behavior is possibility to failure occurrence, which direct cause is the loss of insulation properties of the high moisture material. The obvious conclusion, to be drawn in the face of the presented statements, is the need to seek non-invasive and unequivocal measurement method that allows estimation of moisture level of paper-oil isolation [1].

Measurement method

Among the methods used to determine the cellulose moistening, we distinguish two main divisions: methods based on measurements performed by applying the alternating or direct voltage. In the case of alternating voltage, the most common method is dielectric spectroscopy in the frequency domain (FDS) [2]. In the domain of direct voltages the most common methods are recovery voltage method and the polarization and depolarization currents method (PDC) [3].

The objective of our research is to analyze the polarization and depolarization currents by PDC method, occurring in specifically prepared samples of electrical pressboard.

The basic model showing the electrical properties of the solid isolation presupposes the existence of two parallel elements such as capacitance and resistance. The correctness of the assumed model confirms the hypothetical results of measurements by PDC method (Figure 1), which course can be divided into two main stages.

In the first stage constant voltage is applied to sample. The main component of the current flowing initially is a capacitive component, resulting from the charging of the capacitor. Then,

due to the charging of the capacitor ends, the current flowing through the sample stabilizes. This current determines the resistive component, which has been included in the model.

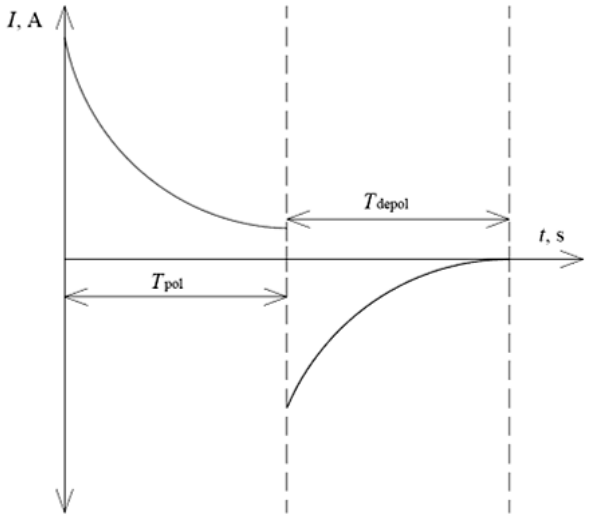

Figure 1 – Sequence of measurement of polarization and depolarization currents by PDC method

After complete stabilization of the polarization current, the second stage of measurement begins, in which the measuring capacitor is disconnected from the power source and short circuited through ampere-meter. Current flowing through the sample is the result of a discharge capacity in the model. Finally, the measurement is terminated when the current flow through the sample decays, that is when capacity is totally discharged.

Measurement stand

The scheme of the measurement stand presents Figure 2. For measuring the polarization and depolarization currents the measuring capacitor was made of a flat three electrode arrangement of electrodes (Figure 3).

In order to stabilize temperature during the measurement we used thermostatic oil chamber, characterized by stabilization of temperature with accuracy of 0,001 °C.

As a source of voltage and ampere meter Keithley 6517B meter was used. It allows to measure currents from 20 mA (resolution of 100 nA) to 20 pA (resolution of 100 fA). Keithley 6517B meter has adjustable voltage source which ranges from minus 1000 to 1000 V. The resolution is 0,001 V for voltages in the range – minus 100 to 100 V, and 0,01 V for the higher voltage ranges.

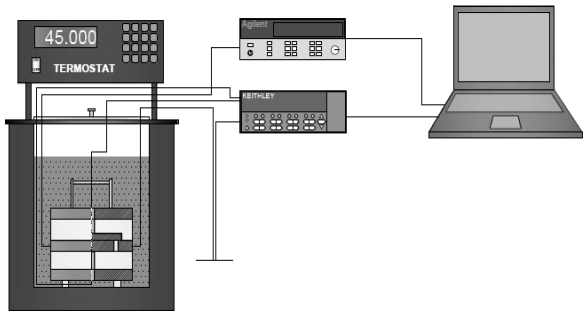

Figure 2 – Scheme of the measurement stand

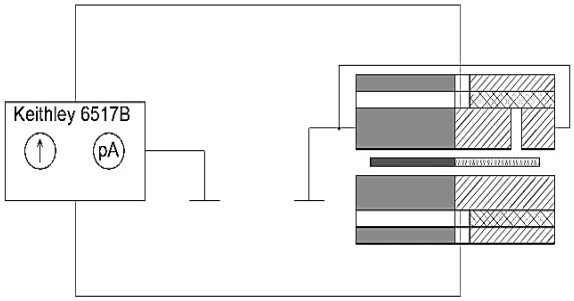

Figure 3 – Wiring of measuring electrodes

To measure the sample temperature Agilent 34970A multichannel recorder with PT1000 sensor was used. In order to monitor the measurement an application for a PC was created, enabling, among other things, remote devices control, measurements and parameterization of their registration.

During test measurements, carried out in order to calibrate the measuring stand, we noticed inconsistency with the expected (Figure 1) polarization current readings, which were characterized by an increase of value after earlier apparent stabilization. The analysis of the recorded data showed a significant effect of measuring capacitor temperature on measured currents values (Figure 4). In order to eliminate the influence of unstable temperature of the measuring system on the measuring results, the analysis of the temperature distribution inside of the measuring capacitor, in time was performed (Figure 5).

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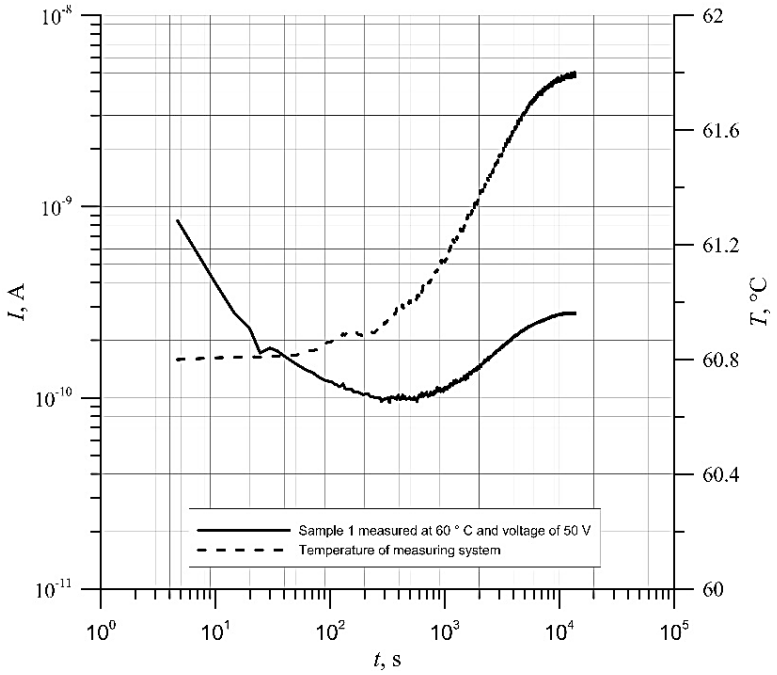

Figure 4 – Polarization current waveform with respect to the temperature measuring system

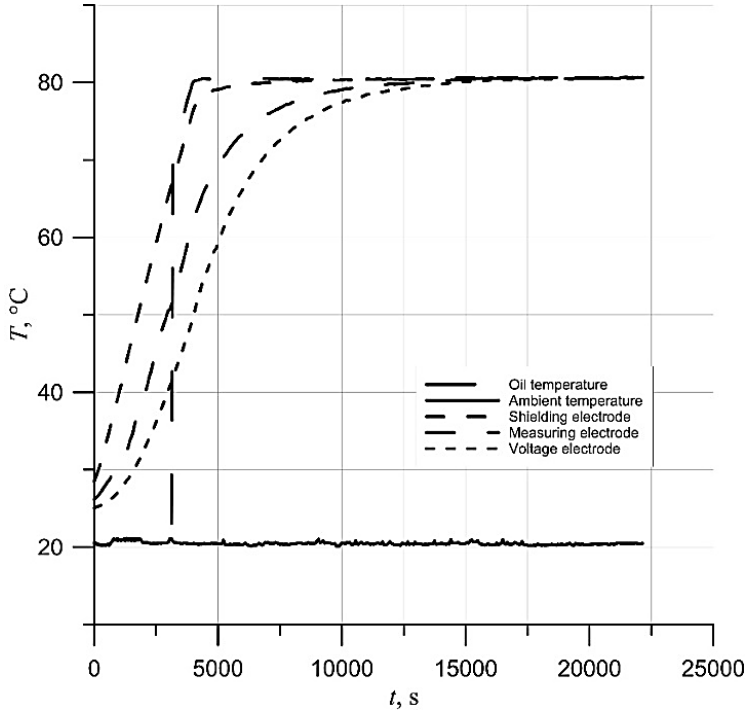

Figure 5 – Temperature distribution inside the measurement system

Preparation of samples

Circular samples of diameter xx, thickness of 2 mm and a density of yy g/cm^3, were cut from electrical pressboard sheet, made by Weidmann company. Samples were then dried for 8 h in a vacuum chamber, at a temperature of 80 °C. The moisture content of the dried samples was determined by the KFT method, and it amounted 0,55 - 0,60 % of their weight.

The next stage was hydration of the samples, which were moistured in the air until the percent of moisture content reaches the assumed level. The final step in the preparation of the samples was their impregnation with transformer oil for 7 days at room temperature.

Sample results of the research

The results of the measurement samples polarization current, which moisture was 3,8 %, are depicted in Figure 6.

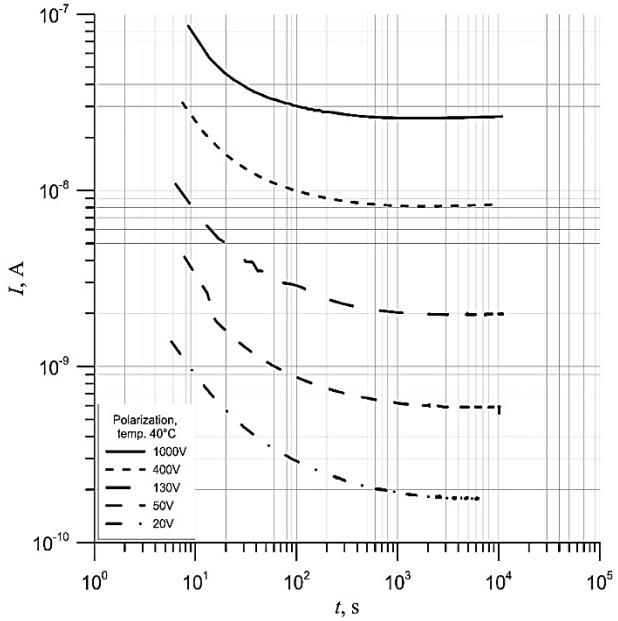

Figure 6 – Polarization curves of the current for sample with 3,8 % moisture content and temperature of 40 °C

The measurements were performed at 40 °C for successive electric field intensities ranging: 10 kV/m, 25 kV/m, 65 kV/m, 200 kV/m and 500 kV/m.

Based on the obtained results, the correlation between the conductivity of damp pressboard and the electric field, was specified (Figure 7). The analysis of the results revealed a weak and nonlinear correlation between the pressboard conductivity and the electric field intensity, which does not occur for low intensity of electric field, but appears for higher.

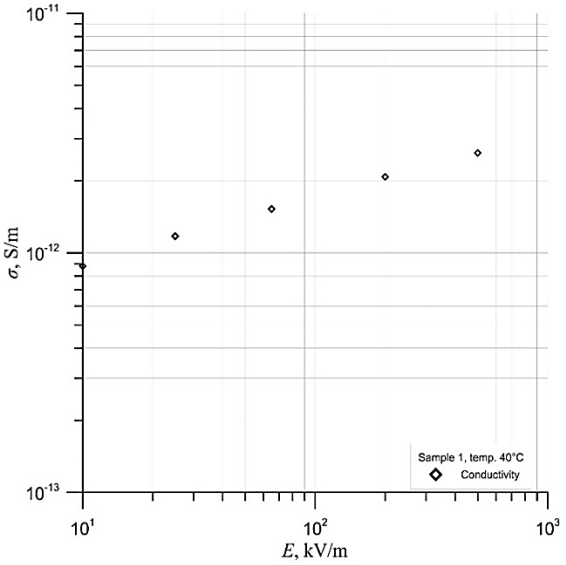

Figure 7 – Conductivity of damp pressboard with moisture content of 3,8 % by weight, measuring at temperature 40 °C

Conclusion

The presented measurement system allows to take precise measurements of polarization and depolarization currents by PDC at fixed temperature conditions. The measurements allowed us to determine the dependence of the electric field conductivity σ.

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УСТАНОВКА ДЛЯ ИЗМЕРЕНИЙ ЭЛЕКТРИЧЕСКИХ ПАРАМЕТРОВ ИЗОЛЯЦИОННЫХ МАТЕРИАЛОВ МЕТОДОМ ПОЛЯРИЗАЦИИ

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Описана установка для измерений токов поляризации и деполяризации электротехнического картона методом PDC с максимальной точностью измерения силы тока 10^{-15} А. Точность стабилизации температуры трехэлектродной измерительной системы, находящейся в масляной камере, составляет 0,001 °С.

Ключевые слова: материал изоляционный, метод поляризации, ток поляризации.

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