Analysis of Transformer Humidity by Capacitance Measurement

[1]M. Kučera, [1]M. Gutten, [1]S. Kučera, [2]J. Kúdelčík,

[1]Department of Measurement and Application of Electrical Engineering
[2]Department of Physic
Faculty of Electrical Engineering, University of Žilina, Univerzitná 1, 01026 Žilina
Email: kuceram@fel.uniza.sk

Abstract. *To prevent failure states of transformers, we perform different types of measurements. They shall illustrate a momentary state of the measured equipment and if necessary to draw attention in advance to changes of parameters, which have specific relationship to no-failure operation of the equipment. Water presence in oil transformer causes deterioration of its insulation and finally thermal defect of solid insulation.*

Keywords: humidity, transformer, dissipation factor, capacity

1. Introduction

State of new insulation in operation mostly deteriorates due to surface contamination of insulators and insulation, their moistening and ageing. If no measures are taken in time so as to avoid this degradation, the situation usually results in damage of insulator and consequently in stop of electrical device. State of insulation of important electrical devices, such as transmission transformer which bring huge economic cost due to each stop in operation, needs to be checked regularly.

Water presence in oil transformer causes deterioration of its insulation and finally thermal defect of solid insulation. Dielectric warming can be so high that the temperature increase is out of control and transformer becomes dangerous for its surrounding.

2. Theoretical Analysis

The measurements of dissipation factor and capacities of transformer windings are used for additional determination of insulation quality as whole or only of some parts of transformer. The value of dissipation factor indicates presence of polar and ion compounds in oil and it also determinate the aging of oil. The degree of oil humidity can be measured by temperature dependence of $\mathrm{tg}\delta$ [1].

The frequency dependence of capacity is next method for determination the degree of oil humidity (to 10 kHz – Fig. 1). In wet isolation, the absorption current is negligible to leakage current, which is independent on frequency. The stage of insulation can be determined as the ratio of capacities at two different frequencies (for example 50 and 100 Hz).

The next method on the determination of oil humidity was the measurement the value of capacity at various temperatures. The capacity is also the function of the absorption processes, which are characterized by their time constants, and distribution of absorption charges. This method is base on the determination of the ratio $\frac{C_{75}-C_{20}}{C_{20}}$, where C_{20} and C_{75} (or C_{80}) are capacities at 20 and 75 °C (or 80 °C). For some disadvantages of experiment this method was substitute by previous method base on the determination of the ratio of capacities at two different frequencies.

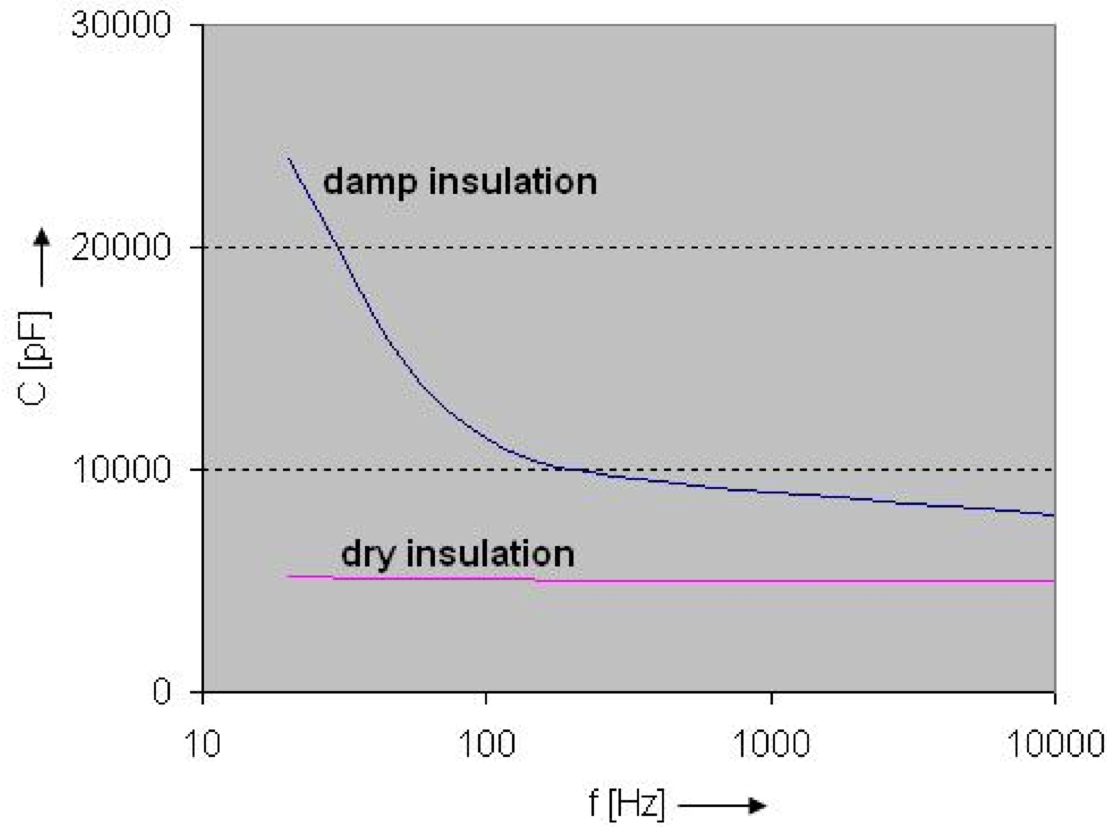

Fig. 1. Frequency dependences of capacity at dry and damp insulation

3. Description of experimental measurement

Experimental measurement on test transformer 60 VA, 220/52 V immersed in tank with transformer oil ITO 100 is provided as an example of safety and reliability inspection of transformer based on insulation humidity.

State of insulation was measured step by step - with no water content in oil and after water was added in amount of 0,05%; 0,15% and 0,25% of transformer tank volume filled with oil. The aim of experiment was to verify relation between increase in oil humidity and capacity-frequency characteristics (see Fig. 3).

In the second step, we measured frequency dependence of capacities at different temperatures in oil: 25, 35, 45, 55, 65 and 75 °C. The experimental measured values showed the connection between the increase of temperature and the change of frequency development of capacity (see measured values Fig. 4).

We were measured capacities as function of oil temperature, applied frequency (to 10 kHz) and oil humidity (water content in oil). The results were compared with the value of insulation resistance. The measurements were automatic using RLC meter and computer.

Computer program set the values of voltage and its frequencies for RLC meter and then it read electrical parameters of selected transformer, which were determined by RLC meter. All measured values were plotted using Excel.

3.1 Description of experimental instrument

Automatic RLC meter Fluke was used to measure dependence of capacity on frequency (Fig.2). Measuring principle of RLC meter is based on measuring selected voltage and current values of measured impedance between transformer's Z_X, see Fig. 2.

The component measurement is based on the current and voltage technique [4]. The component voltage and the component current are measured and converted into binary values. Each measurement cycle lasts approximately 0,5 seconds. For AC measurements one cycle consists of seven single measurements, the results of which are stored and arithmetically evaluated. Finally, the result is transferred to the display.

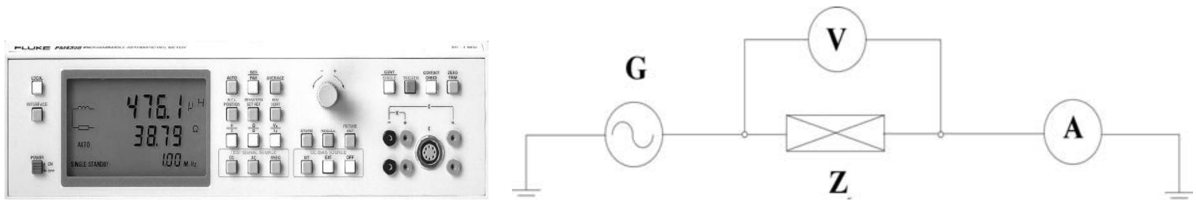

Fig. 2. RLC meter and setup of experiment

The microprocessor uses the measured values to calculate the equivalent series resistance R_s, the equivalent series reactance X_s, and the quality factor $Q = X_s/R_s$ of the component. In AUTO mode, the microprocessor determines the dominant and secondary parameter, calculates its value; and displays it together with the equivalent circuit symbol.

3.2 Results of measurements

Based on measurements, we proved correctness, reliability and high sensitivity of the method for determining humidity in transformer. After water was added in amount of 0,05% of transformer tank volume filled with oil, we already experienced significant change in curve upwards (increase in humidity – Fig. 3).

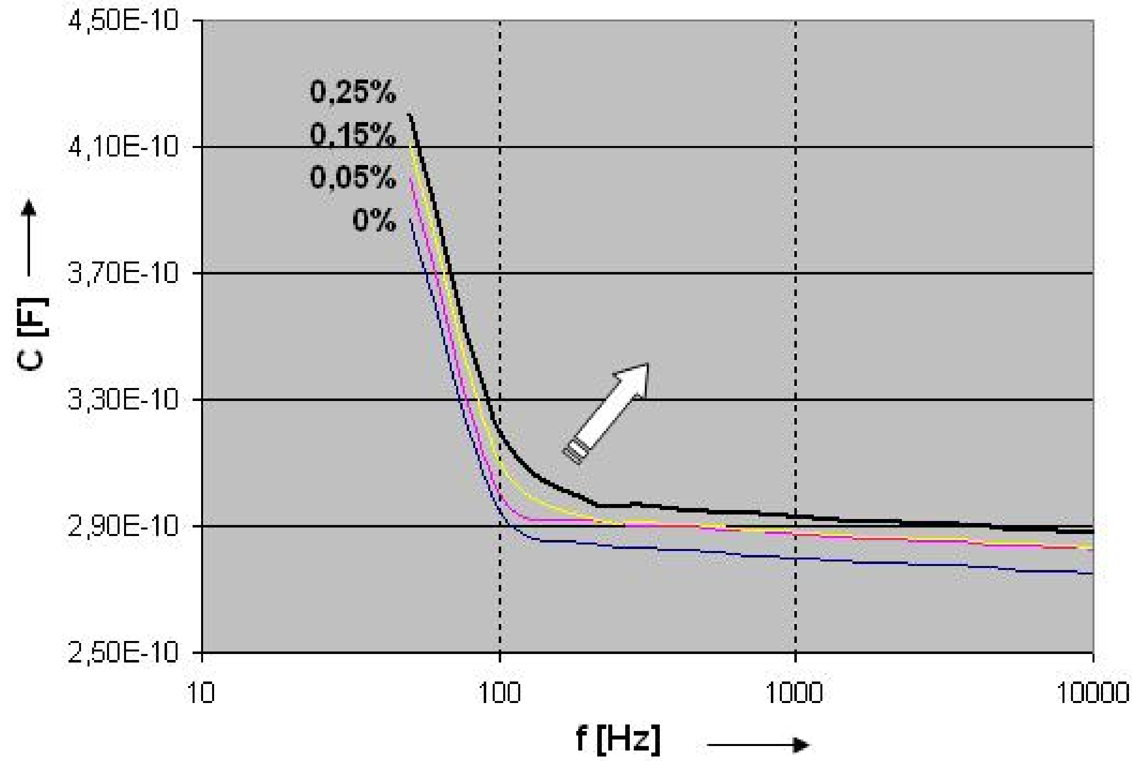

Fig. 3. Frequency developments of capacity as function of water contents in oil: 0; 0,05; 0,15 and 0,25 % (curve increase with water content); ratio $C_{50\,Hz}/C_{100\,Hz} > 1,2$ - damp insulation for all the examples

In the second step of measurements (see Fig. 4) it is different frequency dependence of capacities at temperatures in oil: 25, 35, 45, 55, 65 and 75 °C. The experimental measured values we verified the connection between the increase of temperature and the change of frequency development of capacity, i.e. the capacity is also the function of the absorption processes, which are characterized by their time constants, and distribution of absorption charges.

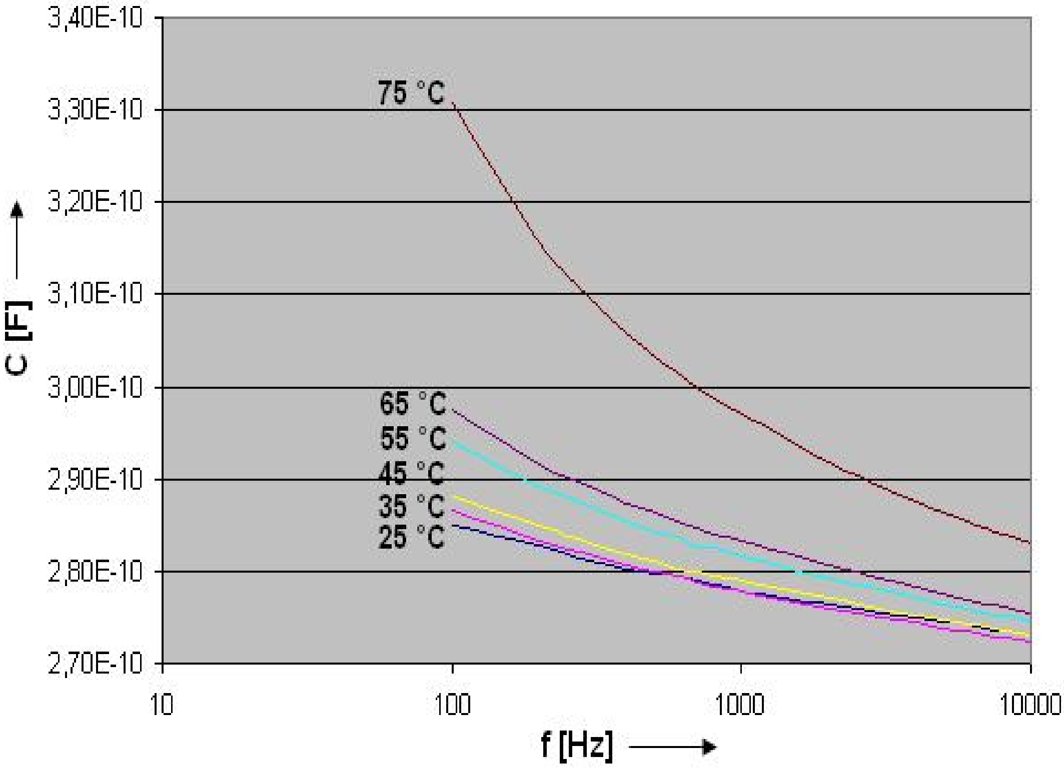

Fig. 4. Frequency developments of capacity as function of oil temperature

4. Conclusions

On the base of measurements, we proved correctness and high sensitivity of both methods for determination of oil moisture in the transformer, i.e. the frequency monitoring of capacity to 10 kHz.

These methods can be utilized to determine insulation state during short term layoff of transformer and thus increase its reliability and safety.

Acknowledgements

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