DIAGNOSIS OF MOISTURE PAPER-OIL INSULATION OF POWER TRANSFORMERS BASED ON THE METHOD OF CX/CY

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Abstract

The article describes a problem in the effective diagnosis of power transformer insulation, in particular, presents the problem of evaluation of moisture paper-oil insulation. Proposed to measure the dielectric dispersion coefficient Cx/Cy as an indicator of the quality of insulation, and presented the idea of the measurement system used for its determination.

1. Introduction

Diagnosis of power transformer is a problem, with which engineers have been dealing for tens of years. Various diagnosis methods are being used for evaluation of power transformer insulation. It often happens, that it is difficult to evaluate state of insulation, because of different measurements results. In this case one can use knowledge and experience concerning this matter. As it is shown on Fig. 1, the main reason of breakdowns of transformers in Poland is bad condition of paper-oil insulation. Its degradation is being caused by natural processes of aging , which can be accelerated by incorrect operation conditions. Transformer units working in aerial stations deserve for special attention, because they are exposed on contact with water, what can cause moisture of paper – oil insulation. That would be reason of lower dielectric endurance and faster degradation of paper – oil insulation.

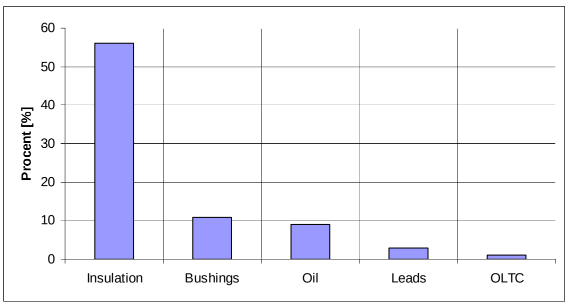

Fig.1. The main cause of the failure of transformers in Poland [1]

2. Moisture of paper – oil insulation

Methods of measurement of water content in paper – oil insulation are:
- Electrochemical – Karl Fischer method – Involves taking a sample of oil or paper and subjecting them to titration. Paper insulation condition assessment is based on standards (4)
- Physical – vacuum method (Edwards)
- Electric - constant current (R60/R15, RVM - recovery voltage measurement, PDC - polarization and depolarization currents) and AC (C_2/C_{50} or C_0/C_∞ - measurement of dielectric dispersion coefficient; FDS - dielectric spectroscopy method).Electrochemical and physical methods, because of its direct nature demanding physical collection of samples to determine the water content in oil and paper are not convenient methods of diagnosing the state of moisture. Currently, to assess the condition of the insulation electrical methods are used, in particular the PDC and FDS supported by RVM. These methods often produce inconclusive results. To interpret the response waveforms of the transformer and also to assess moisture of insulation it is necessary to have experience and a wide database of tested types of transformers. In the literature it becomes apparent that there is a trend to eliminate the human factor from the process of interpreting the results and to replace it with artificial intelligence. Attempts were made to use neural networks for this purpose due to their large processing capabilities in the decision process with large number of parameters. However, it seems that this method will only reduce the range interpretations obtained with mentioned methods: PDC, FDS and RVM. Therefore it seems necessary to try to ensure the simple, noninvasive method of measuring moisture of isolation of transformers, which would give unambiguous results. Thus it would make assessment of state of isolation independent from the experience of interpreting person. In Figure 2 the possible sources of moisture in paper-oil insulation are shown.

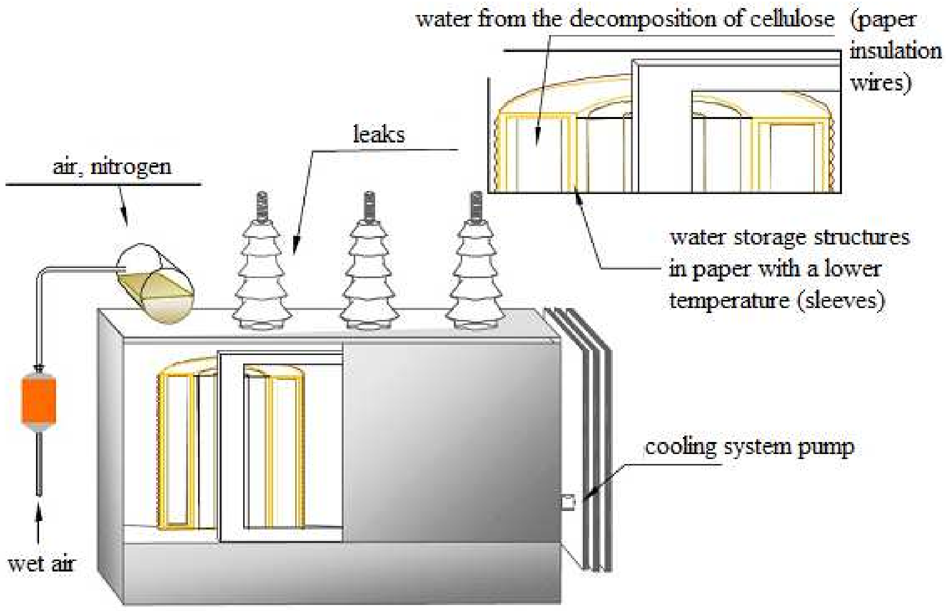

Fig.2. Sources of insulation moisture [2]

3. Moisture indicator: C_x/C_y

The method of determining moisture based on the use of changes in insulation's dielectric constant at different frequencies of voltage of transformer (measurement of dielectric dispersion coefficient) seems to be forgotten by the world of professional energetics. The main reason for this is probably the lack of measurement tools that use this method. It happens because of difficulties in measurement that occur when one try to measure by this method modern designed transformers.

In the middle of last century, it was proposed to use the phenomenon of increase of the resultant of dielectric constant to assess the moisture of paper and oil, caused by its moisture. Increasing electric perspicacity causes enlargement of capacity of insulation system. It can especially be seen in measurements subacoustic frequencies of test voltage. Then it was proposed to measure the coefficient of C2/C50, where C2 and C50 are the capacity between the HV and LV windings of the transformer, respectively at 2 and 50 Hz.

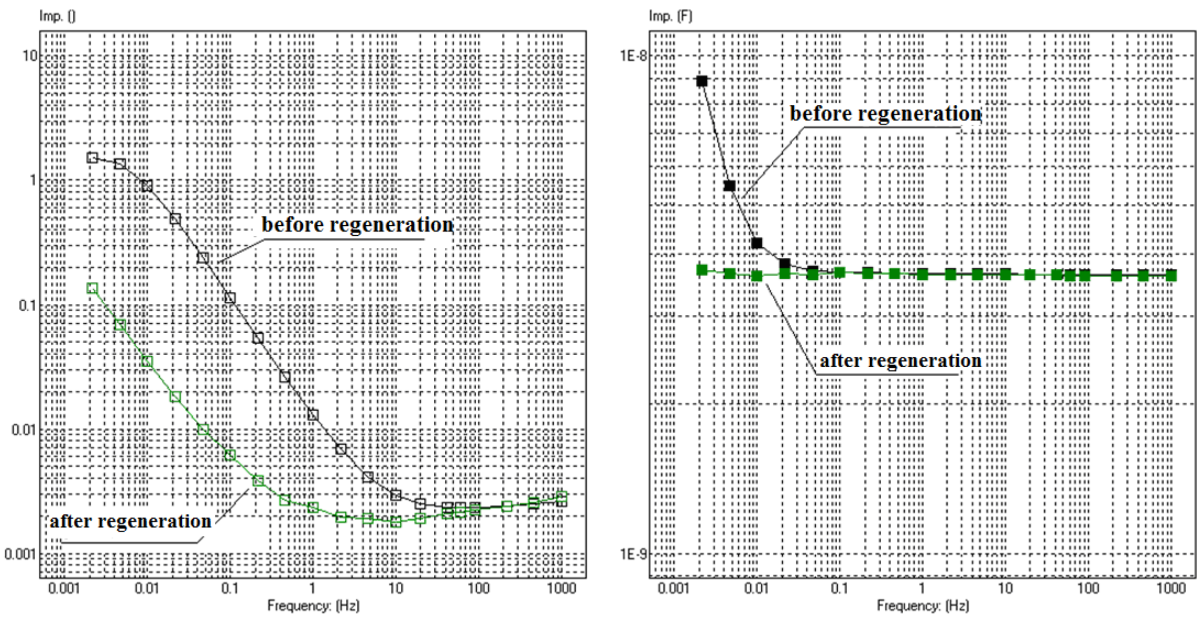

Fig. 3. Comparison of frequency characteristics of isolation between HV and LV windings made with IDAX-300, a) tgδ, b) capacitance C

The criterion for acceptable operation of the transformer due to the degree of moisture was defined as C2/C50 <1.3. Today's measurement capabilities allow the measurement of capacity in a much wider range of frequencies. An example of this may be apparatus IDAX-300's PaxDiagnostics (now Megger) [9], which measures the volume in the frequency range 1 mHz - 7 kHz. Figure 4 presents the characteristics of tgδ and capacitance as a function of frequency for the same transformer, which has been subjected to regeneration because of high water content. They provide a basis to conclude that the nowadays the idea of determining the coefficient C_x/C_y aimed to determine the degree of moisture of paper and oil is the most reasonable.

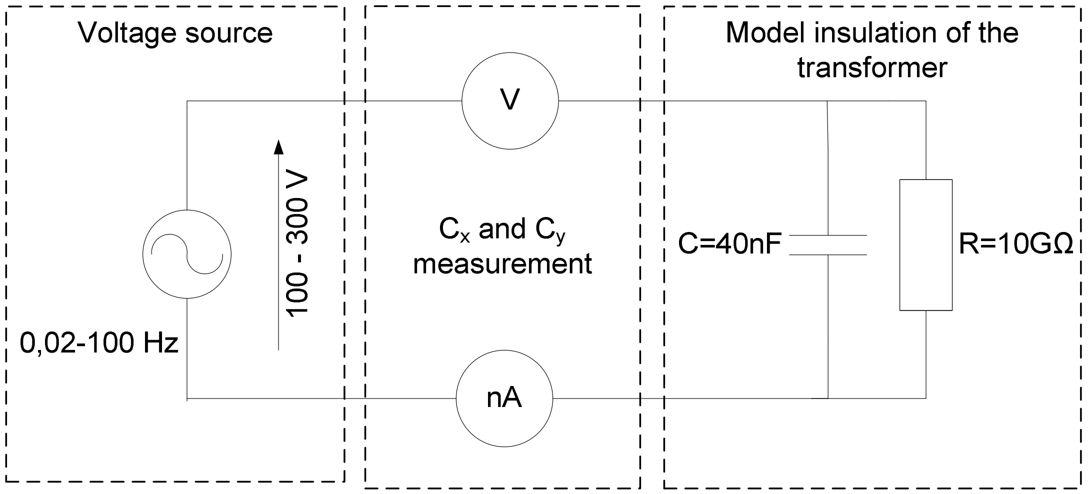

Fig. 4. The proposed measuring system for testing the coefficient Cx/Cy

4. Proposal for measuring system

Figure 4 shows the concept of measuring system for determining the coefficient C_x/C_y. The system consists of three blocks. The first block is a sinusoidal forced voltage with frequency control. Voltage is fed to a model transformer insulation consisting of parallel combined resistance and capacitance. The values of these elements were chosen to correspond to the actual values of transformers in service in Poland. In the third block digital measurement of voltage and current flowing in the circuit is made. Current response is estimated at nanoampers. There are difficulties of construction and metrological nature in each of previously discussed blocks. First problem is to construct a voltage source of adjustable frequency of 0-2 kHz and a value above 100 Vrms. There are no commercially available ready-made solutions for power generation of the required parameters. Therefore, it is proposed to generate the required voltage source using the DAC transmitter (voltage level + - 10V) and a suitable power amplifier (20x). To build a block used to measure C_x and C_y, the system consisting of the NI CompactRIO cRIO-9014 controller equipped with a voltage measurement card NI 9225 with a measuring range up to 300 Vrms, and the NI 9239 for the voltage to 10V can be used. Additionally, the controller with the NI 9263 card that generates voltage in the range of + /-10V will allow the generation of a voltage signal (after amplification) used to build a voltage source of the first block. The measurement of current flowing in the circuit will be realized by using the converter I / U and NI 9239 card. Model of transformer isolation can be built with a resistor and standard capacitor. Constructed this way measuring system will allow to perform a series of tests on the model of transformer isolation in the laboratory and after verifying the effectiveness of method, it will allow to take measurements of actual objects in the field.

4.1 Determination of the coefficient C_x/C_y

To determine the coefficient C_x/C_y one must calculate both the capacitance C_x and C_y and then divide it by themselve.

To determine the capacity C_x one must measure the resultant phase shift between current I and voltage U, as shown in Figure 5. Then one must calculate the angle δ (90 - φ), from which we can determine the capacitance C_x using the formula:

$$C_x = \frac{1}{2\pi f_x R \mathrm{tg}\delta} \qquad (1)$$

The resistance value should be set supplying the system shown in Fig 4th DC voltage source

Similarly calculate the capacity of C_y, for which the frequency of the voltage will correspond to the frequency f_y.

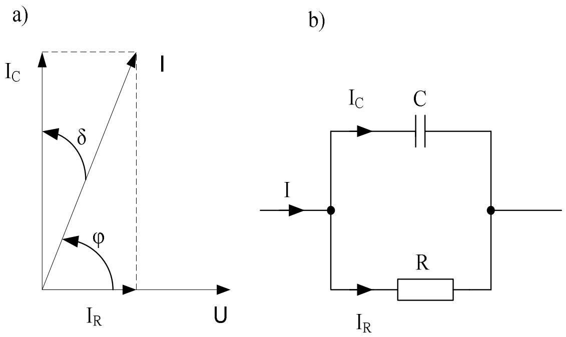

Fig. 5. Vector diagrams real capacitor (a) and corresponding equivalent circuit (b)

5. Summary

In this article the idea of determining the degree of moisture of paper and oil power transformer insulation by measuring the ratio C_x/ C_y was presented. Using the experience of the last century, based on the ratio C_2/C_{50}, it appears possible to define a new type of capacitive coefficient using the phenomenon of dispersion for the diagnosis of the insulation. Measurement system that would allow the designation of the coefficient C_x/C_y was presented. Frequencies x and y should be chosen experimentally, so that determined factor would be characterized by a high sensitivity to changes in humidity. The technical possibilities of current measurement in values of nanoampers should be examined.

The ability to create a mobile measuring system able to verify the results of the model with reality should be tested. Problems described above will be material for a further studies for the author.

6. Bibliography

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