

MEASUREMENT AND DIAGNOSTICS OF POWER TRANSFORMER BY FREQUENCY METHODS

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Abstract

Paper presents experimental diagnostics of insulating system oil-paper for power transformers, mainly by progressive frequency method – dielectric spectroscopy. The introduction of the article is described the base analyzing for measurement insulating elements (oil and paper) of power transformers. The next part of article is described application of dielectric frequency domain spectroscopy (FDS) method for high-voltage power transformers. Diagnostic methods are used for measurement of insulating state of high-voltage devices with insulating parts as oil-paper. It was present that the values of these measuring results are highly impacted by the temperature of operating during the experimental diagnostics. Conductivity and moisture between dielectric transformer paper and insulating oil in a dielectric system are highly dependent from internal and ambient temperature. In the final section the article are presented experimental values of the diagnostic analysis for an operating oil traction transformer at different internal temperatures and conditions (with oil filling and without).

Keywords: frequency dielectric spectroscopy, high-voltage transformers, moisture, temperature

1. INTRODUCTION

The important problem of actual energetic companies is that the data big number of measured parameters from the diagnostic measurements are not adequately further studied. Main technical problem is identification of power transformer condition, mainly in terms of their residual lifetime. The fault may occur in an unpredictable moment of transformer operation. The fault result may be the power breakdown for a short or long time.

It is necessary to analyze the measured values of transformer parameters, even for using monitoring. Therefore it is necessary based on knowledge of exposure to adverse influences of energetic phenomena, for example short-circuit currents, overcurrents or overvoltages. Achievements of these objectives by using suitable the diagnostics may help to identification the adverse effects of short-circuit and propose new measuring procedures. Moreover it is possible to identification forthcoming failure into transformer. Some steps are possible to propose in advance (e.g. repair of single parts of transformer) [1].

The quality of the insulating parts of the transformer in the oil-paper fabrication can deteriorate over a period of several years. If this part of the equipment is not checked regularly, the insulation parts will be damaged, which in turn leads to a dangerous destruction of the entire transformer.

It is therefore necessary to properly diagnose the dielectric properties of this device. The increase in moisture and the formation of water in oil results of a transformer in a worsen of the transformer's operating condition and consequently presents a risk of serious failure (for example winding failure and feed, aging of insulation barriers and paper, deterioration of oil cooling and insulation) [1].

As the humidity increases in the insulating parts of the transformer, the quality of the insulating paper insulation deteriorates, which can lead to an increase in partial discharge. Partial discharges can affect the temperature rise in the entire transformer. This temperature rise can become uncontrollable and the device becomes dangerous by possible fire. It is necessary to know condition of transformer insulation, dielectric elements and insulating properties in operating state.

The first approach, called recovery voltage method (RVM – Fig.1), is nowadays already known. The newer two methods, frequency domain spectroscopy (FDS) and polarization and depolarization currents (PDC), demonstrated their relevance for measurement of transformer, and at present are frequently used. The advantage for these methods is that it is possible to detect humidity in insulating paper and conductivity in oil of power transformers [2].

Transformer oil analysis is part of the overall diagnostics of the dielectric subsystem of each electrical equipment filled with oil. This diagnostic includes tests and measurements to verify the insulation and cooling properties of the oil. It acts as an interface for the transfer of such components as moisture, air, aging products, mechanical impurities and the like.

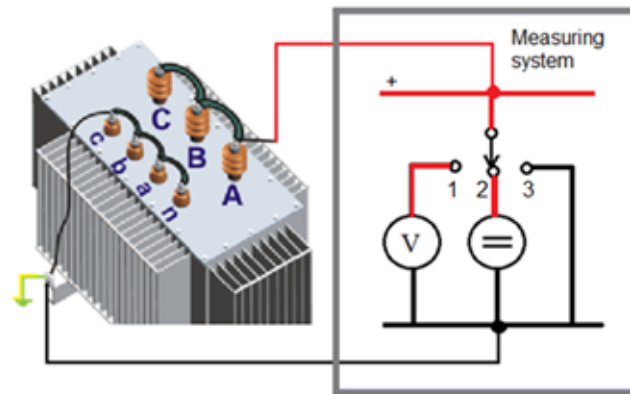


Fig. 1. Principal scheme of RVM method

Electrical and thermal stresses transform insulating oil in different gases. These gases indicate developing defect of the devices or machine. Their timely indication helps early damage and the costly removal of large-scale damage. The gas formed dissolves in the insulating oil in a quantity dependent on the type of gas, the quality of the dielectric oil, temperature, pressure and viscosity [3].

The failure in the transformer can develop slowly or rapidly depending on the type. Therefore, it is advisable to monitor the operation of the transformer in real time to keep track of what is going on inside. By transforming the transformer oil into several gases, it is easiest to follow this medium [3].

2. DIAGNOSTIC METHODS FOR TRANSFORMERS

The disadvantage of some energy companies is that data on a large number of diagnostic parameters from experimental measured values are no longer adequately studied. The main technical problem is the identification of the state of the power transformer, especially in terms of their residual life.

It is also possible to identify future transformer failures. Some steps can be designed in advance (for example repair of individual parts of the transformer) [4].

Due to the adverse effects of short-circuit currents that damage the coils, taps and magnetic structure, the following diagnosis is performed on the disconnecting distribution transformers:

- diagnostic and measurement of voltage and current in impedance of insulation properties (winding capacity, real and imaginary permittivity, resistances and loss factor $\tan\delta$),
- diagnostic and analysis of values in time methods (return voltages RVM method and depolarization and polarization currents in DC (PDC method in Fig.2),
- values analysis of the transformer in frequency method by Sweep Frequency Response Analysis method (SFRA),
- winding measurement for parameters the power transformer at short-circuit state,

- measurement of breakdown oil parameters of transformer,
- measurement in time dependence of windings the transformer using the high-voltage impulse source by impact test,
- chromatographic diagnostics of the oil analysis of transformer,
- diagnostics of insulating parameters by frequency method using dielectric spectroscopy (FDS) [5].

The use of these methods is only applicable if the transformers are disconnected.

Early diagnostics and monitoring of the technical condition of the equipment also result in an early detection of a malfunction (early stage malfunctions) which could cause relatively large damage during operation (e.g. early replacement of the bearing prevents it from burning or prevents the accident for electric rotary motors, generators, transformer core, windings, taps and ventilators, and the like).

If we want to measure online, while the transformer is in operation, it is possible to use measurement methods using thermovision and radiation analysis in the electromagnetic or noise range. The following online methods were used in our department, which were applied to several electrical machines using experimental techniques [6], [7]:

- thermovision analyzing,
- measurement of radiation of electromagnetic field from power devices,
- analysis of emission of acoustic field from transformers.

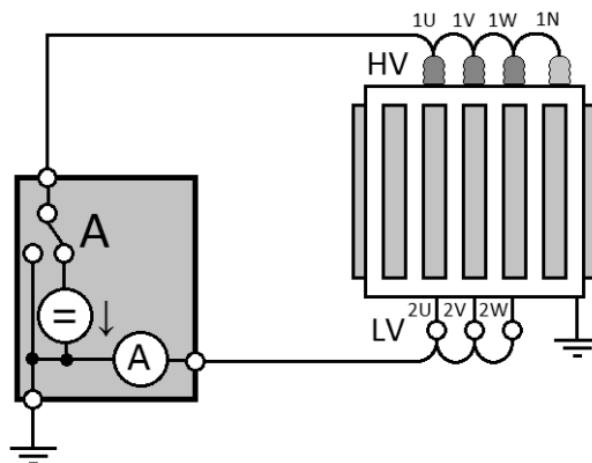


Fig. 2. Principles of an easy PDC system

Radiation of hot sources acts (in respect of surrounding conditions), like visible light. To display temperature fields we can use visualization techniques used in optics. The only differences are materials used for elements of visualization systems, size of values which are derived from the wavelength of radiation, and also sensitivity of sensors for recording the signal

At present, it is possible to use the measurement of acoustic waves using a microphone system for the analysis and diagnostics of electrical machines. Using the analysis of acoustic emissions (AAE), this method can be used especially in on-line measurements [9].

Measurement of acoustic signals using microphones can thus become an important alternative in the field of power transformer diagnostics [10].

3. METHOD OF DIELECTRIC SPECTROSCOPY

Previous research in the diagnosis of dielectric isolating parameters has shown that dielectric frequency method by analyzing of spectroscopy measurement is one of the most important analyzing of a high voltage transformer in insulating oil paper.

Particular emphasis is placed on comparing currently available methods of dielectric spectroscopy with traditional measuring methods, such as dielectric dissipation factor ($\tan\delta$) tests at power frequency and 0.1 Hz, dielectric adsorption ratio and polarization index [11]. To measure the dielectric responses, a sinusoidal frequency measurement in the range 0.0005 Hz to 10 kHz is used, depending on the moisture and conductivity values of the measured machine.

Fig. 3 shows the dissipation factor of a press plate containing 1% moisture and oil together with the effect of interfacial polarization (insulation geometry). The frequency range of 1,000 - 10 Hz is dominated by cellulose insulation, but this area is also affected by measuring cables and connection technology. The conductivity of the oil causes a sharp slope at 1-0.01 Hz. Dissolved by-products of conductive aging, carbon black and high molecular weight acid increase the conductivity of the oil and thus affect this area. The interaction polarization determines the maximum at 0.003 Hz [12].

The frequency values are compared according to Fig. 3, depending on oil conductivity, humidity, geometry of insulating parts of transformer, temperature of ambient or machines [11], [13].

Method FDS is mainly used for oil-paper insulation; it can also be used for dry transformers or high-voltage equipment with ferrofluid in magnetic field [14].

This experimental analysis is determination of new set of diagnostic and measured techniques for the analysis of the condition of selected type of oil filled power transformers [15].

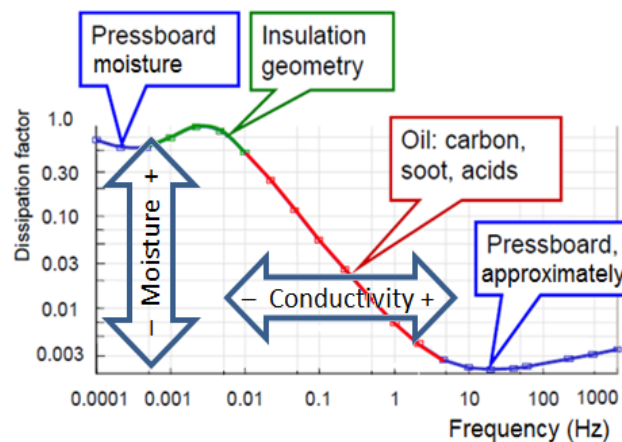


Fig. 3. Insulating waveform of FDS method of the measured power transformer [12]

4. DIAGNOSTIC MEASUREMENT AND ANALYZING

The diagnostic measurement and analyzing was performed on a 110/27 kV single-phase traction transformer, which is located in a power station for traction system, by humidity analysis by frequency dielectric spectroscopy. The diagnostics was performed for + 15 ° C with oil of transformer and - 5 ° C without oil.

The device IDAX-350 by MEGGER company with the connection is shown according to Fig. 4. This device analyze transformer using dielectric spectroscopy (method FDS) by parameter analyzing of the permittivity, percentage loss factor, capacitance as a function of frequency 1kHz to 0.0001Hz in a sinus source 140Vef [14].

At the introduction analysis with oil at +15 °C - the whole isolating condition of the machine at 20°C / 50Hz was “good condition” according to dissipation factor in percentage ($\%tg\delta = 0.25$) and moisture of paper was “good condition” (1.95 %) using the rating graphs of measuring device 350 IDAX (Fig.4).

At the next analysis without oil at -5 °C in the comparison - the whole isolating condition of the machine at 20°C / 50Hz was better according to $\%tg\delta = 0.22$ and humidity of paper was better too (1.50 %). Insulating system capacity was significantly smaller (Fig.5), because machine oil is significant part of total transformer insulating system.

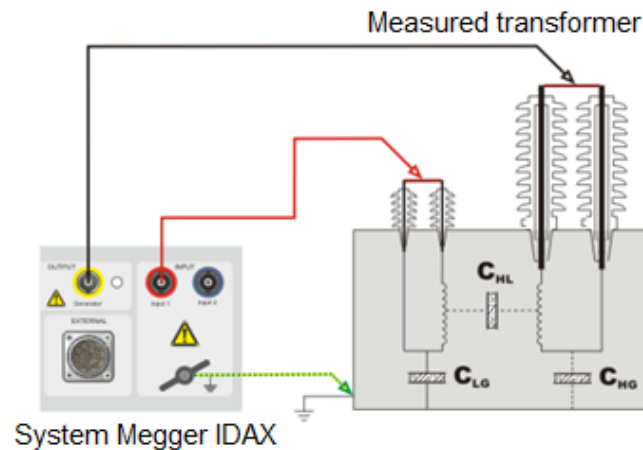


Fig. 4. System MEGGER IDAX-350 and connection of the measured electric machine 110/27 kV

A lower temperature causes a shift of the course towards lower frequencies (direction to the left - Fig. 5). This moving the claim was confirmed of the theoretical graph according to Fig. 3.

Another effect on the shift in the curve was the oil drain before the second measurement, as the conductivity of the transformer oil was reduced to zero (direction of oil conductivity to the left according to Fig 3).

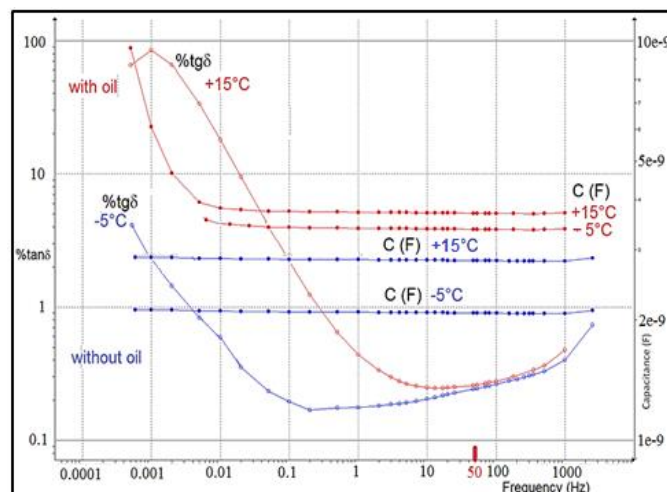


Fig. 5. Measured curves of measured traction transformer 110/27 kV using FDS method

Because measurement is performed at very low currents, it is necessary consistently linking all connections according to Fig.4.

Since the device separately distinguishes measurement of individual capacities, it is necessary to thoroughly clean the location for connection of the ground conductor of the device. Poor connection results in errors in current measurements (and then calculated value of percentage loss factor - %tg δ) at frequencies above 200 Hz (Fig. 6).

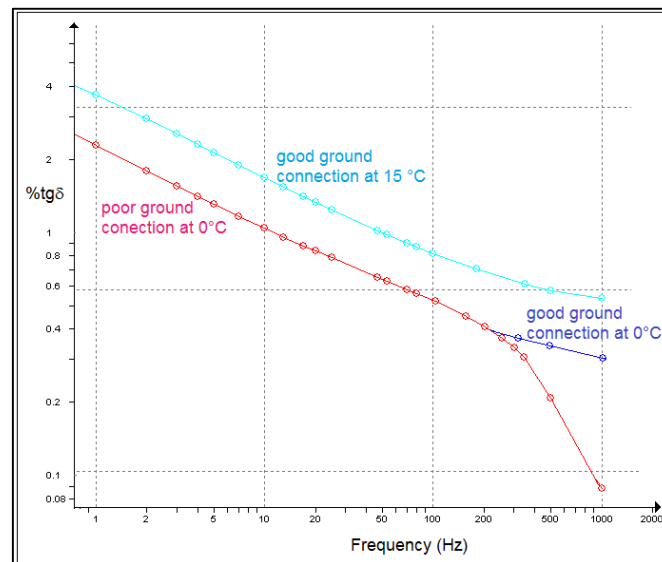


Fig. 6. Waveforms of measured machine at different states and poor/good ground using Megger IDAX-350

5. CONCLUSION

In the paper is presented the experiment for analysis of state insulation of high-voltage power machine by using the frequency dielectric can be suitable to diagnostics moisture of insulating paper and conductivity of transformer oil for various temperatures and conditions (with oil and without, good ground and poor grounding).

This experimental analyzing is used to determine a new set of diagnostic measurement techniques for analyzing the condition of a selected type of filled oil power devices.

More serious diagnostics of insulating system will be made on the base of complex analysis of measured values using the other added measurements from selected and new diagnostic methods and techniques, simulated and experimental analysis and electronic equipment.

We will also connect physical models describing measurable parameters of partial discharge process with the effect of the degradation of insulation state of oil transformer with the increased originality and the innovation and on that basis will be created new diagnostic system with possibility of classification and analysis of possible failures on high-voltage transformers.

It was detected interesting fact by frequency dielectric spectroscopy that transformer, which was out of operating a few months, had the highest moisture in paper insulation - it can dangerous for operating and lifetime of transformers.

According to insulation condition of transformer is the better, that transformer is operating - transformer is dried.

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