DIAGNOSTICS OF TRANSFORMER COMBINED WITH THERMOVISION

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Abstract: *Power transformers are key equipment for transfer and distribution of the electric power. Considering the significance of the power transformers in the electric system, their price and possible damages occurred by accidents, it is necessary to pay attention to their higher prevention. 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.*

Key words: diagnostics, transformer, monitoring, insulation, thermovision, temperature

1. Introduction for a Diagnostic of Power Transformers

It is in principle about tests applied for test equipment with an aim to detect weak points in insulation system and to determine stage of progressive devaluation of this system as the whole. They are specific terms, which considering the necessity of short-time shut-down of equipment from an operation (it is not recommended to use time demanding methods) and minimisation of number of an operations, which are required to make a machine preparation for a individual measurement.

2. Diagnostic testing methods

To prevent a damage state of transformers, we perform different types of the measurements that should illustrate an actual condition of the measured equipment. It is therefore important to choose a suitable diagnostics for the right prediction of such conditions.

2.1 Insulation oil analysis

Main parameters of the insulation oil analysis are [3]:

- *Breakdown Voltage* - On the basis of the analysis results we can assume if oil contains emulsified water, over-saturated gas or conductive impurities. It does not indicate the stage of operation ageing (fig.1).
- *Dissipation Factor* - Loss factor indicates presence of polar and ion substances in oil. Therefore, it indicates oil ageing. Heat dependency (tgδ) may indicate presence of foreign soluble matter in oil.
- *Resistivity* - Resistivity indicates foreign matter of conductive character (including water) present in oil.
- *Relative Permittivity* - This factor provides rough information on oil ageing degree, but not moistening.
- *Ageing Factor* - determines the quality of new oil. Considering operation it serves to define the ageing degree.
- *Interfacial Tension of oil against water* - serves for new oil quality assessment. Considering operation it serves to define the ageing degree. It reacts sensitively onto soluble sediments creation.
- *Density* - represents a quality factor considering both new and used oil. It is essential for surface tension calculation.

Fig. 1. Measurement of oil breakdown voltage by testing equipment Megger

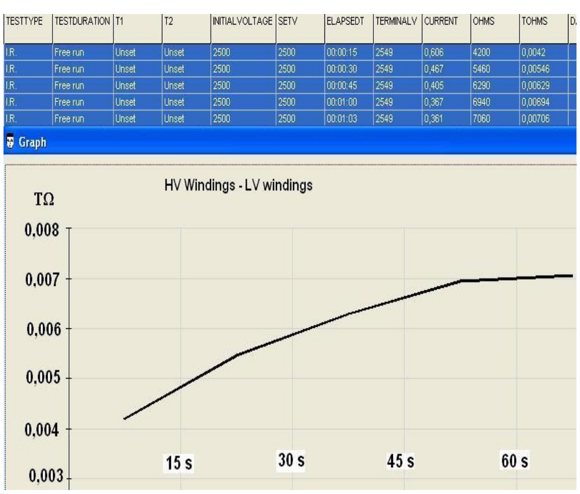
2.2 Thermal and electric defects detection in oil transformers

Main parameters of the thermal and electric defects in oil transformers are [3]:

- *Total Gas Content in Oil* - Considering new transformers this factor impacts assessment of degasification of the insulation system of the machine. Considering hermetic machines it verifies the sealing effectiveness. It represents factor significant for detection of kinetics of the thermal defect (fast or slow process) if we take machines with thermal defects into consideration.
- *Chromatographic Analysis of Gases Dissolved in Oil* **-** method used for determination of thermal and electric defects in transformers filled with oil. It enables to detect the defect location, intensity of the process and kinetics of development (that means the rate of risk taken during consequent operation of the transformers).
- *Chromatographic Analysis of Gases from Gas Relay* - method used for determination of thermal defects

2.3 Measurement of power transformers insulation characteristics

Measurement of power transformers insulation characteristics (measurement of loss factor, capacities, insulation resistance – fig.2, polarization index calculation, non-temporal constants in various connections of measured winding) is to detect the operation ageing degree, insulation systems moisturizing and to detect defect creation location in each section of insulation systems.



TESTTYPE	TESTDURATION	T1	T2	INITIALVOLTAGE	SETV	ELAPSEDT	TERMINALV	CURRENT	OHMS	TOHMS	D.
I.R.	Free run	Unset	Unset	2500	2500	00:00:15	2549	0,606	4200	0,0042	
I.R.	Free run	Unset	Unset	2500	2500	00:00:30	2549	0,467	5460	0,00546	
I.R.	Free run	Unset	Unset	2500	2500	00:00:45	2549	0,405	6290	0,00629	
I.R.	Free run	Unset	Unset	2500	2500	00:01:00	2549	0,367	6940	0,00694	
I.R.	Free run	Unset	Unset	2500	2500	00:01:03	2549	0,361	7060	0,00706	

Fig. 2. Measurement of distribution transformer insulation characteristic

2.4 Short-circuit currents effects analysis

SFRA method belongs to current most effective analyses and allows to detect the influences of short-circuit currents, overcurrents and other effects damaging either winding or magnetic circuit of the transformer. This all can be performed without a necessity of decomposition of device and subsequent winding damage determination, which is very time consuming. The method of the high-frequency analysis (Sweep Frequency Response Analyzer – SFRA [4]) is also one of the methods of undisassembling diagnostics of transformers. No intervention to the construction of tested device is demanded, the whole measurement is performed on detached device (not under the voltage). This method is applicable mainly for determination and measuring immediately after the manufacturing of device, i.e. for measuring of reference values (fig.3). These parameters are consequently compared to the other measurements performed on the transformer, which is decommissioned, after the damages or revisions of transformer etc.

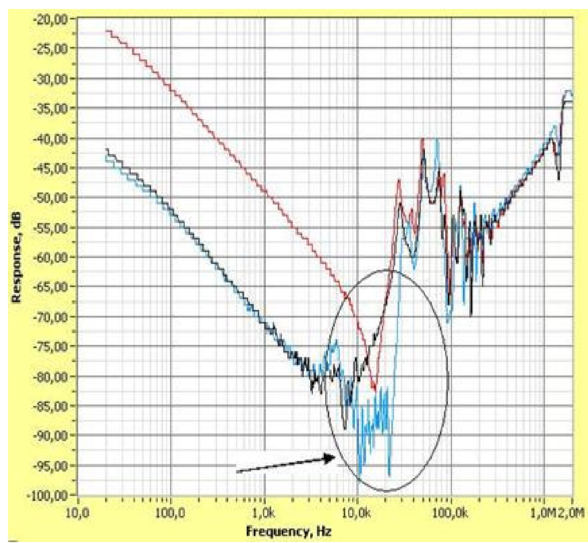


Fig. 3. Turn-to-turn fault detection in transformer primary (damaged A phase)

SFRA as a one of the most predictable methods is based on functional high-frequency generator and spectral recording analyzer principle, which are set up and controlled by computer. This method is used also by M5100 measuring system (see Fig.4) constructed by American DOBLE company [4].

Fig. 4. DOBLE M5100 measuring system

3. Monitoring transformers

There is established the monitoring system, which eliminate specific disadvantages of classic methods (buck of equipment, the necessity of personal activity right at the place), and which is used for preventive and continual data summarisation and their complex evaluation (fig.5). There are two main purposes that are followed by an insulation state monitoring of power transformers:

1. Early evaluation of safety state of transformer. The system evaluates time behaviour of monitored parameters as critical and early makes a warning signal before pending accident of the equipment.
2. Transformer maintenance practised in longer time intervals on the base of insulation state evaluation of the equipment by its continual monitoring.

Among assumptions for open loop system there belong these solution elements:

- modular design of measuring and decoding PC,
- measurement channels of slowly variable parameters,
- measurement channels of alternating parameters,
- records of fast and splitting parameters,
- registering of impulse actions – counters,
- digital inputs and outputs,
- resistance against interference and against don't care state.

Selection of parameters for permanent monitoring of insulation state of equipment is up to a certain extent in influenced by choice of the range of the monitoring system.

Fig. 5. Monitoring system in Department of Measurements and Applied Electrical Engineering Žilina

4. Thermovision addition in monitoring of power transformers

The temperature measurement by means of contact (invasive) a method is in many cases very difficult and from working and safety reasons nearly impossible. For this reason it is necessary to aim at such measuring equipments and methods of temperature measurements which do not require the direct contact with measured equipments. Diagnostics of equipments satisfying these conditions are based on the radiated infrared energy scanning. Infrared techniques thus finds its application anywhere such physical quantity, like temperature, gives us information about the technical state of the equipment in question or about some its part.

Infrared thermograph is a contactless (non-invasive) way of temperature distribution measurement on the scanned object surface in the infrared area (1μm - 13μm) of the electromagnetic spectrum.

Infrared measurements can be realized quickly and economically with the minimum time and work as they do not require any adaptations or turning-out of measured equipments. Thermovision techniques are used at the transformers control in order to find out whether the temperature of its some parts does not raise (fig.6). Also the transformer's bushings (fig.7), thermal field distribution on oil transformer tanks are tested, etc.

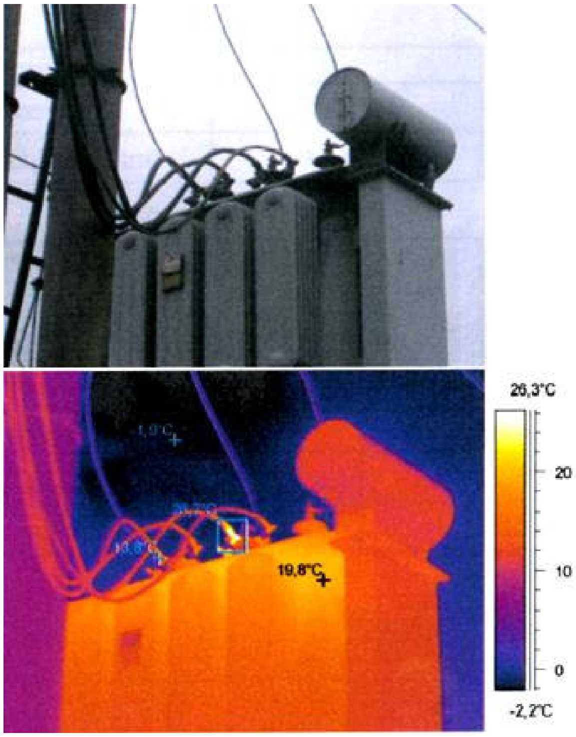


Fig. 6. Real transformer temperature picture

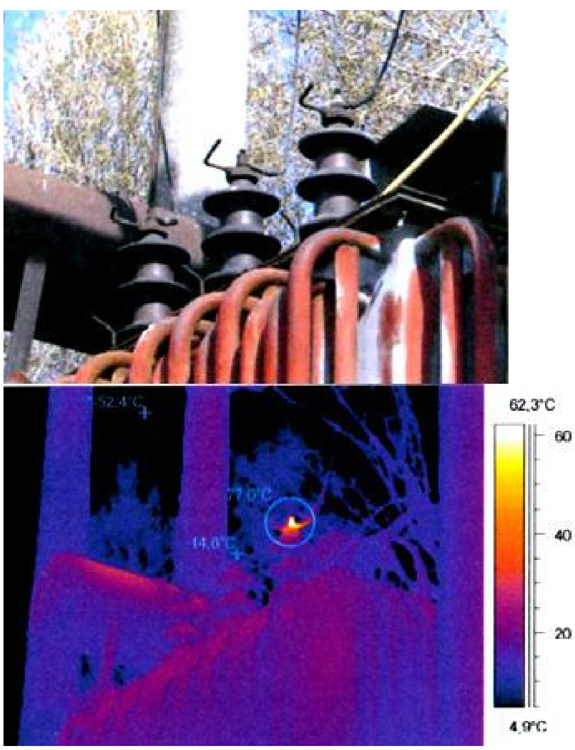


Fig. 7. Real transformer temperature picture (connection transformer – bushing – line)

Measurements where the percentage current load is not possible to obtain (circuit is loaded less than 50% current load). If we use the equation for temperature calculation, increase to 100% current load. To evaluate the quality we obtain significantly larger figures of the calculated temperature increase than of the real measured temperature increase.

The result is incorrect evaluation for the operation to be cut off because of the error, useless waste of material for the replacement of the false parts and of course, a negative economic effect.[5]

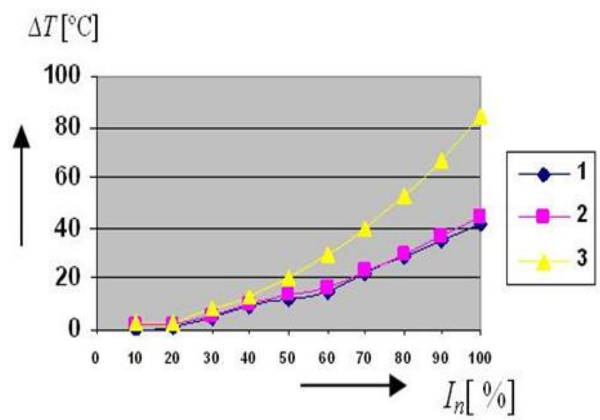
Measured data can't be used as a limits factors (perturbing influence of the environment, currentweigh, voltage fluctuation, effect of the objects´ emission nearby the measured object).

The calculation does not consider the following elements influencing the exactness of the measurement:

- cooling due to the object's emission,
- influence of the temperature on the conductor's electric resistance, size of the object, convection process,
- size and quality of current load, quality of voltage (higher harmonic).

If we do not consider these elements in course of calculation, there the negative influence of the results of the thermovision diagnostics will be possible.

In the fig.8 there is the relation of the conductor temperature increase and percentage of its current load compared with the temperature increase for 100% current load.



1- experimental figures of the temperature increase when the current load is 25% ,
2-calculated temperature increase concerning the percentage mistake of the measurement,
3-calculated temperature increase when the current load is 100%.

Fig. 8. Relation of conductor temperature increase and percentage of its current load

5. Conclusions

We think that combination of thermovision diagnostics, oil chromatography as well as others diagnostic methods themselves create very good conditions for realisation of qualitative and non-destructive defectoscopetion these machines.

The important attribute of the designed system would be the ability of autonomous operation without intervention of an operator. So at relatively favourable costs and minor intervention into monitoring equipment they can perform the basic function, i.e. to signalise and control the impairment of equipment insulation state within single decoding point.

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