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# THE POSSIBILITY OF INVESTIGATION OF THE DETERIORATION OF ELECTRICAL INSULATIONS BY NON - DESTRUCTIVE METHODS

The most significant electrical characteristics of an insulation is its dielectric strength. Due to the deteriorating processes (e.g. ageing, moistening etc.) the electric strength of an insulation, thus its reliability, too, decreases during its operation. From the point of view of the practice it would be of a great importance to follow the changes of the dielectric strength. Unfortunately, this cannot be carried out by direct measurements, as this would spoil the insulation. Thus the deterioration-process of the insulation has to be followed with other, non destructive testing methods and the conclusions concerning the change of its electric strength - and of its reliability, as well - have to be drawn from these investigations.

Non-destructive tests can be carried out by measuring the dielectric characteristics of insulations. The electric field in dielectrics effects two fundamental dielectric processes, the conduction and the polarization. The process of conduction can be characterised unambiguously by a single quantity, by the specific conductivity of the material, while to characterise the other process, the polarization, the use of the polarization spectrum of the material is required, what describes the distribution of the intensity of the elementary processes against the time-constant [2].

The deterioration causes chemical-physical changes in the structure of the material. As all of the electrical properties of the material are in strict relations with the microstructure of the dielectrics, by these micro-changes due to the deterioration not only the dielectric strength

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of the insulation will be influenced, but the conductive and polarisation processes, as well. This connection between the structure and the properties of the material makes it possible, to follow the progress of the deterioration by non-destructive dielectric measurements, thus to conclude indirectly to the change of the reliability of the insulation, too [1].

A great deal of information can be gained about the deterioration processes by investigating the various time-constant-ranges of the polarization spektrum. In Fig.1. the specific polarizability $\alpha$ of the dielectric is plotted against the time constant T. The polarization spectrum of a dielectric extends from cca. $10^{-12}$s up to $10^{4}$s time constants. Each of the processes is related to a well-defined type of charge carriers (ions or molekule-groups). If the density of a certain charge carriers changes due to the deteriorating processes, the intensity of the elementary polarization processes, related to these particles will change, too. That is, the change of the polarization speotrum, resp. the change of its parts will show the progress of the deterioration unambiguously. .

The various time-constant-ranges of the polarization spectrum can be examined by different measuring methods [4]. Infrared Spectroscopy is especially suitable for investigating the range of the shortest time-constants (i.e. $T < 10^{-10}$s), the range of cca. $10^{-9}\text{s} < T < 10^{-1}$s can be examined by measuring dielectric loss at radio-, sound- or industry frequencies. The value of the dielectric loss measured at a certain frequency is determined by the intensities of polarization processes of a narrower, approx. of a 2 - 3 decade range of the spectrum, thus it is possible, by changing systematically the measuring frequency to scan a wider part of the spectrum step by step [4].

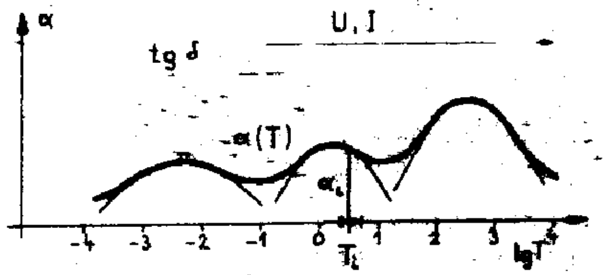


Fig.1. The polarization spectrum

DC methods are suitable for examining time constant ranges of $T > 10^{-1}$ s. These methods are based on measuring the current or voltage-response of the insulation to a voltage step. The current response of the insulation, e.g. charging current, decreasing in time, consists of three components.

$$I(t) = I_c(t) + I_p(t) + I_k$$

where: $I_c(t)$ - the capacitive component transporting the free charge, required to build up the electric field,

$I_p(t)$ - polarization component appears because of the developing of polarization processes, its value is proportional to the intensity of the processes,

$I_k$ - conductive component comes up in consequence of the finite insulating resistance of the dielectric.

Most of the information about processes arising in the insulation can be gained from the $I_p$ polarization component. It can be proved, that the $I_p(t_1)$ value measured at $t_1$ moment is determined only by elementary polarization processes of an cca. three decade range of the spectrum around the $T_k = t_1$ time constante. This relation enables to determine the distribution of intensities of the polarization processes from the $I_p(t)$ curve in a wider section of the spectrum [3,5].

By DC methods based on measuring the voltage-response of the insulation either the discharge voltage (after a longer excitation, so called "charging" period) or the return voltage (after a longer charging and a shorter discharging period) can be measured on the electrodes of the insulation. It can be proved that the initial slope of the return voltage curve is directly proportional to the intensity of the polarization processes, and so is the slope of the discharge voltage to the conductivity of the insulation [1,2]. Thus from the wiew-point of information-contents the discharge voltage is equivalent to the conductive current, while the return voltage to the polarization current component of the insulation.

The time-constant-range of a width of about three decades, effecting the return voltage, is determined by the charging and discharging periods only. By measuring return voltages with systematically changed charging and discharging times, it is possible - similarly to measuring loss factor in function of the frequency to scan a wider time-constant-range of the spectrum step by step [5,6].

The testing methods enlisted offer the possibility of investigating the conductive and polarization processes in the insulation, resp. by performing the measurements in regular intervals the changes of the processes due to the deterioration of the insulation, the progress of the deterioration can be followed.

As example for practical application of the testing methods, some results obtained by using the method of return voltage for testing insulations of power transformers are presented: insulations of the following four transformers of 120 kV were tested:

No.1. transformer after one-year operation, practically in a new condition,

No.2. transformer after 15 years of operation, with renewed insulation,

No.3. transformer after 6 years of operation, with a medium-state insulation,

No.4. transformer after 17 years of operation, in a very bad condition.

The return voltages were measured with U = 2 kV charging voltage. The charging and discharging periods were changed so, that the time-constant-range of approx. $10^{-2}$s $< T < 10^3$s of the polarization spectrum was examined.

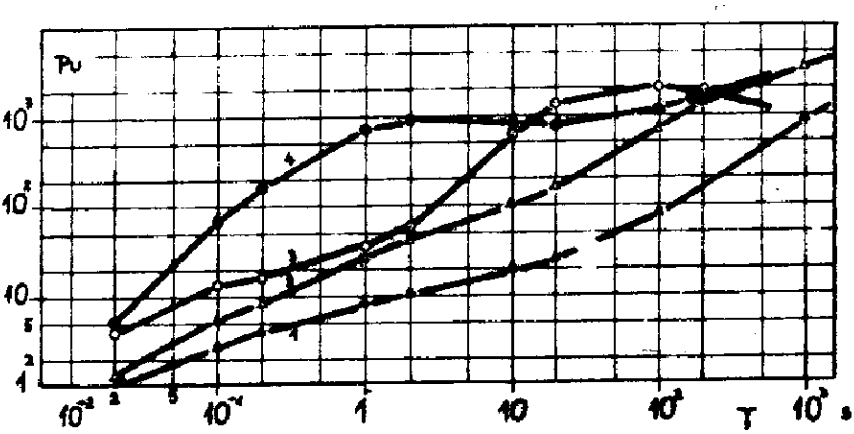


Fig.2. Polarization coefficients obtained on transformer insulations of different conditions

Fig.2. shows the $p_U = S \cdot T_k$ polarization coefficients plotted against time constant, calculated from the S initial slopes and the $T_k$ central

time-constants of the measured return voltages. The polarization coefficients are proportional to the intensities of the elementary polarization processes [5].

It can be seen, that the deterioration of impregnated paper insulation appears in the intensifying of polarization processes, esp. in the range of $10^{-1}$...10 s, unambiguously. In this range of polarization the deterioration process effected an increase of almost two scale of the intensity of polarization processes.

The measurements were carried out by the Insulation Control Service of the Hungarian Electricity Works (MVMT). The measuring instrument was prepared by the Research Institute of Electroindustry (VKI). The author thanks for the permission to publish the measuring results.

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