The Experience in Applying New Recovery Voltage Parameters for the Impregnated Paper Insulation Cable Condition Diagnostics

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ANNOTATION

New diagnostics parameters have been examined for the electric insulation technical condition estimation, which are calculated from the recovery voltage curve. It has demonstrated that their application gives an opportunity to control insulation ageing by both the volume charge condition change, and conductivity change. The experience in using these parameters is contributed for estimation of the technical condition of the impregnated paper insulation power cables after a long-term service in cable premises of nuclear power stations. The experimental results have shown that through the introduction of new parameters recovery voltage becomes a powerful method for controlling electric insulation at early stages of ageing and all the way down for it to achieve a limit state.

KEY WORDS

Electric insulation, recovery voltage, diagnostics parameters, conductivity, volume charge, polarization, cable, impregnated paper insulation.

INTRODUCTION

The recovery voltage (RV) measurement in cable and electrical equipment insulation is used as a method of their technical condition control including the paper impregnated lead cables (PILC). There are two main processes that determine the RV value: volume charge (interlayer) polarization and volume conductivity [1]. This gives reason to believe that control over ageing and moisturizing of the paper electric insulation can be performed by the RV value and form. That said, a wide introduction into practice of this method is restrained due to lack of full understanding of how does one get quantitative data from the RV curve in order to describe insulation ageing and moisturizing, and the effort to extract the input of conductivity and polarization to this curve remained unsuccessful. The task becomes even more difficult due to the dependence of both the RV value and form from the temperature and geometry of the controlled insulation, its type, and the parameters directly forming the RV value and form: charging voltage U_{ch}, charging time t_c and partial preliminary discharging time t_d.

This article presents a new approach towards estimating an electric insulation condition, which allows sharing the input of volume polarization and conductivity gained pursuant to the RV measurement results in the 6 kV PILC with different insulation ageing degree after a long-term service in NPP cable premises. Apart from the RV measurement for the cable condition control there were measurements of insulation resistivity, wide band dielectric dissipation factor, parameters of the partial discharge (PD) at damping oscillating voltage (the OWTS method) conducted, and time-space reflectometry was used.

IDENTIFICATION OF THE DIAGNOSTIC PARAMETERS FROM THE RECOVERY VOLTAGE CURVES

The basis for developing new diagnostic parameters (DP) is the approach for describing the recovery voltage curve $U_r(t)$ based on the traditional fitting, where the real relaxation polymer spectrum is replaced with the discrete set of Debye relaxation oscillator [1]. This allows conducting analysis in terms of the linear electric circuit theory, presenting the complex of the Debye relaxation oscillators as an equivalent electric circuit of the shunted R_iC_i circuits($i = 1, \dots, n$). The assessments provided in [1] have shown that relaxation oscillators with characteristic time scales making (0,2 - 50) $\cdot t_d$, while the RV maximum is formed through relaxation processes with time scales of about 100 $\cdot t_d$ and volume conductivity of an insulation material. For practice the important part is that the reduction of the relaxation processes down to three with constant time scales of about 1, 10 and 100 *s* almost doesn't lose the description precision of $U_r(t)$. Based on the assessments provided in [1] for $U_r(t)$ description one can use a semi-empirical model as a sum of exponents with constant parameters A_i and τ_i

$$U_r(t) = \sum_{i=1}^{n} A_i \cdot exp\left(-\frac{t}{\tau_i}\right), \qquad (1)$$

where t is time. And to describe actually measurable RV curves in the time band of 0,1 – 2000 *s* it would be sufficient for the *n*-value to amount to 3,4 or 5. A typical curve and its components defined by the model (1) are presented in Fig. 1. Here, as is customary, the RV polarity is negative, so the short-lived components are of positive polarity. It seems obvious that parameters A_i and τ_i or the RV maximum U_{rm} and its position in the time scale T_{rm}, may serve as the electric insulation DP, but these parameters depend, firstly, on the geometrical insulation dimensions, and secondly, these indicators don't allow simultaneously conducting a quantitative assessment of both the conductivity change, and the change in insulation polarization properties.

Usually $U_r(t)$ parameters are used for the electrical insulation moisturizing assessment, since it's fundamentally clear that the increase of the conductivity will lead to $U_r(t)$ curve "suppression", i.e. to value reduction and to the shift to the left on the curve time scale $U_r(t)$ [2, 3]. In practice such limited RV use when conducting technical diagnosis may lead to wrong conclusions on the insulation condition. By way of example of such errors, diagnostics of the PILC with typical defect – paper insulation shrinkage can be considered. Such defects are developed in vertical sections of cable routes after a long-term service due to saturant depletion. The development of such defects up to a certain point leads to the $U_r(t)$ curve shift to the right and the increase of its maximum. Thus, the use of the