A NUMERICAL METHOD FOR 3D-DESCRIPTION OF SCATTERED CHARACTERISTIC AGING DATA FROM MULTISTRESS AGED XLPE-CABLE INSULATION

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ABSTRACT

In the field of state estimation and insulation characterization of electrical equipment for power systems the main tasks for research work are actually represented by the development of diagnostic measuring techniques including appropriate data evaluation procedures, and tools for remaining life estimation. On the basis of experimental data yield by several diagnostic measurements on multistress aged XLPE-cable insulation in this contribution a numerical procedure is presented, which is intended to used as an analytical method for the description of the life volume for electrical equipment. By application of multivariate interpolation techniques from the field of scientific visualization a life volume based on experimental values from accelerated aging tests up to 1 year and simulated data with a maximum aging duration of 10 years is determined. The accuracy of this method is checked by comparison of the resulting simulated data and further experimental values, which were not included in the modelling procedure.

KEYWORDS

Numerical modelling, 3D scattered data, multistress aged XLPE-cable insulation, life volume

INTRODUCTION

XLPE is employed widely as insulating material for power cables predominantly owing to ecological and economical reasons. Especially good experiences in service and enhanced manufacturing procedures enable the use of XLPE as insulating material for high voltage and extra high voltage cables. For receiving a deeper understanding of the actual insulation state of the operating resource the comprehension of aging mechanisms resulting from multistress operating conditions, which are mainly characterized by the simultaneous presence of electrical and thermal stress, constitutes an essential task. Due to direct interaction between the aging factors synergic effects arise, and will affect the aging mechanisms however. For evaluation of the impact of interacting aging factors on the insulation condition suitable preferable non-destructive diagnostic techniques with derivable meaningful quantities are needed. The improvement regarding the sensitivity of well known diagnostic parameter and the development of new aging markers are still in an ongoing process [1], [2].

In addition most current efforts in the prediction of the remaining life of polymeric cable insulation are directed towards accelerated destructive aging tests, and the determination of the time to failure. This approach is applied for a long time, and leads to the development of some phenomenological aging models [1], [2]. These models are mainly based on thermodynamic relationships, though it should be noted that the basis for thermodynamics is strongly influenced by probability considerations. Therefore the relation between aging rate and life time is under discussion, and different approaches relating to this point exist. Moreover the impact of empirical experience on the adjustment of free equation parameters has to be taken into consideration when the gained results are compared with the data from other procedures [2].

With regard to the outlined focus in this contribution a different approach is presented, which is free from thermodynamic relationships, and not restricted to a specific measuring or testing procedure.

EXPERIMENTAL PRELIMINARY WORK

At the beginning of this research work an extensive laboratory aging course on full-sized XLPE-model cables with high voltage insulation quality and reduced insulation thickness was carried out with different combined electric field strengths, conductor temperatures, and test durations. The maximum aging parameters ranged between 20 °C...130 °C, 0 h...8760 h, and 0 kV/mm...52 kV/mm. After fixed time steps up to one year experimental investigations on different aged cables were performed. The tests consist of destructive and non-destructive methods, which are described in detail in [3] and [4]. The results obtained by diagnostic techniques like isothermal depolarisation current measurements or unilateral low-field nuclear magnetic resonance measurements provide suitable parameters to characterize synergic phenomena within the insulation morphology resulting from interacting aging factors. However the sensitivity of these techniques is observed for the applied aging parameter range, and stress conditions above aging thresholds discussed in relevant literature [1], [5].

Besides aging markers gained by non-destructive measurements classical insulation characterization was performed by destructive tests in order to determine the residual electrical strength of different aged XLPE-model cables too. Thus a proposed structure for a clear reference of every experimental data point in 3D space stretched up by the aging parameters electric field strength, conductor temperature, and test duration is summarized in Table 1.

Table 1: Summary of data structure for scattered data modelling of aging markers in 3D

x_i	y_j	z_k	G_{ijk}	method
coordinate			attribute	
ϑ_a	t_a	E_a	$E_{r,\,bd}$	residual electrical strength
ϑ_a	t_a	E_a	τ_i	isothermal depolarisation current
ϑ_a	t_a	E_a	T_2	nuclear magnetic resonance

This type of data structure constitutes in the field of numerical