C2.11

Life modeling of AC cable insulation based on space-charge inference

MAZZANTI G., MONTANARI G.C., University of Bologna, Italy
DISSADO L., Leicester University, United Kingdom

Résumé

Dans le travail présent, une procédure pour l'estimation rapide des paramètres du modèle de vie des charges d'espace récement développé par les auteurs de cet article est décrit. Il est basé sur les résultats des appropriés tests à court terme, parmi lesquels figurent des tests de durée de vie et des mesures de charges d'espace. La procédure est appliquée à une série de données provenant de minicables XLPE et donnent des valeurs de paramètres en assez bon accord avec le résultat des tests de durée de vie. Ainsi, la caractérisation de la résistance, la comparaison des matériaux et la perturbation de la durée de vie aux temps courts deviennent un but plus réaliste, ce qui apporte par ailleurs une signification pratique au modèle.

Abstract

In the present work, a procedure for short-time estimation of the parameters of the space-charge life model recently developed by the authors of this paper is described. It is based on the results of proper short-term tests, among which are life tests and space-charge measurements. The procedure is applied to data sets relevant to XLPE minicables and provides model parameter values that fit life test results quite well. Thus, endurance characterization, material comparison and life inference in short-times by means of the space-charge model become more realistic goals, which brings out the practical significance of the model.

1. Introduction

Recently, the authors of this paper have developed, within a thermodynamic framework, a life model for polymeric dielectrics based on the role of space-charges trapped inside insulation [1, 2]. The model, initially valid only for dc conditions, has then been extended to ac regime by explaining the dependency on supply frequency [3, 4].

The thermodynamic approach to life modeling involves the concept of thermally-activated reactions, that cause aging by transforming the material from reactant to degraded state through the crossing of a free energy barrier. The space-charge model assumes that space-charges trapped within the insulation when voltage is applied are responsible for electromechanical energy storage that, in turn, lowers the energy barrier, thus favouring degradation and shortening life [1-4]. The model is fully-explicit in both electric field and temperature, but is characterized by a fairly large number of parameters, i.e. 6. These parameters were determined numerically, in previous papers, by exploiting the results of accelerated life tests lasting up to (and sometimes more than) one year, according to the traditional approach to life modeling.

Here, attention is focused on the possibility to estimate space-charge model parameters in short times. By this way, both material characterization and indications on design stresses that the material can withstand in service can be attained quickly, thus providing useful indications for material selection and electrical insulation design. In order to achieve this goal, a procedure has been developed by means of proper rearrangements and simplifications of the model equation. This procedure leads eventually to a system of relationships in which quantities measurable by short term tests only appear. The system solution provides all model parameters.

The procedure for model parameter estimation is then applied to the results of tests performed on XLPE cable models and the relevant results are discussed.

2. The space-charge life model

According to the thermodynamic approach [5], insulation time-to-failure is inversely proportional to the rate constant of the main degradation reaction; in turn, the rate constant rises with temperature according to a Boltzmann-like law, governed by a free energy barrier that must be overcome in order that the degradation reaction can take place. Some authors (see, e.g., [6]) claim that electric field E lowers such barrier by rising reactant free energy, G_1 $(G_1(E\neq 0) > G_1(E=0))$.