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TOOLS FOR UNDERSTANDING THE THERMO-ELECTRICAL BEHAVIOUR OF XLPE INSULATION IN POWER CABLES AND ACCESSORIES

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ABSTRACT

We have developed numerical models of bipolar charge transport, featuring specific cases and geometries in order to predict the space charge behaviour and improve the knowledge on polymeric insulation under electrical stresses. This communication briefly describes the models, and shows comparisons of the numerical results with experiments, for 3 specific cases: a plan parallel geometry, a cylindrical geometry featuring a cable, and a dielectric-dielectric interface encountered in cable joints.

KEYWORDS

Space charge, cable insulation, joints, modelling, transport, organic insulation

INTRODUCTION

Polyethylene has advantageously replaced oil-impregnated paper as insulation in high voltage (HV) cable for electrical energy transport. However, after some fifty years of use, the drawbacks remain the same. We do not yet know how charges appear inside the insulation properties, how they behave and how they affect the dielectric under long periods of electrical stress. We have to improve our knowledge on this type of materials, and their behaviour once submitted to electrical stresses. Models could help in that way. We have developed a modelling approach, based on a step by step evolution of the models, in order to understand the behaviour of polymers under electrical stress [1, 2]. In this paper, we present a model of bipolar charge transport in polyethylene under DC stress, for three different case studies, i.e. a plane-parallel geometry, a dielectric-dielectric system, featuring the interface encountered in joints and terminations, and a cylindrical geometry, reproducing the cable system. This paper briefly describes the model, equations and their numerical resolution, and shows a comparison between experiments and simulation results for each case.

MODELS DESCRIPTION

Common features

Each model is one dimensional, function of the thickness of the dielectric. Figure 1 shows a schematic representation of each system used for the simulations, i.e. a plane parallel system (1.a), a dielectric-dielectric interface (1.b), featuring cable joints, and a cylindrical geometry (1.c) featuring a cable. Whatever the type of model, it is bi-polar, and features injection of electronic charges at both electrodes, charge trapping in traps distributed exponentially in trap depth, and hopping transport. For sake of simplification, recombination of charges and internal generation are not taken into account.

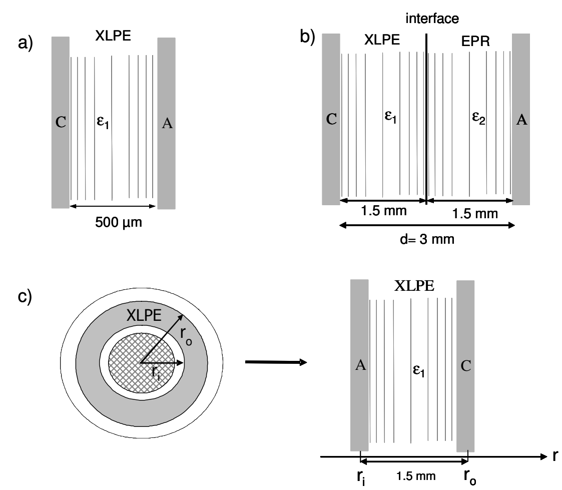

Figure 1: schematic representation of the one-dimensional systems used for the simulation. a) plan-parallel system, b) dielectric-dielectric interface, and c) cylindrical geometry.

Trap distribution: The chemical structure of the material is taken into account by considering an exponential distribution of trap levels (Figure 2), i.e. a large amount of shallow traps corresponding to physical defects, and a smaller amount of deep traps corresponding to impurities. This exponential distribution of traps has a maximum limit in trap depth, and is of the form:

$$N_{t(e,h)} = N'_{(e,h)} \exp\left(\frac{-\Delta_{e,h}}{k_B T_{0(e,h)}}\right) \qquad \Delta_{e,h} \le \Delta_{max(e,h)} \qquad (1)$$

Where $N_{t(e,h)}$ is the trap density distribution and is characterized by the parameters N', T_0 and the maximum limit in trap depth Δ_{max}. This exponential distribution of trap levels holds for each kind of carrier (electrons and holes). In the case of a dielectric-dielectric system, the exponential distribution of traps also holds for each type of material, only the values of the parameters change from one dielectric to the other. Traps are considered to be filled from the deepest level upwards.