Electric field distribution in polyethylene insulation used in the electric cables affected by water trees in the presence of space charges

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ABSTRACT

The aim of this work is to determine the distribution of the electric field in polyethylene insulation used in the medium voltage cable, affected by water trees and space charges, on the basis of numerical method results using Comsol Multiphysics.The results of investigation showed that the presence of water trees and accumulation of the space charges induce a significant variation of electric field close to the two semiconductor layers and in the volume of insulation. The repartition of the electric field depends on the magnitude of space charges density and their dynamic movement in the insulation with defects.

KEYWORDS

Electric cables, polyethylene insulation, water trees, electric field, space charges.

INTRODUCTION

The extruded polymeric materials are largely used as insulation of electric cables. Particularly polyethylene is widely used because of its good electrical properties (non-polar structure) combined with good physical properties. However, in a humid environment, the penetration of water inside the insulation can play a significant role in the formation of water trees [1]. Generally, water trees grow in the polymeric insulation in the presence of an intense electrical field, particularly in inhomogeneous areas which contain micro-cavities [2, 3]. These defects constitute an important factor in the electrical degradation process of the polymer insulation, induced by the change in the dielectric constant of the insulation. The dielectric properties of the polymers are probably modified by impurities. The ionization and migration of impurities under electrical stress will present the appearance of space charge [4-5]. Many studies have been carried out for a better comprehension of the space charges generation in the polymeric insulations. This work was directed so far towards the study of the space charge characteristics under D.C current, while the study of the dynamics of the space charge and its impacts on the electric defects under AC current caused only one limited attention [6]. Indeed the behavior of space charge in the water tree under AC current is still badly understood. To understand the displacement mechanism of space charge in the presence of defects in polymer, an evaluation of the electric field distribution is essential. In our study, conducted under Comsol Multiphisics environment, we chose the individual vented tree model with homogeneous electrical properties, illustrated in Figure (2). The aim of this work is to determine the electric field distribution in polyethylene insulation used in the medium and high voltage cables, affected by water trees in the presence of space charges. The investigation results showed a significant variation of electric field close to the two semiconductor layers and in the volume of insulation. The electric field distribution depends on both length and permittivity of water trees, as well as on the quantity of space charges accumulated and their dynamic movement in the insulation with defects.

THE GEOMETRIC AND PHYSICAL PROPERTIES OF THE CABLE MODEL

The model in figure (1) shows a 12 kV single core power cable with polyethylene insulation and 15 conductor's screens distributed along the outer circumference

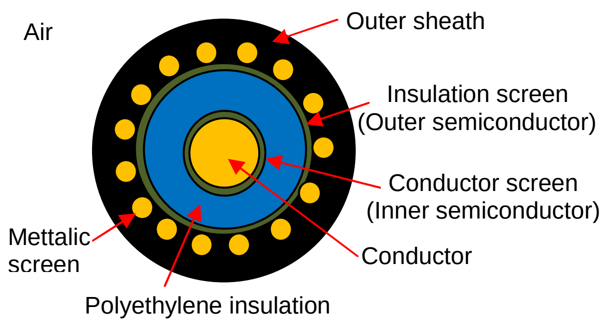

Fig. 1: Distribution cable cross section

The geometric and physical properties of the cable model are given in the table (1); the constituent materials of the cable are isotropic with constant permittivity.

Table.1 Geometric and physical properties of the cable

Characteristics	Dimension(mm)	Permittivity ε_r	Conductivity $\sigma(Sm^{-1})$
Conductor radius	3.5	$3.03*10^{7}$	1
Polyethylene insulation thickness	5.5	10^{-15}	2.3
Semi-conducting layers thickness	0.5	0.1	500
Neutral conductor radius	0.65	$5.99*10^{7}$	1
Jacket (polyethylene) thickness	2	10^{-10}	2.3