Influence of Relaxation Polarization on Charge Transportation in a Cable Geometry

Yunlon **SUN**, Zhonghua **LI**, Wenmin **GUO**, Yongsen **HAN;** Harbin University of Science and Technology, P. R. China,
sunyunlong_hust@qq.com, drzhhli@hrbust.edu.cn, g_wenmin@163.com, 327325977@qq.com

ABSTRACT

The influence of polarization with relaxation on the electric field distribution and charge transportation process in LDPE is studied by bipolar charge transportation model in a cable geometry. A relative permittivity depending on relaxation time constant which is a function of temperature is introduced in the model to describe the polarization process. The results in this paper show that the polarization will affect the evolution of space charge and electric field with time.

KEYWORDS

Low Density Polyethylene (LDPE); cable insulation; Bipolar Charge Transportation (BCT) model; polarization; temperature gradient; transient process

INTRODUCTION

In long distance power transmission, High voltage direct current (HVDC) power transmission has been preferred for its merits of large capacity, low dissipation and so on [1]. HVDC cables as a necessary component play an important role in power transmission. Lots of HVDC cables has been in service nowadays and the reliability of HVDC cables for long time service is mainly determined by cable insulation and always draws great attention [1]. Polyethylene (PE) is a favorable choice for HVDC cable insulation [2]. However, it is well known that space charge in polymer insulation can distort electric field drastically and once the local field exceeds the limit field strength the cable insulating materials can bear, the insulation failure happens [3].

The Bipolar Charge Transportation (BCT) model which takes charge injection by electrode, trapping, de-trapping and recombination into consideration is implemented in many papers to study space charge and the electric field distribution in polymer insulating materials [4-6]. However, the influence of polarization on charge transportation is rarely taken into consideration, which may make the calculation not reflect the real physical process and lead to inaccuracy results, because charge transportation and polarization happen simultaneously in insulation when a voltage is applied to a cable.

In this paper, a permittivity which depends on temperature is introduced in the model to describe the polarization process. We aim to study the influence of relaxation polarization on the electric field distribution and charge transportation in low density polyethylene (LDPE) based on the BCT model in a cable geometry. And the temperature gradient is also taken into consideration in the simulation.

SIMULATION MODEL DESCRIPTION

Bipolar Charge Transportation Model

The Bipolar charge transportation (BCT) model describes the charge transportation process in dielectrics as shown in Fig. 1, which considers the charge injected by electrodes, charge trapping and de-trapping, recombination during charge moving from one electrode to the opposite one.

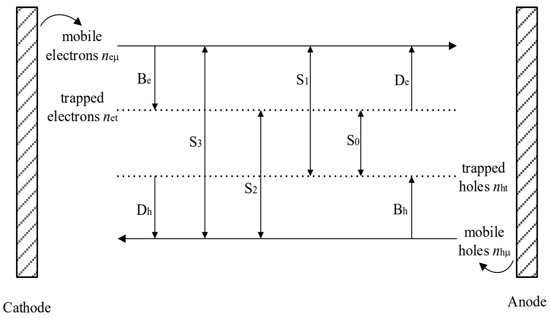

Fig. 1: Schematic of charge transportation.

In Fig. 1, $B_{e,\,h}$, $D_{e,\,h}$ and $S_{0,\,1,\,2,\,3}$ represents trapping, de-trapping and recombination coefficients for electrons and holes, respectively. The subscript e and h in parameters denote electron and hole.

De-trapping coefficients $D_{e,\,h}$ can be described by following expression barriers $w_{Dee,\,Deh}$ for electrons and holes. They have the form [6]:

$$D_{e,h} = \nu \cdot \exp\left(-\frac{e \cdot w_{Dee,Deh}}{k_B \cdot T}\right) \tag{1}$$

where:
ν: vibration frequency, here equals $k_B \cdot T/h$ (s^{-1});
h: Planck constant.

The recombination coefficient S_i, for example, S_3 has the form [2]:

$$S_3 = \frac{\mu_e + \mu_h}{\varepsilon_0 \varepsilon_r} \tag{2}$$

where:
ε_0: vacuum permittivity ($F \cdot m^{-1}$);
ε_r: relative permittivity;
$\mu_{e,\,h}$: charge mobility for electrons and holes ($m^2 \cdot V^{-1} \cdot s^{-1}$).

Charge transportation in polymers is often dominated by hopping mechanism, the mobility can be described by the following form [6]:

$$\mu\left(E(r)\right) = \frac{2\upsilon d_t}{E(r)} \exp\left(-\frac{\Delta_f}{k_B T(r)}\right) \sinh\left(\frac{eE(r)d_t}{2k_B T(r)}\right) \tag{3}$$

where
$E(r)$: the electric filed at position r (V/m);
υ: thermal vibration frequency (s^{-1});
d_t: the distance between two hopping positions (m);
k_B: Boltzmann constant ($J \cdot K^{-1}$);
Δ_f: the barrier that hopping charge needs to overcome (eV);
$T(r)$: temperature at position r (K).

Here assuming that the mobile holes and electrons are