Transient space charge phenomena in HVDC model cables

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ABSTRACT

In the development of polymer-insulated HVDC cable systems, space charge and conduction current are among the most important features to analyze. Space charge accumulation in the insulation drives the field distribution and directly impact on the performance of the cable. To have further information on the evolution of space charge, conduction current measurements under various electrical and thermal conditions are of great importance. Reversely, knowledge on space charge features brings understanding in conductivity behavior. The aim of this paper is to investigate the accumulation of space charge and charging current transients under various conditions of temperature and applied voltage in 1.5 mm-thick cross-linked polyethylene (XLPE) insulation of mini-cables by means of simulation and measurements.

KEYWORDS

Space charge, HVDC cable, electric field distribution, current transients.

INTRODUCTION

The number of HVDC link projects is experiencing an unprecedented growth due to the superiority of DC over the traditional HVAC energy transport [1]. Further, the development of insulating materials for HVDC cable manufacturing, especially polymers provides advantages in terms of cost, operating temperature, the risk of pollution or maintenance in comparison to impregnated paper-based insulation [2]. However, the use of synthetic insulation under electrical stress is generally confronted to space charge accumulation issues which may lead to the reduction of the cable performance and/or lifetime.

Among the various possible mechanisms of charges accumulation, the effect of conductivity gradient in the insulation, resulting from the distribution of temperature and/or electric field, has been the subject of many studies [3, 4, and 5]. It has been pointed out in the literature that the conductivity of polymeric insulator may vary strongly with temperature and magnitude of electric field. It has been also widely shown that space charge amount depends directly on conductivity gradient and thermal activation energy of conductivity. Therefore, conduction current measurements under various electrical and thermal conditions are of great importance to have more information on the evolution of space charge.

The objective of this paper is to report on transient space charge phenomena amongst which front of charges and charging current transients obtained under various conditions of temperature and applied voltage in the insulation of mini-cables. Several hypotheses are raised for explaining the front of charges and possible correlation to current transient in cylindrical geometry. The study requires assessing the evolution of conductivity vs. thermal and electrical stresses in the mini-cable. A two-dimensional function of the cable conductivity can be obtained from the fit of conduction current data acquired under various conditions of temperature (T) and voltage (V) using an analytical function of conductivity following the procedure explained in [5]. The obtained semi-empirical function of conductivity has been subsequently used in simulation to evaluate charging current transients in mini-cable.

EXPERIMENTAL

Samples

Samples used for conductivity and space charge measurements are mini-cables provided by Nexans. The test samples are sections of cables of approximately 3 m in length. The cable characteristic dimensions are reported in Fig. 1 where:

• The radius of the inner conductor is of 0.7 mm;

• The thicknesses of the internal and external semiconductor (SC) are respectively 0.7 mm and 0.15 mm;

• The inner and outer radius of insulation, r_i and r_e are respectively 1.4 mm and 2.9 mm; The insulator thickness is 1.5 mm.

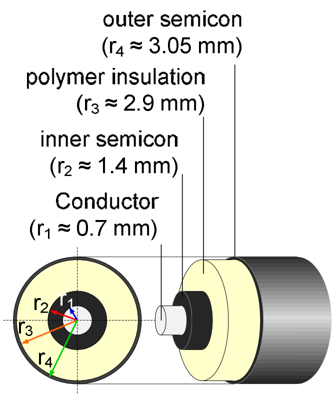

Fig. 1: Section of mini-cable sample

Space charge measurements on mini-cable samples

Space charge measurements have been carried out using the pulse-electro-acoustic (PEA) method through the configuration of Fig.2. The PEA cable device was provided by TechImp S.p.A., Italy. The cable was fixed to the PEA cell using a mechanical holder insuring a good acoustic contact between the outer SC and aluminum