High resolution space charge measurements on HVDC cable insulation systems

Shuo **ZHAO**, Jean-Charles **LAURENTIE**, Petru **NOTINGHER**, Jérôme **CASTELLON,** IES, University of Montpellier/CNRS (France), jean-charles.laurentie@umontpellier.fr, petru.notingher@umontpellier.fr, jerome.castellon@umontpellier.fr

Anthony **COMBESSIS**, Raphaël **GUFFOND**, Dimitri **CHARRIER**, Arnaud **ALLAIS**, Nexans (France), anthony.combessis@nexans.com, raphael.guffond@nexanx.com, dimitri.charrier@nexans.com, arnaud.allais@nexans.com

ABSTRACT

This work concerns the feasibility and the experimental set up of a device, based on the principle of the Thermal Step Method, to measure the space charges in insulating samples with semi-conducting electrodes with a resolution approaching the degree of homogeneity of the interfaces. A heat diffusing component where the heat is transferred to the sample by direct contact, providing a much better efficiency than state-of-the-art structures, is set up. The development of a measurement tool is then presented. Experimental results bring into focus performance several times higher in terms of positioning resolution with respect to the state of the art.

KEYWORDS

Space Charge, Electric Field, XLPE, HVDC Cable Insulation, High Resolution.

INTRODUCTION

The transport of electrical power is nowadays substantially increasing, with more and more demand for underground and submarine HVDC cables. Polymer-insulated HVDC cables are an important way of multiplying the quantities of available components, in complement to classical oil-filled and mass-impregnated cables. These cables with “dry” insulations must have at least the same degree of reliability as those manufactured with “wet” insulations. In the case of polymer-insulated HVDC cables and accessories, the reliability problems are mainly related to the establishment, under high electric field and temperature gradients, of electric charge zones in dielectrics. Such charge accumulations, usually called "space charges" because distributed in an insulating space, locally over-stress the material and can cause premature aging or even sudden failure. The new materials and processes used to manufacture the insulation must make it possible to limit or to control space charge accumulation. Determining the dynamics of space charges in materials is then a key factor, because it is essential to be able to locate and quantify with the greatest precision the fields induced by these charges, in order to anticipate their effects and guarantee the longevity and performance of the components. Consequently, space charge measurements in polymeric insulating materials for HVDC cables are essential.

For several years, non-destructive methods for measuring space charges have been developed. Because of the efficiency of the heat transfer mechanism, thermal techniques (like the Thermal Step Method [1]) allow to obtain high resolutions and sensitivities at electrodes [2]. Thus, resolutions of the order of 1 µm close to the sample surface have been reported in the literature by thermal methods applied to very thin films (5-10 µm) [3-5]. When the thickness exceeds 100 µm, available resolutions can hardly fall below 10 µm.

In the case of the Thermal Step Method (TSM), the thicknesses of the used samples are typically between 250 µm and 30 mm. The method is based on the application of a thermal stimulus in the form of a temperature step on a border of the measured sample, and can be used in flat and cylindrical configurations. The TSM offers a good compromise of sophistication, compatibility with the type of sample to study and possibility of obtaining the desired resolution, which made it a good candidate for this study.

The aim of this work was to make the TSM evolve to contribute to a better understanding of the establishment and evolution of electric fields and space charges at the interfaces between the insulating and semiconducting layers of HVDC cables. Space charge detection at the insulation/semiconductor interface was targeted, with a resolution as close as possible to the spatial homogeneity level of these interfaces (of the micron order).

In order to achieve this objective, specific samples have been designed and manufactured, an innovative thermal diffuser has been specifically developed and a new experimental facility has been set up. Calibration procedures have been set-up and used, and a space charge measurement campaign has been made in order to validate the aim of the study.

SPATIAL RESOLUTION

Spatial resolution concerns the smallest distance between two features that can still be discerned and is a key parameter for the measurement of any space charge distribution [6]. Two types of spatial resolution can be considered [7]. The positioning resolution (PR) can be defined as the smallest charge displacement between two measurements that modifies the signal by the noise level for a given signal to noise ratio (SNR). The discerning resolution (DR) can be defined as the smallest distance between two identical charges producing a signal that differs by the noise level from the signal produced by a charge at the same mean position but of twice the amplitude, for a given signal to noise ratio.

EXPERIMENTAL SET UP

Samples

In order to be compatible with the targeted resolution (of the micron order) while remaining close to the cable insulation system configuration, specific samples have been manufactured (Figure 1). The samples are planar insulating structures with electrodes of a diameter D = 50 mm. They are composed of a layer of crosslinked polyethylene (XLPE) with a thickness d_{XLPE} = 100 µm and of a layer of semiconductor with a thickness d_s between 20 and 30 µm. The structure is placed on a metal substrate for practical reasons. Such a structure was taken as basis for