EVOLUTION OF THE DISTRIBUTIONS OF ELECTRIC FIELD AND OF SPACE CHARGE IN AN EXTRUDED HVDC CABLE

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ABSTRACT

The distributions of electric field and space charge in polymer insulation at DC have gained much attention, and in particular space charge data using the PEA technique have been published extensively. The distribution of conductivity in the insulation layers subjected to high voltage experiments is unfortunately often not addressed. In this paper the relations between conductivity, space charge and electric field are discussed, and it is proposed that typical distributions of space charge can be explained by considering the distribution of conductivity in the insulation layers.

INTRODUCTION

Until the end of the 1980ies studies on polymer insulation for DC applications often focussed on the conduction properties, see e.g. [1] and [2]. It was recognized that different polymers had different conductivity making some materials more suitable than others as DC insulation in e.g. cables. The influence of the composition of a polymer was also revealed, and in order to make repeatable measurements of conductivity on thin plate samples, the use of a vacuum chamber housing the test sample and measurement electrodes was sometimes practiced, see e.g. [3].

From the late 1980ies much focus has shifted from conduction properties to space charge properties, probably due to the development of different measurement techniques that provide observation of space charge and interface charge of solid insulation systems. Almost all research papers published during the 1990ies dealing with polymer insulation for DC cables included comments on space charge properties. New space charge data were presented but the interpretations were often not leading to constructive conclusions.

In the present paper some general observations on conductivity and space charge in polymer insulation at DC will be discussed. Considering insulation materials that are suitable for HVDC cables and reasonable electric fields the space charge distribution in the insulation layer is a consequence of the distribution of conductivity. The electric field and space charge can be predicted with a simple FEM model as long as the conductivity characteristics and detailed composition of the insulation layer is known.

EXAMPLES OF PEA CURVES

The PEA technique (Pulsed Electro Acoustic) has been used extensively to generate profiles of space charge in flat and cylindrical test samples. The measurement principle is that an acoustic pulse is generated from space charge when an electric pulse is applied to the test sample. The acoustic response is detected and a profile of the space charge distribution between the electrodes can be obtained. Often the interface charge at the electrodes is dominating in the acoustic response and a high frequency pulse is needed to obtain good resolution of the space charge close to the electrodes. For thick insulation layers there is always a compromise between resolution close to the electrode that is facing the detector and the signal strength from the insulation further away.

Three typical space charge profiles are shown in Fig. 1. The blue solid horizontal curve represents an insulation layer without space charge. Signals are obtained from the interface charge at both electrodes but no signal is obtained from within the insulation.

The green dashed curve shows negative space charge with largest magnitude close to the left hand side electrode. This type of space charge distribution is often seen in cables and sometimes in plate samples. The space charge close to the left hand side electrode is often described as heterocharge since it has the opposite sign as compared to the voltage applied at the electrode. The charge close to the other electrode, still negative, is described as homocharge since it has the same sign as the adjacent electrode charge. Even in situations with poor resolution of the space charge inside the insulation layer the characteristics of the green dashed curve can be spotted by looking at the interface charge. At the left hand side the interface charge is increased as compared to the interface charge without space charge and at the other electrode the magnitude of the interface charge is decreased. The magnitude of the interface charge is directly proportional to the electric field at the interface and therefore the term field enhancement is sometimes used when the interface charge is increased due to hetero space charge.

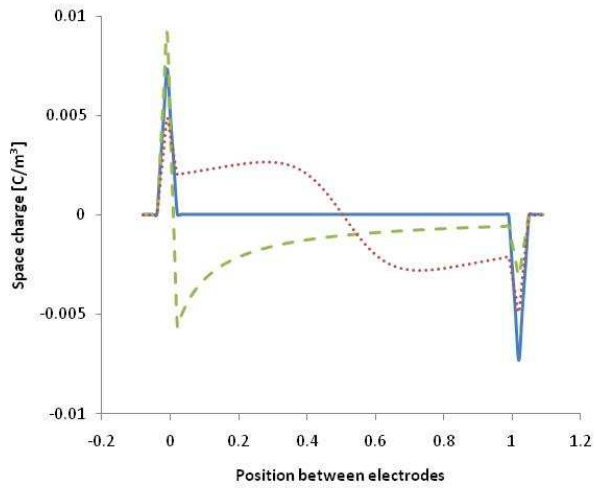

Fig. 1. Example of space charge profiles in flat insulation samples.