Space charge distribution in XLPE plates with non-uniform conductivity

Carl-Olof **OLSSON**, Birgitta **KÄLLSTRAND**, Bin **MA**, Maria **LUNDMARK**, Kenneth **JOHANSSON**, Sara **ARNSTEN**; ABB AB, Corporate Research, Västerås, Sweden, carl-olof.olsson@se.abb.com

Amirhossein **ABBASI**, Markus **SALTZER**, Marc **JEROENSE**; ABB AB, High Voltage Cables, Karlskrona, Sweden

ABSTRACT

The PEA method has been used to measure the distribution of space charge in XLPE plates having non-uniform as well as uniform distribution of peroxide by-products. Based on the one-dimensional space charge distribution, the electric field distribution and conductivity distribution are evaluated. GC-FID has been used to measure the by-product concentration distribution across the plates. The PEA measurements are made at ±40 kV at room temperature. The evolution of the space charge distribution is followed during two weeks for each sample including switching the polarity. It is found that the distribution of peroxide by-products has a strong impact on the field distribution, and the transition time correlates with the conductivity level through the dielectric time constant. It is also found that for samples having uniform peroxide by-product distribution, the electric field can be slightly non-uniform and the steady-state electric field is not fully symmetric when switching the polarity.

KEYWORDS

Insulation, XLPE, space charge, electric field, conductivity, peroxide by-products

INTRODUCTION

Crosslinked polyethylene has now been used in HVDC cables since about 20 years, and the operational experience is very good. The cables provide all the favorable mechanical properties that have been established for HVAC cables. The particular properties required for reliable operation with HVDC have also been mastered – since 2014 for operating voltage up to 525 kV. In the recent development efforts to reach higher voltages, the key parameter has been the electrical conductivity that has to be sufficiently low in order to avoid heating in the insulation due to the leakage current. An additional criterion is that the distribution of conductivity across the insulation has to be sufficiently uniform in order to avoid local field enhancement that could initiate breakdown.

For crosslinked polyethylene, XLPE, the conductivity is influenced by the concentration of peroxide by-products. The higher the concentration the higher the conductivity. This means that an insulation layer that has a gradient in peroxide by-product concentration also would have a gradient in conductivity [1].

The pulsed electro-acoustic method, PEA, has been used to measure the distribution of space charge in insulation samples. The method has been available since about 25 years ago and can be applied to thin polymer films, to plates and to cables, for a wide range of electric fields and temperatures. The equipment used in the present study is the same as the one used 20 years ago [2]. However, the insulation materials have been refined since then. In addition, the dominating features that are observed in measurements can also be explained and illustrated with finite element simulations in which the electrical equations can be combined with diffusion of chemicals and heat conduction [3].

Detailed knowledge of the chemical composition of polymer insulation is often important in order to correlate electrical measurement results with the appropriate parameters. In the current study it is expected that the peroxide by-products should have a dominating influence, and these are quantified by preparing thin slices of the samples and measure the concentration in each slice. It can still not be ruled out that additional parameters might influence the results, such as chemical reactions at the electrodes or traces of water remaining from the peroxide decomposition.

A similar study was made on model cables [4-5], when a concentration gradient was created by degassing a section of an XLPE cable using a hot air gun during 24 h. PEA measurements were made at ±150 kV, with the polarity switch after the first day. The electric field ratios at the interfaces are shown in Fig. 1. The transition to a steady-state resistive field distribution took about 12 h, and at steady-state the electric field distribution was the same for both polarities. The objective of the present investigation is to perform similar PEA measurements but now on XLPE plates. The available literature on PEA measurements is abundant, however there is still not much consensus on what are the useful conclusions that can be expected from such measurements. Due to the possible influence from sample handling and choice of electrode materials on the space charge distribution and interface charge development, measurements on films or plate samples might not always give information relevant for the insulation material as such.

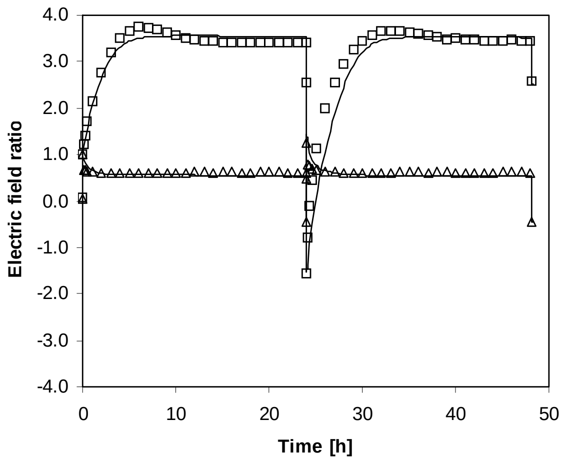

Fig. 1: Electric field ratio in a cable during 23 h at -150 kV followed by 24 h at +150 kV. Solid curves from FEM calculation and markers from PEA