Assessment of the impact of the electrical stress on the ageing for a HVDC model cable

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ABSTRACT

The objective of this study is to investigate the impact of thermoelectrical stress compared to thermal stress on the properties of HVDC model cables. To do so, electrical and physico-chemical characterizations have been performed as a function of ageing time that extends over several months. Electrical characterizations show that the thermoelectrical ageing tends to decrease the conductivity compared to the thermal ageing. The same conclusion holds for space charge, where more charges are observed during characterization for a thermally aged cable, compared to an electro-thermally stressed one. Physico-chemical characterizations do not show significant differences between thermoelectrical and thermal ageing. Both ageing conditions show an increase of the carbonyl index with ageing time.

KEYWORDS

XLPE; HVDC; Ageing; Space charge; Cables; Conductivity.

INTRODUCTION

In the field of electricity transmission (high voltage underground cables), the challenge lies in the development of increasingly compact, reliable and environmentally friendly systems. In this context, polyethylene, notably XLPE has become a material of choice for HVDC cable insulation. However, with the significant growth of the technology over the last 20 years at increasing voltage levels, the behavior of XLPE insulation needs to be better known under higher DC stress. Many ageing studies have been performed on XLPE, but over relatively short periods of time, at temperatures well above the melting temperature without electrical stress or with relatively low DC electrical stress [1]–[3]. The objective of this study is to characterize and compare the electrical and physico-chemical evolutions of a model cable system subjected to thermoelectrical or thermal stress for a long period of time. To do so, the applied thermal stress, although above typical operating temperatures of full size cable systems, was kept under the material's melting temperature, while a significantly higher electrical stress was applied than the typical nominal electric stresses of full size cable systems in operation. Ageing and characterizations are performed on model cables thus taking into account the cylindrical geometry, as well as the presence of semi-conducting layers (SC). Current measurements and space charge measurements, for the electrical characterizations, and Infra-Red spectroscopy as well as DSC have been performed on unaged and aged samples.

SAMPLES AND METHODS

The sample used for this study is a model cable extruded on a laboratory CCV line using HVDC XLPE grade materials. The main advantages of this type of sample compared to plaques are the cylindrical geometry as well as the presence of the semi-conductive layers (SC). The model cables consist of a solid copper core and a three layer insulation system (SC / XLPE / SC). The core radius is r_1=0.7 mm, the inner SC radius r_2=1.5 mm, the insulator radius r_3=3mm and the outer SC radius r_4=3.7 mm. Electrical and physicochemical characterizations were performed on an unaged model cable to provide a reference state of the insulation. These characterizations were also performed on aged model cable to observe the evolution with ageing time. The electrical characterization consists of current measurements, to calculate the conductivity, and space charge measurements using the Pulsed Electro-Acoustic (PEA) method. The physicochemical characterizations were carried out using infrared spectroscopy (FTIR), calorimetric analysis (DSC). Thermogravimetric analysis (TGA) and dynamic mechanical analysis (DMA) were also conducted, but are not presented here as results did not provide any significant information.

Ageing set-up

Two ageing protocols were conducted in parallel in ovens with air circulation for 24 months:

- 1: thermal ageing: 100°C isothermal
- 2: thermoelectrical ageing: The temperature is also 100°C isothermal. A voltage of 90kV DC is applied at the core of the cable providing an electric field of 87 kV/mm at the internal SC/XLPE interface and 43 kV/mm at the external XLPE/SC interface. The average electric field over the thickness is 60 kV/mm.

For each ageing protocol, samples are collected every 6 weeks for electrical and physico-chemical characterizations. The ageing test bench is described in the following publication [4].

Electrical characterization

Each characterization (current or space charge measurement) is performed during 4h / 4h polarization / depolarization.

Current measurements on unaged cable: The measurements were performed at five different temperatures (25-45-70-90-100°C), and four different electric fields per temperature (5-10-15-20 kV/mm). The