Key properties of next generation XLPE insulation material for HVDC cables

Villgot **ENGLUND**, Johan **ANDERSSON**, Virginie **ERIKSSON**, Per-Ola **HAGSTRAND,** Wendy **LOYENS,** Ulf H. **NILSSON,** Annika **SMEDBERG**
Borealis AB, Stenungsund, Sweden, villgot.englund@borealisgroup.com, carljohan.andersson@borealisgroup.com, virginie.eriksson@borealisgroup.com, per-ola.hagstrand@borealisgroup.com, wendy.loyens@borealisgroup.com, ulf.nilsson@borealisgroup.com, annika.smedberg@borealisgroup.com

ABSTRACT

The next generation material for extrudable HVDC cable insulation systems has been developed to support and facilitate further integration of renewable resources into the grid as well as the growing number of long distance interconnectors between countries and regions. The new material presented in this paper has passed both type test and pre-qualification tests according to Cigre TB 496 [1] at a voltage level of 525 kV. The paper describes the material characteristics for cable insulation system.

KEYWORDS

XLPE, HVDC, Cable insulation, DC conductivity

INTRODUCTION

The installation and connection of renewable energy resources in the power grid have during the last decade increased significantly. In addition, the need for interconnectors to facilitate a secure and reliable supply of energy has been receiving much focus lately. The long distances usually existing between power generation and actual load centres has led to a vast deployment of HVDC transmission lines and cables. This deployment has been emphasised with the increase in off-shore wind farms, as well as the long length interconnections in the European transmission grid. For this type of long distance bulk energy transportation HVDC is the only viable alternative, where extruded HVDC cables have played an important and steadily increasing part. The operational experience of extruded HVDC cables is excellent and growing. The expressed future requirements of further increased power transmission capacity will require HVDC power links to operate at increasingly higher voltages and stress levels. To facilitate this, a new material has been developed and successfully tested according to the Cigre recommendations in TB 496 [1] for HVDC cables up to 500 kV. It has been tested in both type test and long term prequalification test at a voltage level of 525 kV (VSC). This paper will summarise the properties of this material both in terms of electrical and short term non-electrical properties. The long-term properties of the same material are described by Eriksson et al [2].

MATERIALS AND METHODS

Materials

The materials discussed in this paper are two XLPE (cross-linkable polyethylene) materials both having high chemical cleanliness and produced in commercial scale, where Material A is the non-filled industry standard material with conventional cross-linking level and the novel Material B is a non-filled cross-linkable polyethylene building on the same technology platform and track record as Material A, but with an optimised composition designed for a low DC conductivity. Furthermore, Material B has a substantially lower peroxide content as earlier briefly described by Englund et. al. [3]. Both materials have an $MFR_{2.16}$ of 2 g/10 min measured at 190°C and a density of 922 kg/m^3. For comparison, a thermoplastic version of Material B has been used in some tests.

DC conductivity

DC conductivity is measured on 1 mm plaques with a diameter of 26 cm. The pellets are compression moulded in two steps: the first step at 130°C for 10 min to melt the material and get a homogeneous plaque which is subsequently cross-linked in a second step at 180°C for 12 min. For the case of non-degassed samples, the plaque is taken directly from the compression mould and put in the three-electrode set up measuring-cell. Otherwise the sample is degassed in an oven at 70°C for 4 or 24 h respectively before it is placed in the measurement cell. The DC conductivity value reported is the average between the 22nd and 23rd hour of measurement, seen as a quasi-steady state. This set-up has earlier been presented in several papers [4, 5].

Degassing

The degassing study was done on cables with 10 mm insulation thickness and two 1 mm semi-conductive layers of a commercially available HVDC semi-conductive material on a 150 mm^2 aluminium conductor.

The methane was analysed with Gas Chromatography (GC), as described in [6], using a pie shaped cable piece containing both the insulation and semi-conductive layers. The peroxide decomposition products (PDP) were analysed using High Performance Liquid Chromatography (HPLC) using 1 g pie shaped samples and analysis method as described in [6]. The HPLC sample was placed in a sealed bottle containing 50 ml of a 50/50 solvent mixture of isopropanol and cyclohexane. The sample was then extracted at 72ºC for 2 h. 10 µl from this solution was injected into the HPLC (Waters 2695) using water and acetonitrile as the mobile phase. The amount of polar peroxide decomposition products was determined.

Scorch performance

The carrot scorch test is a specifically in-house designed method to quantify the degree of scorch during extrusion. It is an accelerated test and simulates the degree of scorch that usually takes much longer time to build up. For this, a laboratory extruder with a special designed die is used.