

Fully-crosslinked XLPE with low conductivity for DC insulation

Timothy **PERSON**; The Dow Chemical Company, Collegeville, USA, persontj@dow.com

Stephen **CREE**; Dow Europe GmbH, Horgen, Switzerland, cree@dow.com

Yong Yong **YANG**; Dow Chemical (China) Investment Co. Ltd., Shanghai, China, YYYang2@dow.com

ABSTRACT

Conductivity and breakdown strength of crosslinked plaques and slices from full-sized cables are measured before and after degassing, and are compared to residual acetophenone content. Conductivity of two fully formulated XLPEs are compared to LDPE crosslinked with a range of peroxide content. Results suggest that low dc conductivity suitable for HVDC applications can be achieved without compromising the thermomechanical properties characteristic of 90C-rated XLPE.

KEYWORDS

XLPE, conductivity, HVDC, byproducts

INTRODUCTION

The use of extruded insulation for high-voltage direct current (HVDC) applications continues to grow with installations up to 320kV and material evaluations above 500 and even 600kV [1,2]. It is generally accepted that the main challenge in materials design for extruded HVDC cables is the management of space charge distribution and the associated internal field enhancement. A field- and temperature-dependent conductivity can naturally lead to a non-uniform charge distribution and an estimate for the steady-state field distribution, which is influenced by the temperature difference across the insulation [3]. However, such steady-state analyses avoid dealing with charge injection phenomena as it relates to bulk conduction, where imbalances can result in homocharge or more severe heterocharge accumulation. In other work [4,5] investigations of the impact of crosslinking byproducts on conductivity and space charge accumulation involved soaking byproducts into polyethylene films at relatively high levels. In general, conductivity was shown to increase and space charge accumulation was enhanced in samples soaked with byproducts. Degassing of cable has also demonstrated that removal of crosslinking byproducts can lead to reduced leakage current [6]. The presence of byproducts with certain antioxidant functionality has also been linked to heterocharge formation [7]. Works such as these have contributed to a general trend to focus on minimizing peroxide byproduct content as a means to reduce leakage current and reduce space charge in HVDC insulation. Some of the most recent materials which claim to be suitable for 600kV DC applications include a crosslinked polyethylene solution with a reduced crosslinking density and an entirely thermoplastic solution, both of which sacrifice thermomechanical properties to reduce or eliminate crosslinking byproduct content.

However, more recent work has challenged the direct relation between crosslinking byproducts and low DC conductivity. Ghorbani [8] studied LDPE and XLPE using various pressing films and heat treatments and did not find a clear correlation between DC conductivity and crosslinking byproduct content. He suggested that

morphological changes must also play a role. Person, et al [9], also found only small changes in DC conductivity between crosslinked films which were non-degassed and degassed, and found significant impact in apparent conductivity due to the nature of the semiconductive shielding material used as the HV electrode. In this paper, the impact of crosslinking byproducts on conductivity and DC breakdown strength is examined in crosslinked films and in samples from full-sized 320kV and 550kV cables with the intent to demonstrate that low conductivity can be achieved without sacrificing the thermomechanical properties associated with 90C-rated XLPE.

EXPERIMENTAL DETAILS

Materials

Two formulated XLPEs are compared in this work. XLPE-1 is a commercially available low-cure HVDC insulation which has been claimed to be suitable for >500kV DC applications. XLPE-2 is a new XLPE which has been modified for HVDC performance. Dicumyl peroxide was also incorporated at various levels into a power cable grade of LDPE without any antioxidant for evaluations of the effect of crosslinking byproducts.

Methods

Peroxide incorporation

Fully-formulated compounds of XLPE-1 and XLPE-2 were utilized as received. Addition of dicumyl peroxide to LDPE controls was achieved by diffusion of liquid peroxide into warm LDPE pellets. Dicumyl peroxide was allowed to melt at 55C. LDPE pellets were warmed in a small jar in a 70C oven for 4 hours. A target mass of molten peroxide was added to the jar with warm LDPE pellets, the jar was sealed and then tumbled for several minutes until the surface of the pellets appeared dry. The coated pellets in the sealed jar were returned to the 70C oven overnight to complete the diffusive incorporation of the peroxide.

Preparation of Crosslinked Plaques

Crosslinked plaques were formed by compression molding of pelleted compositions. Plattens were heated to 130C for 3 minutes at low pressure < 500psi, followed by an increase of pressure over two minutes to a high pressure condition at 2500psi, which was held for 3 minutes. The temperature was then increased to 180C for 12 minutes under high pressure to crosslink the samples, followed by a cooling under pressure.

Crosslinked plaques of approximately 0.2mm thickness for conductivity measurements were formed by compression molding between polyethylene terephthalate (PET) or aluminum pressing sheets. Samples were retained between pressing sheets until immediately prior to testing of conductivity of non-degassed samples. For degassing, the sheets were removed and samples were placed into a