High Performance Thermoplastic Cable Insulation Systems for Flexible Network Operation

Alun **VAUGHAN**, Ian **HOSIER**; University of Southampton, Southampton, SO17 1BJ, UK; asv@ecs.soton.ac.uk, ilh@ecs.soton.ac.uk

Gary **STEVENS**, Amy **PYE**, Janet **THOMAS**; GnoSys Global Ltd, Guildford, GU2 7YD, UK, g.stevens@gnosysgroup.com, a.pye@gnsosygroup.com, j.thomas@gnosysgrpoup.com

Simon **SUTTON;** Consultant and Senior Research Associate GnoSys, Egham, Surrey, UK, simon.j.sutton@gmail.com

Theo **GEUSSENS;** Dow Europe GmbH, CH-8810 Horgen, CH; tgeussens@dow.com

ABSTRACT

Crosslinked polyethylene has a successful history as a cable insulation material. Nevertheless, in recent years, as environmental awareness has grown, concerns about the environmental performance of conventional cables has increased. This paper concentrates on the development of thermoplastic alternatives, PE and PP blends. These blends were examined both on a laboratory scale and as mini-cable. Both blends exhibit superior breakdown strengths and high temperature mechanical stiffness compared to XLPE, making them suitable for HV cable application.

KEYWORDS

Cables, insulation, copolymer, polymer blends, polyethylene, polypropylene, recyclable, dielectric breakdown.

INTRODUCTION

Crosslinked polyethylene (XLPE) has been widely used in power cable electrical insulation systems for different electrical transmission and distribution system applications for many years. While crosslinking confers improvements in high temperature thermo-mechanical properties compared with the base low density polyethylene (LDPE), the maximum continuous operating temperature is nevertheless limited to ~90°C, because the material softens dramatically as the material approaches and goes through the melting transition. This has consequences for both continuous and emergency cable rating which, in turn, has implications for power network operational flexibility.

In addition to the operational considerations, from an environmental and economic view point extrusion and crosslinking of XLPE for polymeric cables is energy intensive with regards to the required crosslinking and degassing steps. XLPE is also difficult to recycle and consequently increasing environmental consciousness has led to the development of XLPE recycling technologies and to the formulation of novel, propylene-based, thermoplastic alternatives.

While high density polyethylene (HDPE) has greater potential operating temperature headroom than either LDPE or XLPE, its stiffness is problematical for cable applications and its microstructure intrinsically contains electrically weak regions that adversely affect breakdown strength.

In this paper we describe the principles underpinning new and patented thermoplastic insulation systems which can be actively designed with improved properties and performance. We will illustrate this in various embodiments involving polyethylene and polypropylene blends.

EXPERIMENTAL PROCEDURES

Sample Preparation

The materials discussed in this paper were as follows:

An HDPE: LDPE utilizing Dow HDPE 40055E and a non-commercial grade LDPE system.

A polypropylene blend utilizing iPP, Dow H358-02 with various propylene: ethylene copolymer systems from Dow's Versify™ range.

Pellets were produced utilizing lab scale extruders with the appropriate melt temperature and screw speeds. Filtration using screens was carried out to ensure the required cleanliness levels and antioxidant packages were utilized at typical commercial levels. The exact preparation methods are described elsewhere for the PE blend and the PP blend [1-2].

Thin film samples for breakdown testing were prepared by melting the pellets between aluminium foils in a Graseby Specac hydraulic press equipped with a thin film making accessory to give disks ~85 µm in thickness. These were transferred into a Mettler Toledo FP82 hot stage, held at 200 °C for 2 min for residual stresses to relax and, finally, either quenched into cold water or crystallized in the hot stage from 130 °C to 90 °C at the required cooling rate.

Mini-Cable Manufacture

Cables were manufactured on a Troester triple extrusion line for both the PE and PP blends, with different operational conditions. These conditions are described in detail elsewhere [1-2]. However, in summary, a 25mm^2 aluminium conductor was used in both cases, and the cable was constructed with a conventional structure (conductor; semi-con; insulation). As a reference, in both work programmes, an XLPE benchmark was also produced for comparison, in exactly the same way.

In the PE blend, preliminary experiments had demonstrated that high voltage breakdown testing of such