Development of a thermoplastic insulation system for medium voltage cables

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ABSTRACT

The industry looked at the challenge of developing an alternative polymer to XLPE for power cable insulation.

We developed an insulation system that is completely thermoplastic, meaning the insulation, the conductor and the insulation screen.

The paper will show the development of a fully thermoplastic insulation system, insulation and semi-conductive shielding for medium voltage cables for a conductor size up to 1200 mm^2.

It will additionally show first results in short term cable testing for water trees. It will show the first laboratory tests that were made to evaluate the suitability for a water tree retardant cable.

KEYWORDS

Thermoplastic insulation, power cable, ampacity, polypropylene

SUMMARY

A fully thermoplastic insulation system based on polypropylene for medium voltage cables has been developed for the Dutch market. The cable did not show significant differences to a cable with an XLPE insulation system.

This development gave us an insulation and semi-conductive compound that has comparable properties to XLPE compounds. It actually has longer elongation at break. Looking at the low temperature performance there is no risk installing this cable down to – 20 °C. A lower temperature was not tested.

The dielectric properties are in the same range as for XLPE with excellent breakdown values.

The resistance against the growth of water trees is, at least in laboratory tests, in the same range as a so-called TRXLPE and better than most commercial general purpose XLPE compounds.

INTRODUCTION

Cross-linked polyethylene (XLPE) has a very good track record for power cable insulation. It has been used for up to 500 kV AC application and is currently tested for 550 kV DC cable systems.

For up to 150 kV ethylene-propylene rubber (EPR) has also been used but due to high losses and cost the use has been limited for truly flexible installation needs and in Europe it is mainly used for mining cable and limited to medium voltage cables.

The disadvantage of XLPE and EPR cables is the cross-linking process plus they require a degassing of the peroxide by-products after production. In order to cross-link, the intern of the cable core needs to reach a temperature of around 180 °C close to the conductor which means that a lot of energy has to be put into the cable in order to reach this temperature very fast. Certain lines put the temperature in the centenary line (CV) tube up to 550 °C. Then the cable core has to be cooled down to a certain temperature before leaving the pressurised CV-tube in order to avoid the creation of bubbles due to cross-linking by products, mainly methane.

Consumer and government attention has moved to recyclable solutions while the cable producers look for shorter production lead times and from time to time even for shorter production length.

In the Netherlands there is a specification for a thermoplastic insulation material for medium voltage cable and certain utilities have already installed several kilometres of these cables. Therefore we developed an insulation system for this application based on a polypropylene base resin for insulation and insulation-and-conductor screen. The insulation screen should be fully bonded. The whole cable should pass the Dutch specification of NEN HD620 S1, DIP 1 requirements. Thus finding an insulation system based on a high temperature thermoplastic polymer like polypropylene was the obvious choice.

PRINCIPLE OF DEVELOPMENT

As a base for the development, a random copolymer polypropylene with a suitable melt index was chosen. Two different suppliers were evaluated in order to have a double source of supply from the start. As an antioxidant some common proposals were used. Additionally, a second polymer was used in order to improve the low temperature behaviour and the overall flexibility of formulation. The second polymer was carefully chosen in order to have a very good compatibility with the polypropylene and low or no impact on the electrical properties.

Mechanical behaviour

We tested different ratios of the two polymers and also the basic properties of polypropylene without any additive. Special care was taken to achieve sufficient flexibility and also still have very good mechanical properties of the expected mixture at higher temperature.

Subsequently, the antioxidant content was determined. We used an electrically neutral antioxidant that could reach good mechanical properties after ageing, even though polypropylene needs higher stabilisation than polyethylene. However, here we do not have to take into account the complexity of the interference of antioxidant and the cross-linking process.