A polystyrene pinning crosslinked polyethylene for potential application in HVDC cable insulation

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ABSTRACT

In this study, a polystyrene (PS) pinning crosslinked polyethylene (XLPE) for extruded HVDC cable insulation material has been investigated. The addition of PS into XLPE results in the decrease of conductivity and the increase of DC breakdown strength in the temperature range of 30~90°C, which may attribute to the increase of activation energy. Furthermore, the simulation results of electric field distribution within cable insulation indicate that PS pinning XLPE shows a potential application for HVDC cable insulation materials.

KEYWORDS

Polystyrene; Crosslinked polyethylene; HVDC cable insulation; DC properties.

INTRODUCTION

HVDC technology has been intensively employed in many applications such as the integration of renewable energy, long-distance transmission and interconnection, given its advantages of low loss and large capacity. Cables play an important role in the HVDC power transmission and during the past 20 years, great attention has been paid to HVDC cables especially to extruded HVDC cables, due to the benefits of light weight, simple structure, convenience to install, and no risk of oil leakage. Now, the HVDC cable system is developing towards tendency of higher voltage and larger capacity, which requires cable insulation materials with higher electrical-tolerance [1, 2].

Chemically crosslinked polyethylene (XLPE) has been used as the insulation material for cables because of its good heat resistance. To fulfil the specific demand for HVDC application, tremendous efforts have been devoted to modify the present XLPE insulation materials by multiple technology routines, such as improving cleanliness, adding nano fillers and voltage stabilizer. However, it is noticed that most studies are carried out at room temperature, which is far from the working temperature of cable. Besides, high-temperature DC performance of modified XLPE is not changed significantly, which might lead to failure when cables are subjected to the condition of higher voltage and larger capacity.

In our previous study, a novel strategy which adds polystyrene (PS) into XLPE to form a polymer pinning structure was proposed to fulfil the future requirements of HVDC cables [3]. PS distributed as particles could participate in the formation of crosslinking network with the help of crosslinking agent, thus forming a polymer pinning structure at the interface between XLPE and PS, which may be the reason for the enhanced DC properties.

PS is a long-chain polymer manufactured through the polymerization of styrene. The reason why PS is chosen is that PS contains special functional group 'benzene rings' and has a relatively high glass transition temperature of about 100°C. On the one hand, benzene rings can act as traps that control electrical performance. On the other hand, a higher glass transition temperature would lead to a better electrical performance at high temperature.

In this study, plate samples of XLPE and PS pinning XLPE were prepared and their DC performances were further investigated. PS pinning XLPE exhibits enhanced electric breakdown strength and reduced DC conductivity in the temperature range of 30°C to 90°C. Based on the experimental results, electric field distribution within cable insulation was studied by simulation. Our investigation may provide a solution on developing HVDC cable insulation materials.

EXPERIMENTAL METHODS

Sample preparation

The commercialized low density polyethylene (LDPE) and polystyrene (PS) were used. The antioxidant 300 was employed and dicumyl peroxide (DCP) was selected as the crosslinking agent. PS with a content of 1phr (phr: parts per hundreds of resin) was introduced into XLPE, and marked as XLPE-1PS.

First of all, pellets of LDPE and PS, antioxidant were mixed by a twin screw extruder. And then a general amount of DCP was added to the blend of LDPE and PS by soaking. Plate samples with different thickness were prepared by hot pressing with a vulcanizer and cooled to room temperature. As a comparison, neat XLPE was treated with the same procedure.

Before tests, all the samples were pre-treated in an oven at 70°C for 24h to remove by-products and internal stress.

Measurement and test

DC conductivity, space charge behaviour and DC breakdown strength are important aspects of materials for extruded HVDC cable insulation. Thus these DC properties were investigated.

For DC conductivity measurements, a three-electrode system was adopted, the diameter of its measuring electrode was 25mm. The whole electrode system was put in an oven to provide a stable temperature environment of 30°C, 50°C, 70°C and 90°C respectively. A series of DC electric field including 10kV/mm, 20kV/mm, 30kV/mm, 40kV/mm and 50kV/mm was applied to the samples respectively and the current was measured by a