

DEVELOPMENT OF NOVEL LIQUID SILICONE RUBBER SOLUTIONS FOR HVDC CABLE ACCESSORIES

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ABSTRACT

Silicones have a long history in electrical power transmission and distribution especially AC systems with applications ranging from composite insulators to transformer fluids to cable accessories. As HVDC power distribution develops, and voltages increase to 500 kV and above, existing silicones show a number of limitations for use as insulating materials in cable joints. To help address these limitations we have developed novel solutions to provide liquid silicone rubbers with tuneable conductivity. This performance feature allows matching of the silicone accessory conductivity to XLPE cable insulation conductivity, whilst maintaining dielectric strength and mechanical properties.

KEYWORDS

Liquid Silicone Rubber (LSR), conductivity, mechanical properties, High Voltage Direct Current Insulation.

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]. Accessories such as cable joints and terminations are key components within power transmission systems but can be weak points where most failures occur [3,4]. The use of silicone as insulating material for accessories in AC applications is well known with application up to 550 kV being reported [5,6]. For direct current applications, the electric field distribution of the accessories mainly depends on the relative conductivity and the interfacial space charge between XLPE cable insulation and silicone accessory insulation [7].

Standard silicone materials show differing conductivity dependencies on temperature and electrical field compared to XLPE and it is therefore rather difficult to obtain a uniform field distribution over a wide temperature or electrical field range. The use of nonlinear resistive field grading materials with strongly field-dependent conductivities has been proposed as a solution to this issue [8,9]. Liquid silicone rubber composites with nano-SiC [10] or ZnO microvaristors [11,12], whilst these approaches can give desired electrical properties they can suffer with issues linked to high filler loadings leading to poor mechanical properties or at lower loadings issues with dispersion and loss of dielectric strength.

In this paper an alternative approach to the modification of liquid silicone rubber conductivity that does not use an electrically active inorganic filler is explored. Our aim is to produce a modified liquid silicone rubber that can match XLPE conductivity across a range of temperatures and

electrical fields whilst maintaining good mechanical properties and dielectric strength.

EXPERIMENTAL DETAILS

Materials

All liquid silicone rubber (LSR) materials were prepared from commercially available intermediates. Materials were formulated as two-part systems with catalyst in part A and crosslinker in part B, these were then well mixed at a 1:1 ratio and deaired under vacuum prior to preparation of sheet samples.

Methods

Sheet Preparation

0.5mm and 2mm sheets were prepared using shaped molds pre-heated to 120 °C. The mixed LSR was loaded between polyester sheets and press cured for 10 minutes at 120 °C. Cured sheets were further post cured in air in vented ovens at temperatures up to 200 °C and times up to 4 hours.

Cure Testing

The curing characteristics were determined using a Monsanto moving die rheometer (MDR-2000, Alpha Technologies) at 120 °C.

Mechanical Testing

Mechanical testing was carried out on 2mm cured sheets using standard rubber test methods; Shore A hardness – ASTM D2240, Tensile Strength and Elongation at Break – ASTM D412, Tear Strength – ASTM D624 Die B.

Volume Resistivity

Measurement according to ASTM D267-14 were made using 0.5 mm thick cured sheets using a Keithley 8009 test cell coupled with a Keithley 5½-digit Model 6517B Electrometer/High Resistance Meter and controlled with Model 6524 High Resistance Measurement Software.

Within the Model 6524 software an alternating polarity test was implemented as an “Hi-R” test to minimise the effects of background currents [13]. Polarization voltage was ±1,000 V with polarization times of 60 seconds.

DC Conductivity

DC conductivity was measured on an AixACCT TFA Analyzer and temperature controller for a low- Ω test cell. The three brass electrodes in the low- Ω cell include high voltage and measurement electrodes of 30mm diameter and a guard electrode of 50mm in diameter, which is isolated from the measurement electrode by an insulating tape. Specimens were die-cut to 47mm diameter and