THE FIRST COMMERCIALLY AVAILABLE LIQUID SILICONE RUBBER FOR HVDC CABLE ACCESSORIES

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ABSTRACT

This paper describes the development of two generations of Liquid Silicone Rubber (LSR) suitable for the production of HVDC cable accessories. Important material properties such as DC conductivity, breakdown strength and space charge behavior were analyzed and are presented in this work. Two different LSR compounds were developed, first and second generation, and their electrical and mechanical properties are described.

KEYWORDS

HVDC Cable Accessories, Liquid Silicone Rubber, Nano Particles, Dielectric Strength, Volume Resistivity, Space Charges, PEA

INTRODUCTION

Key to success for a proper functionality of HVDC transmission cable systems is the right choice of insulation materials. The weakest points or “most challenging parts” in a cable system are interfaces such as in cable joints and terminations.

SiR (Silicone Rubber) and EPR/EPDM (Ethylene propylene rubber) are the materials of choice for the insulation of pre-molded joints for crosslinked polyethylene (XLPE) extruded cables.

SiR has several advantages and is therefore well established in the design and production of medium and high voltage AC accessories. In addition to an easier processing of the low viscous LSR (Liquid Silicone Rubber) the good elasticity of LSR joints allows easier installation with less risks of failures during installation and operation. Due to a higher pressure LSR joints form a tight seal onto the connected cable ends [1, 2]. Figure 1 describes some of the differences between SiR and EPDM [3].

	EPDM	SiR
Chemical Structure	C-chain as basic	O-Si chains as basic
Range of temperature at which electrical and mechanical properties remain stable	-40°C ~ +100°C	-50°C ~ +180°C
Corona and ozone stability	None	High
Elasticity	Limited	High
Mechanical strength	High	Medium
Lifetime factor n[1]	≈ 20	>40
Breakdown Strength	≈ 20 kV/mm	>23 kV/mm

Figure 1: EPDM versus SiR [3]

In DC systems the electric field distribution is more complex than in AC systems as it strongly depends on the conductivity of all insulating parts, e.g., XLPE or other cable insulation polymers, EPDM or SiR. Furthermore, the presence of space charges can lead to increased electric field strength up to the complete failure of the component.

In first DC trials prototype joints made of HVAC-LSR failed already at voltage levels as low as 80 kV while EPDM joints were more promising. In HVDC systems EPDM had a head start.

This paper describes the development of a new LSR formulation suitable for HVDC accessories.

FIRST GENERATION LSR FOR HVDC

First trials with AC materials started already in 2010. The early failures of HVAC-LSR in DC model joints made clear that material development work was needed. However, that time CTQs were rather unclear even among high voltage engineering specialists.

Key for the success was to understand how to improve the dielectric and the space charge behavior of the silicone rubber. There are two main strategies that are considered for insulation materials like XLPE: using very clean materials to avoid the presence of defects, or inserting nanofillers, which act as deep traps and can help modifying the space charge behavior as desired [4, 5, 6].

First studies screening SiR materials with different fillers measuring polarization/depolarization currents and conducting early PEA measurements, indicated that inserting CB (Carbon Black) nanofillers was the most promising approach.

Figure 2 shows SEM pictures of the used carbon black filler (left) and its distribution after incorporation in the LSR matrix. The size of the primary particles is roughly 40 nm. The formulation is designed in a way that conducting paths between the CB particles are excluded and thus a too high decrease in volume resistivity is avoided (indicated in the right picture in Figure 2).

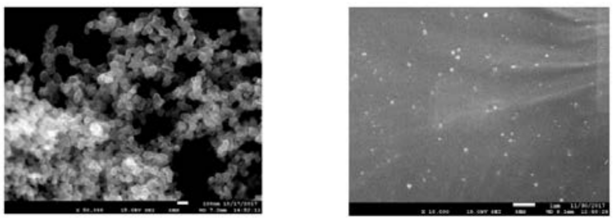

Figure 2: SEM of CB particles (left) and distribution in LSR matrix (right)

A standard HVAC-LSR with 0.5 wt.% CB nanofillers was then used to produce 80 and 150 kV prototype accessories with geometric field control design. Other than with the standard HVAC-LSR these joints passed the type tests according to [16]. Meanwhile the material is qualified for the use in cable systems up the 320 kV and is commercially