Effect of Radial Pressure and Lubricant Types on Partial Discharge Inception in a Slip-On Medium Voltage XLPE Cable Termination

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ABSTRACT

The most critical section in a cable termination or a subsea connector is the interface between the cable surface and the inner surface of the termination body, including the semiconductive geometric field grading. Partial discharge (PD) measurements were performed on a commercial 24 kV slip-on termination installed on a 12-kV XLPE cable, including two different lubricants and two additional external radial pressures, using an insulating vulcanization (IV) rubber tape. The results indicated that increasing the total radial pressure above the nominal level obtained when expanding the termination on the cable core resulted in a higher PD inception voltage independent of the lubricant type. It is also likely that the higher viscosity of the lubricant increased the PD inception voltage of the termination at the same interfacial stress and surface roughness.

KEYWORDS

Cable termination, inception, interfacial pressure, insulating liquid, lubricant, partial discharge.

INTRODUCTION

In recent years, the global rise in demand for renewable energy has led to a significant expansion of offshore wind farms. For offshore wind power, submarine power cable systems (including components such as connectors and terminations) play a crucial role in transmitting power to the shore. However, evidence from the past two decades showed that power cables and connectors have emerged as the primary factor contributing to power supply failures in offshore plants [1]. Despite significant advancements in material science and manufacturing processes, one persisting challenge is the vulnerability of solid-solid interfaces within the cable systems, where the surfaces of two different solid materials come into direct contact [2]. The contacts occur at discrete spots, resulting in a myriad of sub-microcavities and channels forming between adjacent contact points at the interface [3]. Partial discharges (PDs) can occur in the microcavities at the interface at a certain stress level, which may, over time, lead to insulation degradation, increase the risk of electrical breakdown and failure, and thus reduce service life [4].

These interfaces can be found between cable insulation and rubber stress cones in joints and terminations or between rubber stress cones and epoxy components in joints [5]. The most critical section is the interface between the cable and the semiconductive geometric field grading material, as illustrated in the highlighted area ④ in Fig. 1.

The electrical breakdown strength of the interface strongly depends on the interfacial pressure. Surface roughness, elastic modulus, type of lubricant, and temperature change are the other factors that affect the interfacial breakdown strength because they all significantly affect the dielectric properties of sub-microcavities and channels [6]–[8].

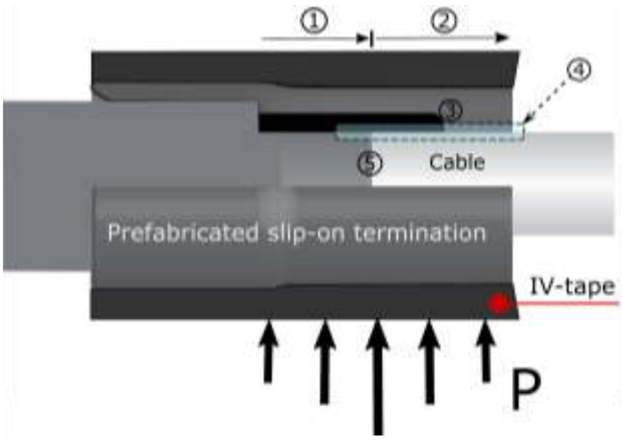

Fig. 1: Illustration of the cable-termination interface. Axial section with 1: no electrical stress outside cable/connector, 2: high electrical stress outside cable/connector. 3: Electrical field grading. 4: Interface between the SOT and cable. 5: End cut of the insulation screen of the cable. P: Uniform radial external pressure on the SOT using insulating vulcanization (IV) tape.

To obtain the needed interfacial pressure, the elasticity (i.e., intrinsic radial pressure) of the rubber body is normally utilized when expanded on a cable core. Three main factors that control the interfacial pressure are elastic modulus, strain, and wall thickness of the rubber termination material. Applying an additional external radial pressure on the termination could increase the inception and extinction voltage of PDs (PDIV and PDEV). Until now, this has not been utilized in terminations or connectors. It is important that the rubber material is retained within its elastic region when applying external pressure; otherwise, plastic deformation will cause dislocations within the material and a permanent change in shape [3]. Furthermore, apart from its dielectric properties, the viscosity of the lubricant present at the interface also becomes a key parameter influencing the PDIV/PDEV in the presence of external radial pressure (see ④ in Fig.1).

The main purpose of this paper is to study the effect of interfacial pressure and insulating liquid types on the partial discharge inception voltage of a silicone rubber (SiR) type slip-on cable termination (SOT).

EXPERIMENTAL WORK

Assembly of test objects

A 6/10 (12) kV XLPE-insulated cable, with a 120 mm^2 cross-section, 3.9 mm insulation thickness, and a fully bonded insulation screen, was used. The sections in contact with the rubber terminations were peeled and polished prior to installation, as illustrated in Fig. 1. The polishing was done using the back side of a 400-grit sandpaper. The SiR outdoor SOT terminations, designed