ABSTRACT

A two-dimensional model based on bipolar charge transport theory was developed to study charge transport dynamics in cable and cable joint under DC voltage. The model is governed by the Poisson, charge conservation, and conduction equations. The charge transport dynamics in insulators with coaxial configuration were obtained by iteratively solving the electric field, charge injection, and transport process. Furthermore, Poisson equation solution accuracy was validated by calculating the potential and the electric field using a 10 kV cross-linked polyethylene (XLPE) cable. The distribution of the space charge and the electric field was measured using the 10 kV XLPE cable under 20 kV/mm electric field. The results of the Poisson equation validation were consistent with the analytical and finite element simulated solutions. Additionally, the amplitude and trend of charge distribution were consistent with experimental results. These results show that the algorithm is applicable to charge transport studies in cable and cable joint. The results show that the discontinuity of insulation screen can distort space charge and electric field distributions along the symmetry. Thus, the end of the high voltage screen should be carefully treated in cable joints. As a preliminary application, the charge transport dynamics in 320 kV overall prefabricated joint was calculated with an ideal interface under room temperature. The results show that the electric field at the end of the high voltage screen was not affected by the injected charge, whereas the internal electric field was strengthened by the injected charge. Moreover, we found that the injected charge resulted in an inflection point of electric field at the interface after polarization. This suggests that the suppression of charge injection in cable joints is crucial in insulator design.

# INTRODUCTION

In the last few decades, the market for high voltage direct current (HVDC) transmission systems has grown dramatically because of electrical, economic, and environmental advantages of HVDC in power delivery over a long distance [1, 2]. Furthermore, extruded HVDC cables have become more commonly used compared with the traditional oil or mass-impregnated cables; and extruded HVDC cables are the only option in certain cases (e.g., for long subsea links) [3, 4]. The cross-linked polyethylene (XLPE) is commercially available for direct-current (DC) voltages up to ±600 kV and 3 GW power ratings [5]. However, the extruded insulation for cables or cable accessories (joints and termination) was affected by trapped space charge when subjected to high direct voltages. The trapped space charge can distort the local field stress and initiate or cause insulation failure, especially in cable accessories where dielectric-dielectric interface is common [6-9]. Studies on the influence of space charge have been conducted using film and plaque samples [8, 10]. Chen et al. reported the effect of the interface between the two low density
polyethylene (LDPE) layers on space charge formation with different electrode materials (Sc and Al) [11]. Lan et al. studied charge distribution at LDPE/ethylene-propylene-diene monomer (EPDM)  interface and found that the surface fluorination considerably changed the interface charge characteristics [12]. Wu et al. reported that the interface charge behaviour is related to contact type and applied stress with a modified pulsed electro acoustic (PEA) method considering the acoustic impedance mismatch of different materials [13]. Due to the limitations of the experimental method, the measurement of charge dynamics in full-sized cable or cable accessory samples has not been extensively investigated.

With the rapid development in computing and numerical method, simulation technology provides a new approach to investigate charge dynamics in solid dielectrics. Most studies have focused on the modelling of the charge behaviour primarily in one-dimensional models.