

Development of 535kV XLPE HVDC Cable System in China

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ABSTRACT

This paper introduces the development of 535kV extruded insulated DC cable system in China. The super clean XLPE insulation and super smooth screen materials have been developed and the 535kV cables with a capacity of 2850A have been designed and manufactured. Meanwhile, both the silicone rubber accessories and EPDM rubber accessories for the cables are designed and manufactured. The two cable systems with different accessories have both passed type tests. Afterwards, a demonstration line consisting of two cables with a joint and two terminals has been laid and installed in Zhangbei 535kV VSC-HVDC transmission system.

KEYWORDS

535kV HVDC cable system, XLPE, screen materials, Silicone rubber accessories, EPDM rubber accessories, Type test.

INTRODUCTION

HVDC cables are indispensable transmission equipment for large-scale utilization of new energy and regional networking. The extruded HVDC cable is one of the most promising cable systems which are widely used in DC power transmission projects. As the recent demand for the increased transmission capacity and restricted routing, it has attracted much attention on developing HVDC cable systems with enhanced voltage level, challenging the reliability of crosslinked polyethylene XLPE cable insulation.

GIGRE TB 496 recommended the testing of DC extruded cable systems for Power Transmission at a rated voltage up to 500 kV^[1], and recent released GIGRE TB 852 in 2021 has improved the voltage level to 800kV^[2]. At present, the highest voltage level for the manufactured HVDC cable can reach up to 640kV, and for the cable system in operation is 400kV. The DC transmission projects with higher voltage level cable system have been under construction. In China, the development of extruded insulation DC cable project has experienced several stages: from Nan'ao project (with 160kV in voltage level and in operation in 2013) to Zhoushan project (with 200kV in voltage level and in operation in 2014), to Xiamen (with 320kV in voltage level and in operation in 2015)^[3], and then to Rudong (with 400kV in voltage level and in operation in 2021). Recently, a new Zhangbei DC transmission project has been completed with the operation voltage of 535kV, and the demonstration project for cable system has been accomplished.

This paper reports the developing of 535kV extruded insulated DC cable system in China. Starting from the fabrication of insulating material and semiconducting material, the 535kV HVDC XLPE cable have been carefully designed and manufactured. Further cable

accessories have been developed using both silicone rubber and EPDM rubber. The testing of 535kV HVDC cable system has been reported, and its installation in Zhangbei project for demonstration is shown in the paper.

MATERIAL DEVELOPMENT AND CABLE DESIGN

Material development

Insulation material

The main insulation of 535kV HVDC cable uses a domestic ultra-clean XLPE insulation material, which is fabricated by regulating the molecular structure of the base material and controlling cleanliness during the material production, storage and transfer. The volume resistivity and space charge characteristics of XLPE have been measured under different field strengths respectively. When the temperature rises from 30°C to 90°C, the resistivity ranges from $10^{14}\Omega\cdot\text{m}$ to $10^{12}\Omega\cdot\text{m}$ (as shown in Fig.1). For the space charge characteristics shown in Fig.2, under the measured conditions, only a small amount of homo-charge accumulates and the electric field distortion rate is less than 12.5%. The hot-set experiment has been conducted at 200°C and 20N/cm². The maximum elongation under load is $79.5 \pm 5.1\%$, and the permanent deformation rate after cooling is $-1.8 \pm 0.6\%$, indicating that the material can maintain structural stability and resist creep at high temperatures. Based on the above analysis, it is confirmed that the XLPE insulation material can meet the requirements as the insulation for 535kV HVDC cable system.

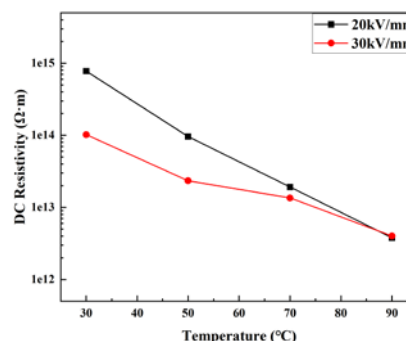


Fig.1: DC resistivity of cable insulation material

Screen material

A new type of ultra-smooth screen material has been developed for 535kV HVDC cable, and the DC resistivity characteristics is shown in Fig.3. Due to the electric field distortion caused by the penetration of carbon black into insulation, attention has been focused on the screen/insulation interface in addition to meeting the requirements of the electrical and mechanical properties of the screen material. The screen material and insulation