

Development and engineering application of $\pm 160\text{kV}$ XLPE insulated cable to three-terminal VSC HVDC project in China

Shuai HOU, Mingli FU, Linjie ZHAO; Electric Power Research Institute of China Southern Power Grid, China, houshuai@csg.cn, fuml@csg.cn, zhaolj@csg.cn
Qiang KANG; Xi'an Jiaotong University, China, kangq828@163.com

ABSTRACT

Nan-ao VSC-HVDC transmission pilot project with extruded cable system is the first three-terminal modular multilevel (MMC) VSC-HVDC system in the world. The project, rated at $\pm 160\text{kV}$ and 200MW, has deployed a 28.3km-transmission line which comprises extruded DC land and submarine cables and overhead lines. This paper summarises the development of cross-linked polyethylene (XLPE) insulated DC cable and its engineering application to the project. A few detailed issues on XLPE properties such as the conductivity correlation with temperature and electric field, and space charge behaviour are specifically investigated. The cable system may experience switching impulse and lightning induced overvoltage in the operation due to the connection with the overhead line, the insulation coordination were calculated and clarified by simulation under PSCAD/EMTDC. As a conclusion, the new testing procedure of AC-DC-AC voltage withstand tests were proposed and conducted to ensure the manufacture quality of the cable. For the first ever such high HVDC cable system in China, some considerations on the preventive test to this cable system listed and discussed.

Keywords

VSC-HVDC, XLPE extruded cable, HVDC cable system, Insulation coordination

INTRODUCTION

The VSC-HVDC transmission has the advantages of strong controllability, high flexibility and less occupied area. As a consequence it offers vast application prospects in the area of large-scale offshore wind farms connection to the main grid, regional interconnections, improving power supply reliability and increasing large cities power supply capacity [1]. By far, there have been several VSC-HVDC transmission projects under construction or in operation in the link routes of cable system or overhead line or the mixture of both [2].

With the rapidly increasing of the off-shore wind farms generation in which long distance transmission using VSC-HVDC technology between wind farm and onshore main grid has been developed and practice over last a couple years. As a desired technology, XLPE extruded insulated HVDC cable systems have undergone an intensive research and long term development process both in China and elsewhere in the world [3].

The Nan-ao Island wind farm, located in Shantou, Guangdong Province, has the installed capacity of 267MW. In the past, the wind power is transmitted to the main grid through the existing AC 110kV oil-filled submarine cable system which has been operated over

17 years. The aging phenomenon of oil-filled cable insulation and several anchoring damages because of lacking of proper protection measures has become the big concern for the system's reliability. In order to improve the safety and reliability of the grid as well as consider wind farm's future extension, VSC-HVDC transmission system by deploying mixed XLPE insulated DC cable and overhead line at the voltage level of XLPE 160kV with the maximum power capacity of 200MW was planned and constructed in parallel with existing AC system. This was the first ever in China at such a voltage level of VSC technology and XLPE insulated HVDC power cable in engineering application, the project has earned the support of National High Technology Research and Development Program of China (863program) (2011AA05102) [4].

The configuration of the Nan-ao project is illustrated in Fig.1. The transmission line between Station A and Station B comprises $\pm 160\text{kV}$ HVDC land and submarine cables and overhead lines with the total length of 28.3km. The transmission line between points 1 and 2, 4 and 5 and points 6 and 7 are land DC cables, the total length of 9.5 km. And points between 2 and 3 and Points 5 and 6 are two sections of submarine DC cables and their lengths are 9.5km and 1.2km respectively. Overhead line with length of about 8.1km is between points 3 and 4. The maximum water depth of the submarine cable laying seabed is about 15m. Station B and C is connected by an $\pm 160\text{kV}$ HVDC overhead line with length of 12.5km.



Fig.1: Nan-ao VSC-HVDC pilot project configuration

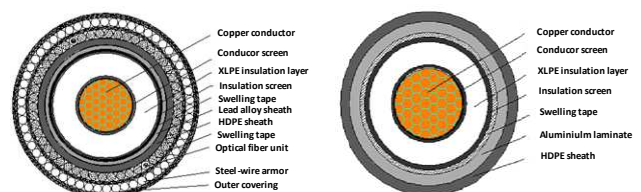


Fig. 2: Configuration of submarine and land cable for Nan-ao $\pm 160\text{kV}$ HVDC transmission system

The XLPE land/submarine cable for Nan-ao $\pm 160\text{kV}$ HVDC transmission system are designed and developed by two Chinese cable manufacturers. The structure details of the submarine and land cable are shown in Figure2.