Development of Semi-wet type HV inter-array cable for off-shore wind power

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ABSTRACT

A semi-wet type AC 66kV tree retardant XLPE (TR-XLPE) insulation cable was developed and tested based on the Regime A and C test in the Cigre TB 722. This was the subsequent development of the semi-wet type TR-XLPE cable that passed the Regime B test in 2020. The cables in this research also satisfied all the requirements in Regime A and C, and we could confirm the long term performance and stability of the developed cables. Development procedures and the test results are explained in this paper.

KEYWORDS

TR-XLPE; 66kV; Semi-wet type; CIGRE TB722; Ageing test; Water tree; Submarine cable

INTRODUCTION

Wind power generation has been mainly developed in the form of on-shore wind power due to of its easy installation. Off-shore wind power gains more and more attractions nowadays however, because it is not affected by the surrounding topography nor the complaints from residents. Also, both the quantity and quality of the wind are excellent. For these reasons, off-shore wind power installations are expected to grow at an average annual rate of more than 16% in each contry, and the annual installed capacity is expected to reach 12GW by 2030. In the off-shore wind power, dry-type HV subsea cable was sheathed with a metallic water barriers, and normally it was a lead sheath. On the other hand, semi-wet or wet-type subsea cable uses special polymeric insulation, TR-XLPE, without any outer metallic sheath. Therefore, the structure of semi-wet or wet-type cable is compact and lightweight. In addition to that, it is environmentally friendly, because it contains no lead metal and reduces the emission of carbon dioxide significantly during manufacturing.

To correspond to the rapidly growing off-shore wind power market worldwide, we developed 66kV semi-wet type cable using TR-XLPE insulation, and it was manufactured and tested according to CIGRE TB 722 [1]. In the previous development, semi-wet type AC 66kV TR-XLPE insulated cable with Cu 300SQ conductor was manufactured and tested based on the Regime B in accordance with the CIGRE TB 722 [2]. Recently, to verify the long term stability of the semi-wet type AC 66kV TR-XLPE cable, we manufactured Al 630SQ conductor cable, and extended the test based on the Regime A and C in the CIGRE TB 722.

PREVIOUS WORK

We manufactured the wet type AC 66kV TR-XLPE insulation cable with Cu 300SQ conductor, and it passed the Regime B test in accordance with the CIGRE TB 722 successfully [2].

The test procedures were as follows: 3,000 hours long term ageing test at 500 Hz was performed with a suitable designed electrical stress. The salt content of the pre-conditioning and ageing water was set to 3.5 % by weight. After the ageing, the cable cut into six test samples of 10 m lengths including terminations. AC voltage test was performed to these samples with a steps within 72 hours after removal from the ageing tank. As results, no breakdown occurred during the 3,000 hours of ageing. After the ageing, the cable was cut into test objects for AC step test. The breakdown test was carried out with a 500 kV and 50 Hz AC transformer equipped with a rapid disconnection unit. The samples should be tested to breakdown with an AC step test within 72 hours after removal from the ageing tank. The samples started at U_0 kV for 5 minutes and the voltage increases in steps of ½U_0 kV every 5 minutes until breakdown occurred. Every sample was AC step voltage tested till 369kV, which was the maximum limit of the test equipment. It was understood that all sample had enough AC voltage resistance than the requirement of CIGRE TB 722 (35kV/mm).

After the voltage test, water tree size was measured from the cable insulation that passed the Regime B testing of 3,000 hours ageing test. The size of the bow tie tree in the cable insulation was found to be approximately 300 μm, and the size of the water tree near the insulation screen was found about 220 μm. It was confiremd that the longest bow tie and vented tree of the cable was small engouh. Also, comparing before and after the AC breakdown test, no significant difference was observed in the water tree size.

CABLE STRUCTURE

To verify the long-term performance and stability of AC 66kV wet cable design, semi-wet type cable consisted of a stranded/compacted 630SQ Al conductor and XLPE insulation was manufactured. The structure was represented in Fig. 1. Conductor was consisted of concentric stranding in accordance with IEC 60228, and the conductor was filled with a semiconducting water blocking compound.

A conductor screen of semiconductor compound was extruded over the conductor. A semi-conducting tape was applied between the conductor and the conductor screen. The insulation over the conductor screen was TR-XLPE. The minimum thickness did not fall below 95% of the specified nominal value at any point. The insulation screen consists of an extruded layer of semi-conducting compound firmly bonded to the insulation. The conductor screen, insulation and insulation screen were extruded simultaneously. Cables to be tested are shown in Fig. 2.