World first DC400kV LCC DC-XLPE cable system to retrofit existing HVDC system

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ABSTRACT

This report describes the world first DC400kV LCC DC-XLPE cable system and fundamental characteristics of the filled type DC XLPE insulation, design approach to realizing LCC operation, type test results and new application of 400kV DC-GIS cable termination.

KEYWORDS

Line Commuting Converter (LCC), Filled type DC-XLPE cable, Polarity reversal

INTRODUCTION

In order to respond to the rapid growth and urgent need of renewable energy, the HVDC inter-connectors between countries or between power grids will play a more important role for the reliable and resilient power supply than in the last decade. For example, the world's first 400kV DC-XLPE cable inter-connector between Belgium and the UK has been constructed and successfully operated since 2019 [1] to respond to variable power demand, especially in the UK. This HVDC line was built using VSC technology with a novel HVDC converter. On the other hand, there are a certain number of classical 350kV-450kV HVDC systems which have been operated with LCC technologies for more than 25 years as inter-connectors in the world, and these transmission lines with paper insulated cable system are already aged and some of them are deteriorated after long service and operated under restricted conditions. On the other hand, the LCC technology HVDC converter itself is generally more robust and easier to maintain than the cable system, so it is desirable to make it possible to replace an old paper-insulated cable with XLPE cable for future retrofitting of classic type HVDC inter-connectors.

The KONTEK 400 kV grid connection is a direct current connection between the German and Danish power grids, which operates the power grid on the Danish islands of Lolland, Falster and Zealand. This high-voltage direct current (HVDC) transmission line operates at 400 kV and transmits a maximum capacity of 600 MW with LCC. Since the commissioning of the 170-kilometer KONTEK HVDC line in 1995, more than 25 years later, the onshore section of the oil-filled cable in Germany has almost reached the end of its service life [2]. The KONTEK Land Cable Replacement Project has started to replace 15 km of the oil-filled cable on the German side by the world's first DC400kV with a filled type DC XLPE insulation. As a future-oriented infrastructure, DC-GIS component will be also installed in the area nearby the converter station by implementing a bypass solution to ensure only short-term interruptions even if any incident occurred.

OPERATIONAL CONDITIONS OF LCC TYPE HVDC CONVERTER

From the cable system point of view, LCC type HVDC converters have the following typical operation modes. Frequency adjustment control mode is when the synchronous generators operating at 50Hz/60Hz could not support the specified power frequency due to rapid increase/decrease in power demand, reversed power flow is provided by the HVDC converter with a polarity reversal of the HVDC transmission line. This operation is typically performed within a few 100msec. Figure 1 shows the actual voltage reversal from -Uo to Uo on the HVDC transmission line with filled type DC-XLPE cable system in the Hokkaido Honshu HVDC line in Japan.

Under normal power demand, power reversal is performed according to the scheduled plan to handle the power price difference between two power systems, in principle to supply more economical power to the system with higher demand. In this case, in order to reduce the risk of deterioration of the existing cable system, slow power reversal is performed. As shown in Figure 2(a), the voltage is turned off within hundreds of milliseconds, followed by a discharge time at zero voltage, then a voltage with reversed polarity is applied as a slow ramp within a few seconds as shown in Figure 2(b) .

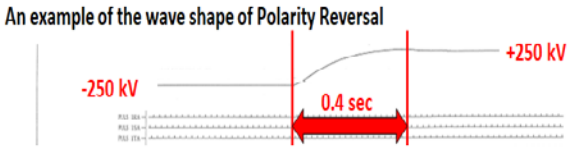

Fig. 1. : Highspeed polarity reversal (Courtesy of J-Power)

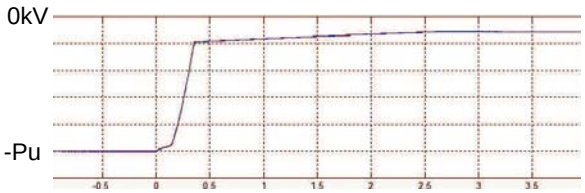

Fig. 2 (a): Slow polarity reversal (switch off)

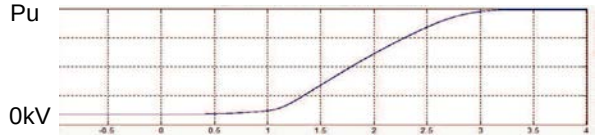

Fig. 2 (b): Slow ramp up after discharge

Some research [3] has already been done on the difference of electrical stresses on cable insulations under fast and slow polarity reversal, assuming uniform