Performance evaluation of 525 kV and 640 kV extruded DC cable systems

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ABSTRACT

This paper presents the test results from the qualification of the 525 and 640 kV systems and investigates the electro-thermal properties that made the qualification successful. Using the experimental results from the qualification and development tests, an electrothermal model has been made to calculate the temperature and electric field distribution of the cable insulation. The DC electric losses considering finite conductivity values within the cable insulation are simulated and the results are compared with the measurements. Furthermore, the impact of thermal and electrical conductivities of the cable insulation on field inversion, DC dielectric loss and thermal stability are studied.

KEYWORDS

HVDC; Cable; XLPE; 525 kV; 640 kV.

INTRODUCTION

High voltage direct current (HVDC) technology is an efficient way of transferring large amount of power over long distances. The HVDC technology is a key component in the current and future energy systems and it is also a prerequisite for reaching globally set environmental targets. This is because the technology enables integration of renewable energy sources located hundreds or even thousands of kilometres away from load centres.

One of the integral parts of such system is the DC cable. Extruded and mass-impregnated HVDC cable systems have substantial track records, where the world's first commercial HVDC mass-impregnated cable was installed between the Swedish mainland and Gotland in 1953 and the first commercial extruded HVDC cable system (that was developed in parallel to the VSC converter technology) was installed on Gotland in 1999.

In the recent years, especially with the increase of public awareness, the interest in polymeric HVDC cable links has significantly increased. Their technical, economic and environmental benefits, make them a preferred option in offshore and onshore power transmission applications such as interconnectors and integration of offshore wind farms.

The request for HVDC cable applications at higher voltages has been continuously growing. This has led to the development and qualification of 525 kV [1] and 640 kV extruded DC cable systems [2] [3] in the recent years.

TOWARD LARGER POWERS

The rapidly growing demand for electricity has been a pushing for transmission of larger powers. Fig. 1 shows the power rating of some of the HVDC projects, both installed and under construction, where the cable insulation was chosen to be cross-linked polyethylene (XLPE). With the technological improvements, the power rating of the cables has been upscaling. Whereas the transmission capacity of the Gotland project in 1999 was 50 MW, the Caithness-Moray HVDC link in 2018 has been made to carry 1200 MW of power. This has been due to two major improvement steps which are visible in Fig. 1. The first one is when the voltage increased from 80 kV to 150 kV in 2002 and the other is when the voltage further increased to 320 kV level in 2015. Due to such growing trend, the demand to further increase the power and mostly the voltage ratings of the XLPE cables was inevitable. Fig. 2 illustrates the approximate power capacity of a pair of XLPE cables at different voltage levels and conductor sizes. The calculation was performed for land cables with copper conductors operating at 70 °C, 1 m burial depth, 1 Km/W thermal resistivity of the soil, 15 °C soil temperature, and 0.3 m core-to-core distance. A power transfer of more than 3 GW with a conductor size of the 3000 mm² has become feasible.

Apart from the increase of power capacity, the lower losses at higher voltages are also favourable. This has been depicted in Fig. 3 where the approximate losses of cable systems at different voltages and conductor sizes operating at full load are shown. The loss is illustrated as the percentage of the transmission power and per 100 km route length. The higher the transmission voltage is, the lower the losses becomes. At 640 kV the full load losses become one half of that at 320 kV system. The lower loss and the consequent lower operational cost make the 640 kV system more attractive.

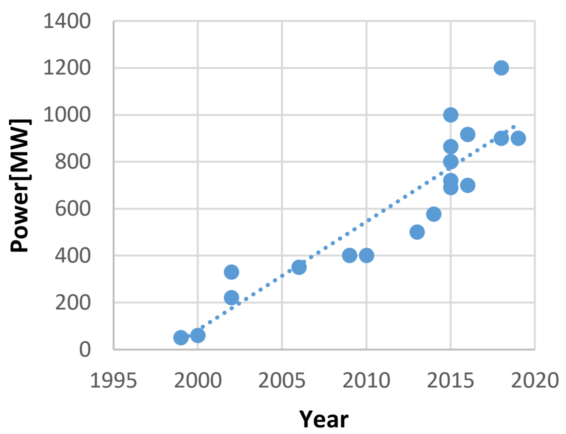

Fig. 1: The power rating development of XLPE HVDC cables (installed or under construction).