Design features of HVDC cables crossing the German North Sea EEZ

Pedro **CAVALEIRO;** Fichtner GmbH & Co. KG, (Germany), Pedro.Cavaleiro@fichtner.de

ABSTRACT

In this paper the technical optimization of subsea MIND and extruded HVDC cables which might be potentially suitable for grid connections of offshore generation or for interconnectors crossing the North Sea German Exclusive Economical Zone, is framed by the applicable restrictions on the cable performance - particularly to limit the maximum temperature rise above the cables to 2 degrees Kelvin at 200 mm and 300 mm sediment depths (2K Criteria).

KEYWORDS

HDVC, MIND cables, XLPE cables, thermal constraints, 2 K Criteria, electric current rating, crossings.

INTRODUCTION

The heat being dissipated away from the cable core, may trigger potential adverse effects on benthic organisms that live in the bottom sediments. To mitigate the potential negative impact on benthos the German Federal Agency of Nature Conservation (BfN) issued a guideline [1] valid for the German North Sea Exclusive Economical Zone (EEZ), proposing to limit the temperature rise above the cables in 200 mm sediment depth to 2 degrees Kelvin (2 K Criteria). Stricter thermal restrictions were imposed by the Nationalparkverwaltung Niedersächsisches Wattenmeer in the Wattenmeer National Park. In this UNESCO biosphere reserve the temperature rise above the cables in 300 mm sediment depth is limited to 2 degrees Kelvin.

In this work we address the influence of the thermal binding restrictions in the design optimization process of subsea HVDC cables for the German North Sea Exclusive Economic Zone (EEZ.)

The specific characteristics of Mass Impregnated Non-Drainage (MIND) and extruded cables, shape to a great extent the way these cables cope with the binding thermal restrictions.

In this paper the design optimization of subsea MIND and extruded HVDC potentially suitable for interconnectors crossing the North Sea German Exclusive Economical Zone is framed by the applicable restrictions on the cable performance - particularly on the electric current rating and losses.

Moreover, and whenever the temperature rise restrictions at 200 mm and 300 mm sediment depths prove to be the driving factor for the HVDC cable sizing, deeper cable burial depths could be achievable without infringing the maximum allowed temperature of the conductor. This feature might ultimately provide enhanced flexibility to cope with additional thermal constraints at specific sections of the cable route which require enhanced protection via a deeper depth of burial - namely for traffic routes, tideways or simply to facilitate the planning of future cable crossings.

THERMAL RATING METHODOLOGY

Steady-state electric current rating is calculated by using heat transfer equations addressing the impact of the conductor electric current on the temperatures within the cable and its surroundings.

The dissipation of the heat generated in the cable is influenced by factors determined by physical constraints along the cable route, particularly the burial depth, spacing between the poles/cables and temperature of the surroundings.

Particularly for the landfall crossings, on which the use of trenchless solutions like directional drilling is envisaged, the depth of burial, as well as the thermal resistivity of the surrounding soil and respective temperature will take a heavy toll on the heat dissipation performance of the cables.

At the detailed design stage of the HVDC cable system the thermal resistivity of the surrounding soil and respective maximum temperatures shall be duly confirmed by suitable in-situ measurements.

The calculations undertaken to estimate the temperature rise distribution in the cable surroundings - and which results are presented in this paper - were undertaken by means of the Line Charge Method (LCM) following the calculation procedures proposed in the IEC standard [2]. The results obtained by using this methodology are expected to be comparable to those obtained through Finite Element Models [3].

The electric current rating for HVDC cables calculated for the above described steady-state heat transfer will be given as follows:

$$I = \sqrt{\frac{\theta_c - \theta_{amb}}{R_c(T_1+T_2+T_3+T_4)}} \qquad [1]$$

Where:

T_1: the thermal resistance of the insulation layer

T_2: the thermal resistance of armour

T_3: the thermal resistance of the outer jacket

T_4: the thermal resistance of surrounding medium

R_c: electric resistance of the conductor at operating temperature θ_c

θ_{amb}: soil ambient temperature (°C)

θ_c: conductor temperature (°C).

For a pair of equally loaded HVDC cables in close proximity (bundle configuration) buried at a depth L, the temperature rise at a point P in the surroundings is calculated through