Hybrid analytical / finite-elements model to design optimal HVDC joint bays

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ABSTRACT

Joint bays are key elements of HVDC underground cable links. The optimization of their design for a greater compactness aims simplified civil works and cost savings. Closer cables or joints means then a special attention to mutual heating.

In this paper, the authors present a hybrid model to study the thermal behavior of HVDC joints, joint bay and soil. This model couples a 2D axisymmetric finite-element model of the cable and the joint, with an analytical model of the joint bay and soil, based on IEC 60287 standard. This approach allows simulating the heat sources and heat transfer in the layers of cables and joints, while considering the longitudinal heat flow towards metallic parts. Coupling finite-elements with analytical formulas allows obtaining accurate results without defining a full 3D model, i.e. at low computational cost. The simulation results are validated by experimental results of laboratory tests.

This hybrid model provides a fast and accurate numerical prediction of HVDC cables and joints temperatures in real operating conditions. It ensures optimized joint bays design without degrading their performance.

KEYWORDS

HVDC, cables, cable accessories, joint bays, current rating, thermal design.

INTRODUCTION

HVDC cable systems have been developed to connect areas, with an increasing economic interest when the covered distance is long. Significant efforts have been made to increase the delivery length on drums, greater than 2 km, even with large conductor and high voltage level (requiring an increased insulation thickness). Joints, which bond cable sections, represent singularities along the cable route, especially from a thermal point of view. The material layers are thicker to withstand electrical stress at the interfaces at any operating conditions, and joints may be subject to very high thermomechanical forces. Joints are installed in a specific controlled environment. A typical configuration is a joint bay, made up of concrete walls, filled with sand. Therefore, the design of the singularity in the power link requires a special care for its design, dielectric, mechanical and thermal. The present paper covers the thermal aspect to optimize the thermal design of the joint bays.

Limiting the risk of premature failure of cables and joints in joint bay requires an accurate estimation of the internal temperature of each system component. This temperature greatly depends on the way the components are installed and, on their environment, [1].

In joint bays, clearance is introduced between the cables to install the joints (space needed by the jointers to ensure the assembly in the best conditions). This is the determining parameter of the bay sizing. Yet a minimum core-to-core spacing should be respected, to guarantee the safe and efficient operation of the joints at temperatures below the maximum allowed [2]. An accurate current rating model of HVDC joints allows determining the core-to-core spacing that guarantees a secure HVDC system and an optimized joint bay design.

First HVDC joints modeling attempts used analytical techniques based on electrical analogues to thermal systems representing their composing materials thermal properties [3,4,5]. Those techniques are practical, quick but limited in term of geometric details.

The emergence of numerical methods allowed models to extend into the third dimension, with a detailed parameter approach [6,7,8]. Yet this quality improvement is limited by the computational power, the execution time and the number of nodes that could be assigned to resolve the problem.

In this paper we present a combination of a 2D axisymmetric finite-element FE model describing the cable and the joint coupled to an analytical model based on IEC 60287 [9,10] standard for the joint bay and soil. This hybrid model allows obtaining accurate results without defining a full 3D model.

DESCRIPTION OF HVDC JOINT BAY

Cable installation over a long distance is split in sections of cable connected to each other by a joint. These cable joints are installed in concrete structures called joint bays buried underground [11]. In the case of HVDC single-phase lines, each joint bay houses two cables as shown in Figure 1.

The current rating simulation model presented in this paper aims to model the thermal behavior of this joint bay to optimize its design.

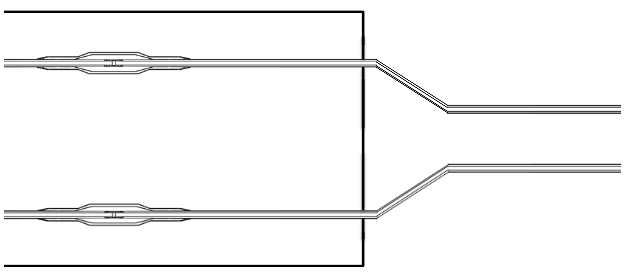

Figure 1: Joint bay installation