DESIGN AND PLANNING APPROACH FOR HVDC SYSTEMS IN LARGE-SCALE TRANSMISSION SYSTEMS

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Background and Objectives

To achieve climate neutrality in the European Union by 2050, a transformation of the energy system is necessary [1]. This transformation involves replacing conventional, dispatchable power plants with renewable energy sources (RES). Integrating these RES into the transmission grid relies on High Voltage Direct Current (HVDC) transmission systems. HVDC systems excel in efficiently transporting large quantities of energy over long distances.

The present planning and commissioning of HVDC connections mainly focusses on point-to-point connections (P2P connections). With the increasing aim of meshing DC topologies up to an overlay DC grid architecture, the systemic interactions within the DC system and especially with the AC system will increase, which will have to be analyzed in terms of reliability and resilience in the future. These include the resulting load flow situation, compliance with voltage band limits, potentials for active and reactive power provision and transient stability aspects. Due to the still-undefined configuration of HVDC systems, various building blocks emerge, shaping the architecture of the HVDC system.

The paper introduces a framework for designing and planning HVDC systems. The aim of the framework is to enable a comparison of different HVDC architecture options. The basis for this is an identical steady state (n-0)-transport task for the AC transmission grid. By using different HVDC architectures and topologies, it is possible to see how the HVDC grid behaves in static redispatch calculations or dynamic RMS or EMT simulations. This means that the results of the subsequent analyses can be attributed exclusively to the HVDC architecture and topology. Moreover, by varying individual architecture building blocks, the impacts on the resilience and reliability of the transmission grid can be assessed.

The work of this paper is conducted within the framework of the HVDC-WISE project, which is part of an EU Horizon project. The objective of the HVDC-WISE project is to explore concepts and develop solutions that enable the establishment of large HVDC-based transmission grids. The emerging HVDC-based transmission grid aims to enhance the resilience and reliability of the existing power grid and facilitate the integration of renewable energies. The project involves 14 partners from 11 countries, including academic and industrial collaborators, as well as transmission grid operators.

Topologies for HVDC Systems

Topologies for HVDC systems can be classified into two major categories – Point-to-Point connections and Multiterminal HVDC Systems (MTDC Systems). P2P connections consist of two converters and can be configured as back-to-back or long-distance configurations. In a long-distance configuration, converters at different locations are linked by a cable or overhead line. [2] [3]

MTDC systems feature more than two independently operating converters. In the topology of MTDC systems, a distinction is made between linear, radial and meshed systems. Linear and radial systems provide a single transmission path between individual converters, while meshed MTDC systems offer multiple transmission paths. [2] [3]

Methodical Approach

Within the developed methodical approach, grid studies based on static load flow calculations for the AC transmission grid are conducted. These studies help to identify areas of interest, including load centers and heavily meshed AC grid regions. Furthermore, regions with existing or planned HVDC

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connections can be areas of interest. The architectural building blocks are assumed to be given. The previously defined areas of interest determine where the architectural building blocks are deployed in the grid.

Figure 1 shows exemplary areas of interest for the continental European transmission grid and the application of the architectural building blocks.

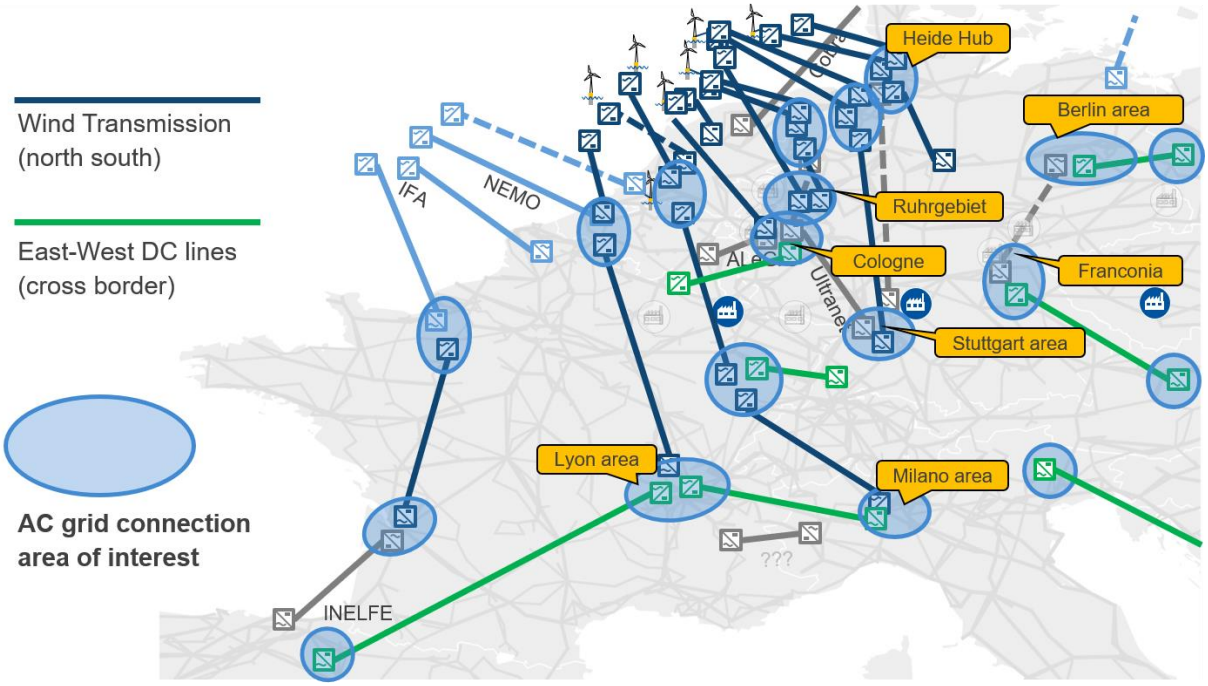

Figure 1: Exemplary areas of interest and application of architectural building blocks

Any HVDC-based architecture has to connect all of these areas of interest by means of different HVDC topologies. However, not all areas must necessarily be connected with a single HVDC grid. Instead, it can be achieved with multiple separate ones or solely with independent P2P links. The HVDC system size and topology may vary between P2P links only, several smaller MTDC or one large MTDC system.

Analysis and Outlook

The analysis focuses on the framework for comparing various HVDC architectures and topologies. The building blocks are presented, and the process of identifying key areas is explained. Load flow calculations on a sample transmission grid help to pinpoint areas of interest, leading to proposals for different HVDC architectures and setups.

References

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