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Question 2.2.1: Planning HVDC transmission systems embedded into an AC interconnected network leads to a variety of challenges. Which design and technology aspects must be considered for embedded point-to-point and multi-terminal HVDC transmission systems?

Contribution

There are a variety of aspects that need to be taken into account when deploying multi-terminal, multi-vendor, multi-purpose HVDC systems. Our paper on the Bornholm energy island feasibility study touches several of them:

1. HVDC system topology (redundancy) and voltage level.
2. Hub configuration and protection strategies: AC or DC hub, selective vs non-selective, etc.
3. TRL of needed technical solutions: DC breaker, full-bridge converters, interoperability, protection strategies, etc.
4. Purpose of connection (e.g. amount offshore wind evacuation + amount of interconnection between countries) and build-out sequence
5. Max loss of infeed limits
6. Stability and interoperability

The contribution tries to address some of the items above, especially #2, #3 and #5.

De-risking of large multi-terminal multi-purpose HVDC projects

When deploying such systems, it must be borne in mind that technical risks play into investment appetite and influence the eventual economic feasibility of the project. Deploying a large system purely relying on solutions that have not been used extensively in the industry before may create significant risk and discourage the investment.

Elements that may right now present a level of maturity that poses significant risks for multi-terminal multi-purpose multi-vendor HVDC systems are for instance HVDC breakers, interoperability of HVDC converters on both AC and DC side, HVDC protection strategies, etc.

A way to reduce the risk is to deploy the system in a staged manner, relying initially on more well-known solutions and introducing new technical solutions incrementally. An example of this would be, in the case of a hybrid interconnector, to first rely on connection on the AC side based on AC hub. This would practically mean installation of two state-of-art radial connections with the possibility to interconnect on the offshore AC side. As a first incremental step, converter interoperability on the AC side would need to be achieved. The next step could be to introduce a DC hub without DC breakers, with the incremental development of DC interoperability, to then be augmented by introduction of DC breakers and selective protection. Necessary space for both AC and DC hub as well as DC breakers can be reserved from the beginning, which is easier in the case of Bornholm (natural island) as compared to the case of offshore platforms or artificial island hubs.

The price to pay for a staged approach would be initial anticipatory investment on equipment and substation footprint and initial larger transmission losses for interconnection between countries. However, this is justified by a much reduced level of risk, which is not an insignificant factor when dealing with such large investments. Moreover, once the system has been completed, transmission losses between countries will be reduced by using the DC hub concept, which can help offset some of the anticipatory investment.

On the other hand, staged deployment means that the addition of each new module over time has to be verified by tests and analysis for the possible combinations of existing modules and the new module. This means that there's a less clear scope and end of test and analysis activities as the staged development can be expected to happen over a number of years. This will need to be managed practically and commercially/contractually between TSOs, owners and OEMs involved as the tests and analysis for the addition of each new module will have to draw on correct information and models for the already existing modules, and probably require support from owners, operators and OEMs.

Loss of infeed limits

Another aspect that is addressed by our paper is the loss of infeed limit. When analysing the pros and cons of different large capacity HVDC transmission solutions for a system like the Bornholm energy island, one quickly realizes that the optimization of the technical solution soon encounters a constraint given by the loss of infeed limit.

Current HVDC converter and cable technology would offer the potential for transmission of up to 2GW over a single monopole (2kA over ±525kV). Loss of such a large infeed is not acceptable in many power systems, as TSOs need to cope with such a contingency by procuring a sufficient amount of reserves to ensure proper control of the system frequency after the outage.

When encountering this constraint, there are many possible solutions, among which:

- A solution included in the paper is switching to bipolar systems to increase capacity beyond the infeed limit without increasing costs proportionally. When parallel systems are deployed, usage of a common metallic return can optimize the economics further.
- A solution that's outside of the scope of the paper is adjustment of the loss of infeed limits. This requires a detailed system-wide assessment from the TSOs and can take place either as an adjustment of the general loss of infeed limit in the power system, or as a dedicated agreement related to a single project.
- An alternative possible solution is coupling the transmission system with quickly adjustable loads in the power system where the loss of infeed limit may be violated. Such adjustable loads may for instance be hydrogen production plants. Such plants could be coordinated with the HVDC transmission link operation and used to turn down consumption whenever a sudden drop in the infeed of power larger than the loss of infeed limit occurs.