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INTEGRATION OF AN OFFSHORE WIND FARM TO BRITNED IN A HYBRID MULTI-TERMINAL HVDC NETWORK

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Abstract. High-voltage direct current (HVdc) provides an efficient option for long distance power transmission. Since its first commercial use, mainly point-to-point HVdc connections have been realized using the conventional line-commutated converters (LCC). With the development of voltage-source converters (VSC), multi-terminal dc (MTdc) grids are easier to be implemented. This paper studies the feasibility of a hybrid high-voltage dc (HVdc) network using two conventional line-commutated converters (LCC) combined with a VSC to integrate an offshore wind farm (OWF). The three converters are connected radially. The start-up and the normal operation dynamics of the three-terminal hybrid HVdc system are studied using Matlab/Simulink. The controllers of the converters are presented and control strategies for the smooth integration of the OWF into the HVdc interconnector are investigated.

Keywords: Control Systems, HVdc, Hybrid networks, Offshore wind farms, Multi-terminal networks.

INTRODUCTION

Due to the increasing integration of renewable energy sources to the electricity grid, long-distance power transmission has become very important for the delivery of power to the demand centers. Therefore, its realization is crucial for the energy future.

In cases where high amounts of power need to be transported over long distances, either via overhead lines, or especially through underground or submarine cables, HVdc transmission is more efficient than high-voltage alternate (HVac) current, both in terms of transmission losses and cost. The advantages of HVdc over HVac include higher power per conductor, higher voltages possible, no transmission distance limitation. However, there are still several aspects to be investigated before HVdc-based multi-terminal networks are realized in a great scale.

HVdc was first commercially used in 1954 to connect the island of Gotland to the Swedish mainland. Since then, most of the HVdc projects include point-to-point or back-to-back connections, whereas only 2 of them have more than 3 interconnected terminals, constituting an MTdc. Depending on the type of ac/dc converters utilized, these can be distinguished in three types [1]: (1) Current-Source Converter (CSC)-based networks, in which all of the connected stations use CSC converter technology; (2) Voltage-Source Converter (VSC)-based networks, where all stations use VSCs; (3) hybrid networks, in which the two converter technologies are both used in different stations.

In this paper the focus is turned on hybrid topologies, which aim at combining the advantages of both converter technologies, providing a more economical, as well as technically robust and reliable solution for HVdc transmission systems. The most important advantages of the hybrid configurations are [2, 3, 4]:

1. the reduction in the investment cost, as LCC-HVdc is an already established technology;
2. the reduction in the power losses, due to the use of less VSCs in a multi-terminal network;
3. feasibility for high power levels resulting from the use of LCC, which is a mature technology;
4. higher controllability derived from the VSC converter controllers;
5. higher voltage stability through the voltage support of the VSC-HVdc link;
6. a more reliable power supply, as VSCs and LCCs can complement each other on the supply of nominal power;
7. the interconnection of weak and passive networks due to the use of VSC technology;
8. lower current ratings of dc breakers are required.

However, the main disadvantage of this technology, so far, has been that the power flow can only be conducted in one direction. This happens since LCC requires the reversal of the dc voltage, while keeping the dc current unchanged, whereas VSC requires the opposite. Consequently, operation needs to be interrupted and the system needs to get de-energised before reversing the power flow [2].

This paper focuses on the integration of an OWF through a VSC to the already established LCC-based point-to-point connection between the Netherlands and the UK (BritNed). The main objectives of this paper are:

1. To set up the hybrid MTdc network using Matlab/Simulink;
2. To implement the respective controllers for the used converters;
3. To analyze the performance of the system during start-up and at normal operation conditions.

INVESTIGATED SYSTEM

The layout of the MTdc network studied is shown in Figure 1. A three-terminal grid in radial configuration is used. VSC is used to support the operation of the OWF, by controlling the weak ac grid voltage and frequency. The VSC is connected to the LCC-based BritNed. Based on the BritNed operation data [5], more than 80% of the annual power transmission is directed towards the UK grid. Therefore, the station on the UK hub uses an LCC in inverter mode, controlling the network dc voltage level, while the NL hub has an LCC in rectifier mode, controlling the dc current. For the study of the system, average converter models were implemented using Matlab/Simulink.

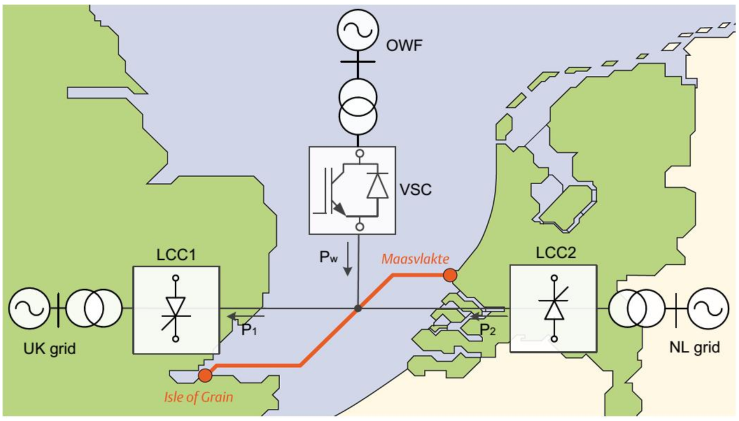

Figure 1. Hybrid MTdc network.

More specifically, the BritNed connection, which is rated at 1000 MW and 450 kV, consists of two 12-pulse LCCs connected via a long dc cable of 250 km. For the cable simulation, a distributed model was used. At the rectifier side (NL), the ac voltage is 400 kV at 50 Hz with a short circuit ratio (SCR) of 3. At the inverter side (UK), the ac voltage is 400 kV at 50 Hz with SCR of 3. The OWF of 300 MW is connected to a VSC which converts the wind power. Via a 50 km dc cable the VSC is linked to the midpoint of the BritNed interconnector. The switching frequency of the VSC is 2 kHz.

CONCLUSIONS

In the proposed paper the operation of a hybrid MTdc network is investigated. It is expected that with the high penetration of renewable energy sources to the grid, the already existing point-to-point HVdc connections will have to be expanded to accommodate new connection hubs. Because of the inability of LCCs to support and connect weak ac grids, wind farms are expected to get interconnected via VSCs. Therefore, this case study can be used as a reference scenario for future implementation of hybrid networks and subsequently can be expanded to networks with more terminals.

In the final paper, the controllers of the different stations will be presented. The network response to the start-up process and to wind power changes in normal operation will be shown. Moreover, control strategies to mitigate the dynamic impact of these phenomena will be presented. Finally, the difficulties and the challenges in the integration of an OWF to an existing interconnector will be discussed.

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