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NORDLINK
Pioneering VSC-HVDC interconnector between Norway and Germany

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Summary

NordLink is a pioneering HVDC project connecting the grids of Statnett in Norway and TenneT in Germany. It will use the first full bipole VSC-HVDC converter rated at ±525 kilovolts (kV) and 1,400 megawatts (MW). ABB has recently been awarded an order for the two HVDC converter stations and the German sector of the HVDC cable system for this project. At a length of 623 kilometers (km), it will be Europe's longest interconnector, enabling power flow between Norway, with its vast amount of flexible hydropower, and Germany with an ever-increasing amount of intermittent wind and solar power. The additional interconnection capacity will enable better utilization of the power markets, potentially bringing down electricity prices while increasing the amount of renewables in the energy mix.

Abbreviations

VSC – Voltage Sourced Converter, MI Cables - Mass Impregnated Cables, HVDC – High Voltage Direct Current, HVDC Light – ABB's VSC-HVDC multilevel converter system

Background: Development of interconnecting capacity between north and continental Europe

The HVDC system will join two of Europe's main power grids, the continental ENTSOE grid and the Nordic grid. These two grids have an installed capacity of close to 600 gigawatts (GW) and 100 GW respectively; however, the increasing share of renewable power calls for more trading capacity.

Over the last four decades, several links have been installed to increase the power transfer capacity between the grid in Norway, Sweden, Finland and Western Denmark, known as the Nordpool region, and Europe's continental grid. As shown in Figure 1, six links have been installed. The NordLink interconnector is the first connection between Norway and Germany, and with its rated power of 1,400 MW at the receiving end in Germany, it is the most powerful and the longest HVDC link in Europe.

NordLink is the second VSC-HVDC interconnector between these two regions. In early 2015, the Skagerrak 4 VSC-HVDC link was commissioned. The use of VSC technology makes it possible to stabilize voltage and power quality on the AC side of the converter. ABB has extensive experience in this area using its HVDC Light technology and now has 23 such projects on its reference list. NordLink represents the world's longest VSC-HVDC link.

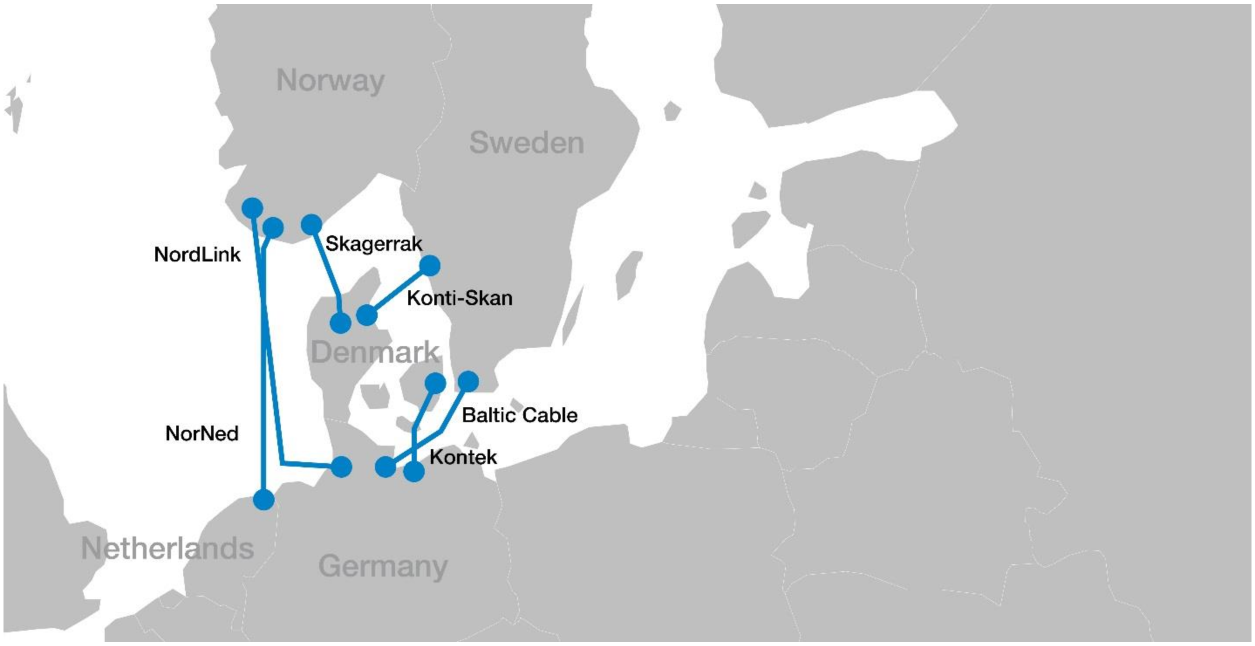

Figure 1: Interconnectors between Nordpool zone and continental European grid

Three good reasons to use VSC-HVDC technology to connect Norway and Germany

Firstly, the HVDC converters have the ability to connect two non-synchronized grids, thereby linking the frequency of the two separated electrical zones represented by the Nordic and continental grids. Secondly, the HVDC connection makes it possible to transmit electricity over long distances with minimum losses. In fact, it is not even possible to transport alternating current (AC) over long distances subsea due to capacitive losses. Finally, the VSC-HVDC converter stations have full STATCOM (Static Synchronous Compensator) functionality to support the AC network at the Norwegian and German point of common coupling.

VSC-HVDC converter stations

Figure 2: NordLink interconnector route

The NordLink interconnection consists of a bipole configuration between Tonstad in Norway and Wilster in Germany. The converter bipole is rated at ±525 kV with a bipolar power of 1,400 MW at the AC connection at the receiving end.

The main circuit arrangement and ratings, as well as the available operation modes, have been designed in compliance with the system requirements. The system is designed to operate in the following modes:

- Bipolar mode
- Monopolar metallic return mode
- Reduced DC voltage operation
- STATCOM mode
- Black Start / Islanded mode

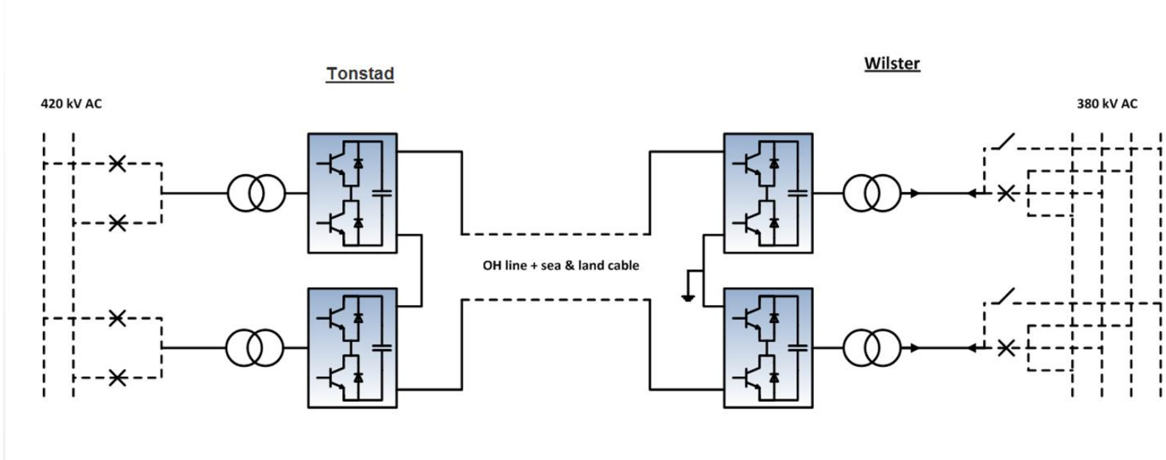

Figure 3: Simplified single line diagram of the NordLink interconnector

The normal mode of operation is bipolar with balanced voltage between the two poles. The interconnector will not be equipped with electrodes or return conductor. However, monopolar metallic return operation is possible by utilizing the conductor of the other pole as the return path. Each converter is also capable of operating as a STATCOM, independent of the converter in the other pole. The reactive power capability allows NordLink to support the AC networks with reactive power in case of disturbances.

The VSC-HVDC system allows for fully independent control of both the active and the reactive power flow within the operating range of the system. The active power can be continuously controlled from full power export to full power import.

The converter is built on ABB's HVDC Light technology, IGBT-based (insulated-gate bipolar transistor) converter cells arranged in series, known as a multilevel configuration. The number of cells per valve is dependent on the voltage rating of the converter.

Figure 4 A) Skagerrak 500 kV converter valve *B) Semiconductor StakPak*

The VSC valve uses an IGBT semiconductor switch with both turn-on and turn-off capability for the current. The voltage rating of the IGBT component is 4.5 kV. This solution allows ABB to propose a converter design with station losses below 1 percent.

The HVDC submarine and underground cable system

Figure 5: Example of MI cable

The planned transmission system that connects the two HVDC converter stations is 623 km in total, consisting of 54 km of underground cable route in Germany, 516 km of submarine cable route and finally 53 km of overhead line in Norway. ABB will deliver and install the mass impregnated (MI) cables for the underground portion in Germany as well as a 154 km long submarine route from the German coast.

The cable circuit consists of two parallel MI cable cores. The submarine cable in the German sector will be buried in the sea floor at water depths of 25 meters or less. The two cables will be installed in a bundled configuration which results in a narrow installation corridor as well as a negligible or nonexistent influence on magnetic marine compasses. Close to the German coast, 12 nautical miles from shore, the 2-K condition applies. This requirement stipulates how much the cables are allowed to increase the temperature of the sediments in the sea floor. The cables in this application are designed for extra-low electrical losses, obtained with a large copper conductor. The burial depth of the cables in the sea floor is also oriented towards the requirements of minimal environmental impact during service life.

Their installation in shallow waters near the shore is itself a challenge and requires dedicated laying vessels, sometimes differentiated from vessels suitable for open sea. In order to achieve a functional and effective solution, a compromise between load capacity, weather durability and the vessel’s draft has to be achieved.

The design of the submarine cables includes a copper conductor, an impregnated paper insulation system and double steel wire armoring. The outer diameter of the cable is approximately 15 centimeters. The cable system is put through an extensive test program before the design and the manufacturing processes are fully approved. The test voltages will qualify the cable system for the maximum rated voltage of 525 kV.

The cable will be loaded in several different shipments at ABB’s high-voltage cable plant in Karlskrona, Sweden and the separate lengths will subsequently be jointed together at sea. The maximum lengths of the cable are limited in practice by the capacity of the cable-laying vessel.

Figure 6 A) Land fall installation of a submarine power cable. B) Preparations for jointing an underground HVDC cable in an open trench

The underground cable is rather similar to the submarine cable with the exception of the lack of wire armoring. Further on, the outer yarn serving is replaced with an extruded PE sheath. The underground cable mass is approximately 45 kg/m. The cable is delivered on site in lengths exceeding 1,000 meters on specially designed cable steel drums.

The route includes crossing of the Kiel Canal, which will be achieved by use of a horizontal directional drill (HDD) 25 meters below the channel’s floor. Most of the underground cable will subsequently be installed by cable pulling into an open trench.

For reference list, project summaries, technical papers and further reading, see www.abb.com/hvdc