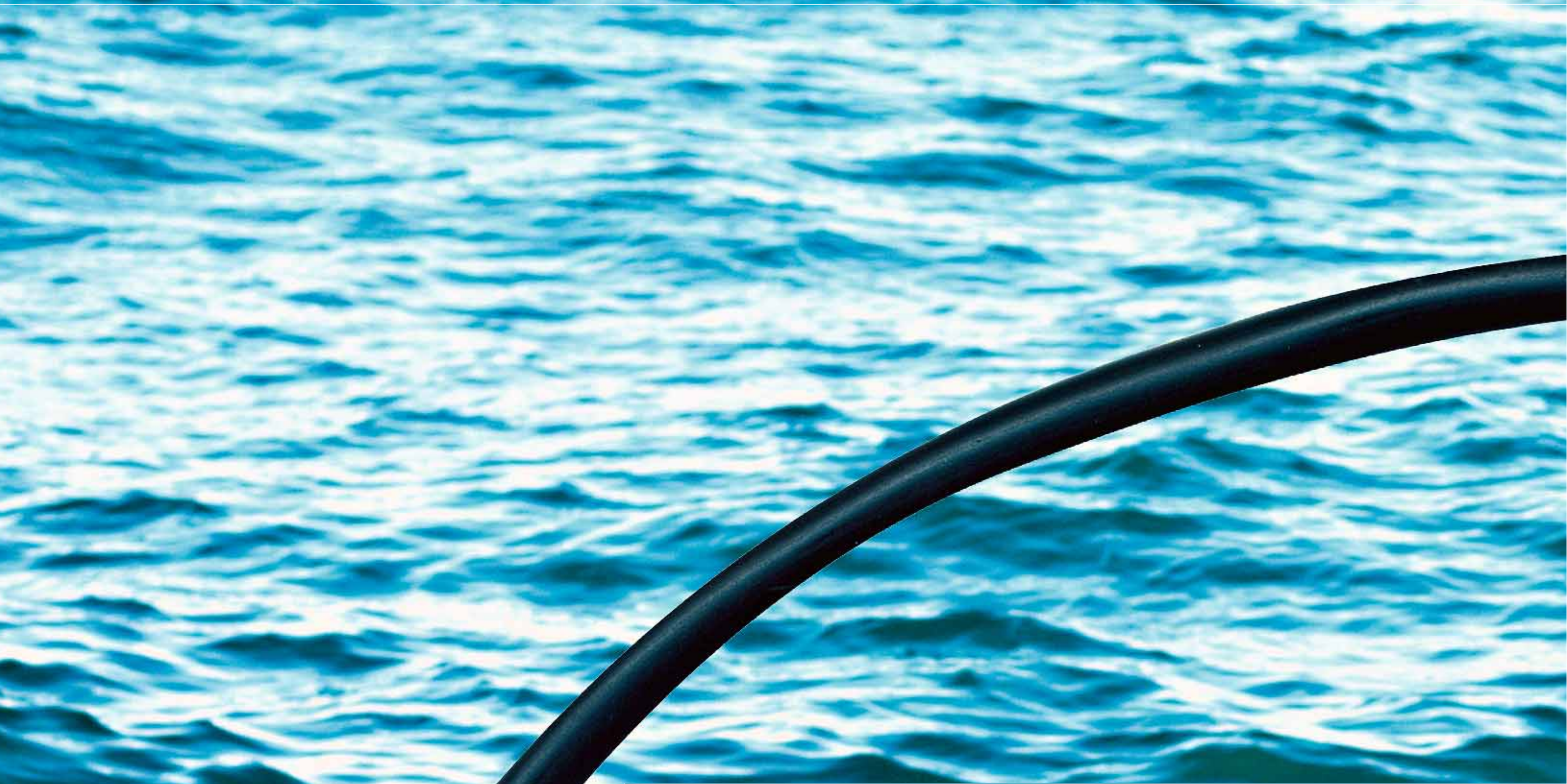


The future is now

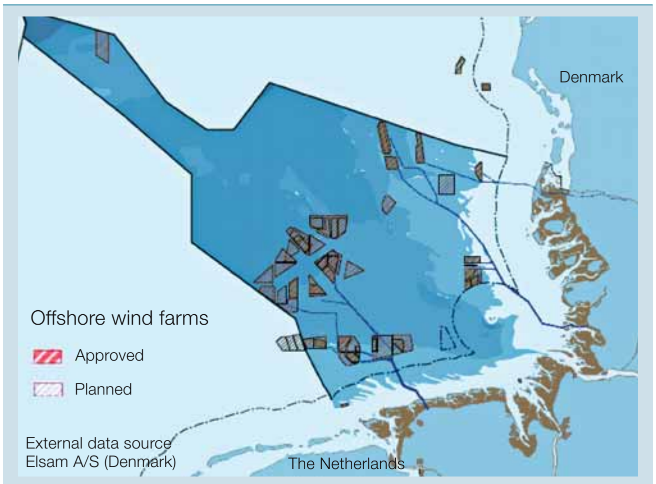
Linking up the world's largest offshore wind-farm area with HVDC transmission

Jochen Kreusel

Renewable energies that provide electricity without emitting any CO_2 are rapidly advancing all over the globe. As one of the major industrialized nations, Germany is pursuing a highly ambitious strategy: The target is to increase the proportion of renewable energies from today's 13 percent to as much as 25 to 30 percent by 2030. There is still a long way to go, and the key to achieving this target is out at sea – in Germany this means the high seas. Offshore wind energy has been earmarked to fill a large portion of the gap. In late 2006, a vital statutory precondition for this was put in place; meanwhile wind farms with a total rating of more than 15,000 MW are being planned for the North and Baltic Seas, with the first of them already in the implementation phase. But how is the electricity going to reach dry land and the actual consumers?

With this question, Germany is entering virgin territory, since the offshore wind farms already installed in other countries are all significantly nearer to the coast than the areas selected in the North Sea. Because of the need to protect the tidal shallows, distances of more than 100 km must in some cases be overcome using submarine cables 1. The use of three-phase cables is financially and technically unsuitable for distances of this magnitude. Thus, the submarine cable links installed in Scandinavia, for example, and between Scandinavia and Continental Europe, are executed as high-voltage direct current (HVDC) systems. However, it is not possible simply to adopt this field-proven solution for network linkage of offshore wind farms.

1 Planned offshore wind farms in the German North Sea



Classical thyristor-based HVDC transmission needs short-circuit power for commutation (ie, turning off the thyristors), which has to be provided by the surrounding networks. This is indubitably assured when it comes to linking up the interconnected networks of Scandinavia and Continental Europe, and for large-scale long-distance power transmission in China and South America, the most important HVDC applications hitherto. For an offshore wind farm, which firstly does not possess a powerful network and secondly also has to be capable of starting up from a de-energized state, the lack of what is called "black-start capability" constitutes a fundamental problem.

HVDC Light® for offshore wind energy

The technical innovation that solves this problem is called self-commutated HVDC transmission. It is based on state-of-the-art power transistors (insulated-gate bipolar transistors, or IGBTs), and was premiered in the mid-1990s by ABB under the name of HVDC Light; it is meanwhile being used in numerous projects with steadily increasing ratings. Today, system ratings of up to 1,100 MW can be implemented using this technology.

The power transistors used in self-commutated HVDC applications are, in contrast to the thyristors used in traditional systems, able to not only switch electricity on, but also off again. This means they can be utilized for pulse-width modulation, which in comparison to traditional HVDC technology leads to much better approximation of the sinusoidal voltage characteristics and thus to a much reduced filter requirement. Three properties combine to make it an ideal solution for linking up offshore wind farms:

Unrestricted reactive power provision

The converters of an HVDC Light system can provide any active/reactive power combination within their design limits, swiftly and without the gradations required in traditional systems 2. They therefore offer the full functionality of a controllable compensator at both ends of a transmission system (static VAR compensator, or SVC). In the case of wind-farm links, this means that reactive power can be provided for the offshore network inside a wind farm, and that the voltage stability at the connection point can be supported. This enables the high power levels of the offshore wind farms to be fed into the network (which in coastal regions is often weak) without impairing system compatibility.

Black-start capability

The transmission system can be started from the de-energized state, eg, if the wind has not blown at all.

Reduced filter requirement with concomitant space savings

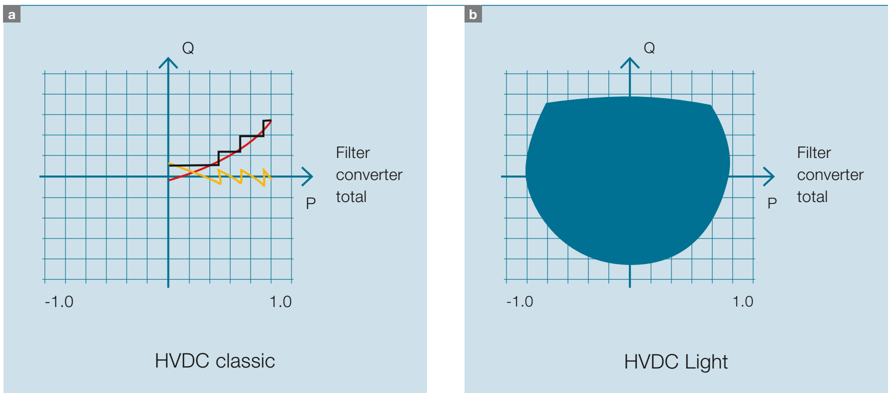
In comparison to traditional HVDC transmission, the offshore platform can be significantly smaller in size and designed for considerably less weight.

For an offshore wind farm, the lack of what is called "black-start capability" constitutes a fundamental problem.

A world record

Another advantage of self-commutated HVDC transmission is that it can be combined with simple, lightweight, eco-friendly polymer cables, since the voltage peaks in the DC link encountered in traditional HVDC transmission

2 P-Q diagram showing a traditional HVDC system a and the self-commutated HVDC Light b. HVDC Light is able to control every point of the four quadrants swiftly and continuously.



do not occur. In addition, the HVDC converters are nowadays designed in a modularized, largely prefabricated construction, enabling the network links required for the planned offshore wind farms to be implemented with sufficient celerity. This has most recently been demonstrated with the Estlink between Finland and Estonia inaugurated in late 2006, which was completed in just under 20 months – a world record for an HVDC transmission system [1].

Self-commutated HVDC transmission is based on state-of-the-art power transistors and was premiered in the mid-1990s by ABB under the name of HVDC Light.

Green light for the North Sea network

By the summer of 2007, all technical preconditions for beginning construction of the offshore network in the North Sea had been met. E.ON Netz then put the first stage out to tender for the first link to a commercial offshore wind-farm area in the North Sea – the Borkum 2 cluster. On completion of the wind-farm projects currently underway in this area, the North Sea wind-farm network will have a rating of approximately 6,300 MW.

Since the German Infrastructure Planning Acceleration Act[1)] places the responsibility for network linkage of the offshore wind farms with the transmission network operators, the network link can be optimized irrespective of the particular wind farms involved [2]. Several "seaborne power sockets," to which the completed wind farms can be connected, will accordingly be provided for the Borkum 2 cluster. ABB has been asked to supply the first of these power sockets, featuring an HVDC Light system rated at 400 MW. 128 km of submarine cable and 75 km of underground cable will connect this first joint node for several wind farms to the transmission grid at the Diele transformer substation 3.

In June 2008, work began on laying the underground cables, dimensioned for a DC link voltage of ± 150 kV 4. The very small diameter of the cables – about 8 cm, typical for HVDC Light systems – can be clearly seen. The cables are laid on land in 750 m sections at a depth of about 90 cm in existing soil material, and are protected by a plastic cover.

By 2009, the network link will already have gone into operation. This means it will have been completed just as swiftly as the Estlink between Finland and Estonia. The plan is to gradually expand this initial link as the wind-farm area is upsized in the future. 5 shows the basic concept involved for network linkage of the wind-farm area pursued by the network operator E.ON in its own sphere of responsibility. Each wind farm has its own transfer platform, on which the 30 kV cables arriving from the wind-energy installations are grouped together. Using relatively short high-voltage three-phase cables, these platforms are in turn connected to the E.ON platforms – the power sockets – where the current is converted into DC. At the same time, the converter station is able to cover the reactive-power requirements of the offshore network. Several of the E.ON platforms and several HVDC Light systems can be connected at sea using a three-phase busbar, which enables additional transmission systems to be successively integrated in parallel to the present one as the network link is expanded in the future.

On completion of the wind-farm projects currently underway in the Borkum 2 cluster, the North Sea wind-farm network will have a rating of approximately 6,300 MW.

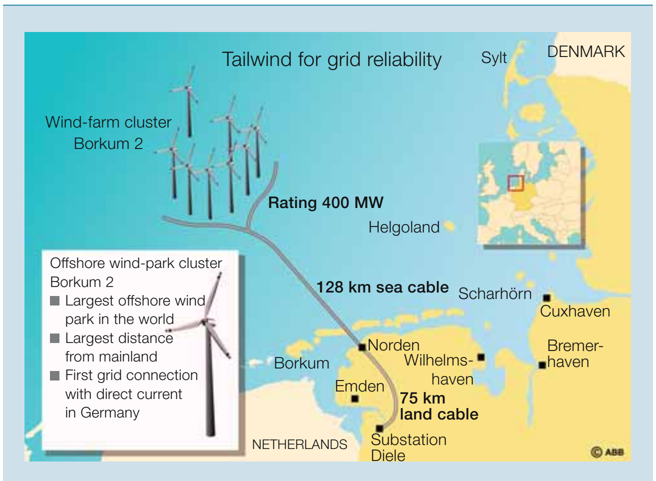
Network design enhancement on land

The solution has thus been found for transporting the electricity generated at sea to the mainland. But this does not yet mean that all impediments to achieving the German federal govern-

Footnote

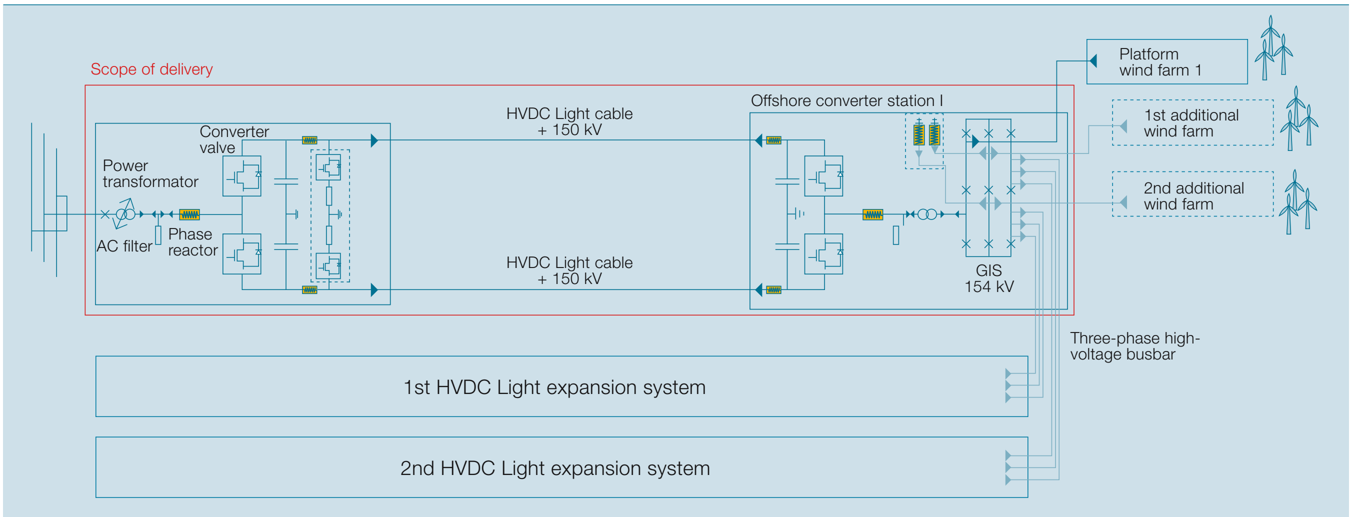
1) Infrastrukturplanungsbeschleunigungsgesetz

3 Network link between the cluster Borkum 2 offshore wind-farm area and the German grid



4 Laying the first sections of cable (operating voltage 150 kV, transmission rating 400 MW) in Aurich County, Germany in June 2008

5 Expansion concept for the network link of the cluster Borkum 2 wind-farm area



ment's energy policy objectives have been eliminated, since the users of the electricity are not necessarily located in the coastal regions of northern Germany. And in all likelihood, they are not even living in the nearest conurbation, the Ruhr, since there, new thermal power plants are currently under construction – more plants than in the past and more than are actually required in this region. There is, however, a need for additional generating capacity in the south and southwest of the country, where numerous nuclear power plants are still supplying the grid.

ABB has been asked to supply the first of several "seaborne power sockets," featuring an HVDC Light system rated at 400 MW.

In the future, the German transmission network will have to be focused much more on actual transportation tasks than has been the case in the past. This first contribution will come from the upgrades to the existing 400 kV network determined as necessary in the first dena (German Energy Agency) network study for the period up to 2015 [3]. But Germany will also be requiring a dedicated transport infrastructure – long-distance transport cables that supplement the existing 400 kV network beyond the above-mentioned upgrades. Technically, this infrastructure, known as an overlay network, can be imagined as a three-phase extra-high-voltage network with voltages of up to 800 kV, but also in the form of HVDC cables that are fundamentally predestined for long-distance transport by virtue of their smaller losses and the fact that they do not require reactive power.

When looked at more closely, the network link for the Borkum 2 cluster wind farm already signposts the probable direction of development: Here, the DC cable does not end at the coast, because there is no suitable connection point available there, but is continued 75 km further over land to a fitting location. This, it can be predicted, is precisely how the first DC long-distance cables will be premiered in the European transmission network. This estimation is also shared by the German federal government: In the draft bill for accelerating the upgrading of extra-high-voltage networks approved by the federal cabinet on June 18, 2008, HVDC transmission systems are explicitly mentioned as a solution for transporting electricity to the south of Germany [4].

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