

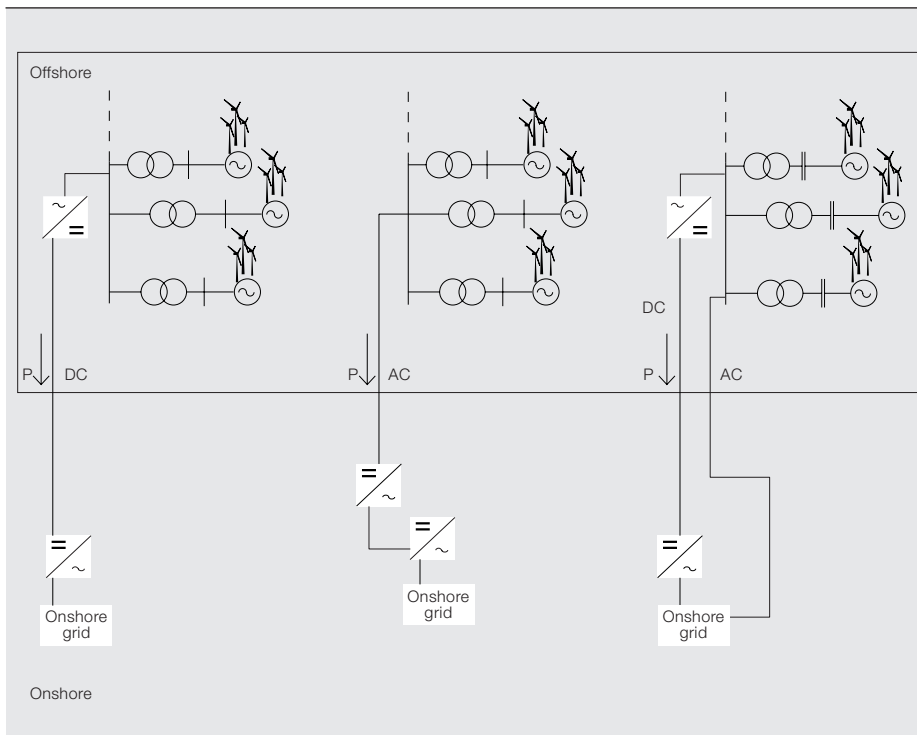


Strong winds, high yield

HVDC Light® technology goes farther out to sea

PETER SANDEBERG – Under pressure to decrease the environmental impact of generating electrical power, coupled with continuously increasing demand, energy producers must utilize more of the earth's natural resources to harvest additional power. While many parts of the world bask in glorious sunshine, northern Europe tends to experience winds that can wreak havoc. On the flip side, the construction of onshore and offshore wind power plants have successfully

exploited these winds to produce clean energy. Given that the higher average offshore wind speeds can result in an energy yield of up to 70 percent higher than that generated on land, it is no wonder that the next 15 years will see an increase in the number of offshore plants. However, the farther out to sea, the greater the challenge of ensuring the transmission of a stable energy supply to the mainland. This challenge is being met with ABB's HVDC Light technology.



1a Direct connection solution

1b Back-to-back solution

1c Parallel solution combines HVAC and HVDC

The United Nation's Intergovernmental Panel on Climate Change (IPCC) has predicted that clean energy will have to at least treble in output in order to avoid catastrophic climate change [1,2]. Over the past few decades, wind power generation has been making a vital contribution to the global effort of lowering the environmental impact of electrical power generation. Championed as an increasingly important source of renewable energy, its contribution is set to increase over the next 15 years with the construction of large offshore wind parks in Northern Europe with a planned capacity of up to 40GW of power. One of the main attractions of going offshore is the frequency of very strong winds, which in turn can yield up to 70 percent more energy than onshore wind parks. Even though it is costlier to construct offshore wind power parks, this increase in yield combined with the fact that many renewable energy technologies have substantially advanced in terms of performance and cost, could offset these costs in the long run.

As well as growing in terms of rated power, offshore wind power plants are being located farther from the coasts and the grid entry points. The impact of large-scale offshore wind power penetration may potentially affect the stability

of the mainland grid, particularly considering the intermittent nature of wind. The tendency toward long distances in combination with often weak coastal connections mean that tough technical challenges need to be overcome:

- The power level of the connected park
- The distance to the connection point
- The type of transmission
- The AC network strength at the connection point
- The fault ride-through capability in case of AC grid faults
- The start-up of the wind power park
- The environmental impact of the transmission system

Average offshore wind speeds can result in an energy yield of up to 70 percent higher than that generated on land.

In addressing each of these challenges, ABB has, using its HVDC Light transmission technology, developed a detailed design for offshore HVDC (high-voltage direct current) systems that can safely and reliably integrate large-scale wind-power production.

To begin with, given that each wind power plant will typically be in range of a few hundred MW up to several GW, HVDC is capable of transmitting power levels of between 100MW and 1,200MW with only one cable circuit. It is considered an economically viable solution especially in situations where the distance to the connecting AC grid exceeds 70 to 120 km.

Closer to shore, a wind power park could be connected with either AC or DC transmission or a combination of these systems. It offers support to meet onerous grid access requirements and helps to improve power quality issues at the connection point.

Its technology provides superior control and quick power restoration during and after disturbances and contingencies including blackouts. And it supports weak grids with

black-start capability, fine-tuning of AC voltage and reactive power and the ability to energize wind power parks at zero or low wind conditions. Last but not least, this transmission system is ideal for stabilizing irregular electricity flows by quickly compensating for power fluctuations.

Offshore wind power plants are growing in terms of rated power and are being located farther from the coasts and the grid entry points.

2 Offshore wind projects connected by HVDC Light

Project	Company / location	Rated power (MW)	System voltage (kV)	DC cable length (km)	Year of completion
BorWin1	TenneT (Germany)	400	DC: ±150 AC: 155/400	SM*: 2x125 UG*: 2x75	2009
DolWin1	TenneT (Germany)	800	DC: ±320 AC: 155/400	SM*: 2x75 UG*: 2x90	2014
DolWin2	TenneT (Germany)	900	DC: ±320 AC: 155/380	SM*: 2x45 UG*: 2x90	2015

*SM = Submarine; UG = Underground

Capturing offshore wind with HVDC solutions

A variety of different transmission schemes are possible using HVDC technology alone and in combination with HVAC → 1.

The direct connection solution shown in → 1a and the back-to-back solution illustrated in → 1b can use a frequency in the wind power park that is not synchronized with the onshore grid. The wind power park is also isolated from electrical disturbances in the onshore grid, meaning that significant “fault ride-through” capability is achieved.

The parallel case demonstrated in → 1c shows how HVAC and HVDC can be combined and is an example of a step-wise expansion approach that enables transmission capacity to be added in stages. The advantages of such a scheme include higher energy availability, the potential to include changes and incorporate new technology as the wind power park develops and, from a business point of view, incremental investments.

At startup, an HVDC Light converter station provides fast and efficient voltage control as the offshore grid is being energized. The voltage is ramped up smoothly at a rated frequency (to prevent transient overvoltages and inrush currents) after which the wind turbine generators are safely connected to the offshore grid. The onshore (receiving) converter station is located either near the shore or farther inland. Even though the grid is often weak along the coastline, HVDC Light technology is designed to enhance the system by providing voltage stability support. Moreover, this technology will literally make the offshore grid, including the connected wind turbines, electrically

immune against transient disturbances originating from the onshore grid. For example, during onshore AC network faults the onshore converter station can bypass the surplus energy from the wind power plant into a braking resistor. Once the network fault is cleared the resistor is disconnected and normal power flow is re-established. This practice protects the wind turbines and other equipment from stresses which, in the long term, helps extend their life cycle.

From an environmental point of view, HVDC Light transmission systems provide many benefits, including:

- An underground, oil-free extruded cable system from the shore to the AC connection point
- Twin cable installation, which in turn neutralizes magnetic fields
- An enclosed converter station to efficiently suppress noise
- A smaller station footprint

Offshore platforms with dual functionality

The trend nowadays is toward large offshore power plants located remotely in a harsh and unforgiving environment that can accommodate both HVDC converters, as well as operations and maintenance personnel. The first two platforms built for offshore wind HVDC converter stations were based on a conventional topside jacket solution. In close cooperation with a Norwegian yard, ABB developed a flexible, highly innovative, robust and scalable platform for greater production efficiency and ease of installation (no heavy-lift vessels or jack-up operations are required). This platform is based on a combination of semisubmersible and gravity-based designs – ie, it acts as a semisubmersible platform

3 Dörpen West onshore station for the DolWin1 wind farm



3a Back view



3b Side view

during transport and installation, after which it is ballasted down to sit solidly on the seabed.

HVDC in action

The increasing number of wind power parks combined with the growing distance between offshore power generation and onshore consumption are two of the main driving factors for the adoption of HVDC Light. In fact, HVDC has been and will be used in some major European projects, all of them in the North Sea → 2.

BorWin1

In 2007 ABB received an order from E.ON-Netz (now TenneT) to integrate one of the largest and most remote offshore wind power parks into the German grid by means of a 400 MW HVDC Light system. The project order, known as BorWin, is the world's first offshore wind HVDC connection. Full grid code compliance ensures a robust network connection of the wind power plant, which consists of 80 wind generators rated at 5 MW each; offshore and onshore converter stations; and 75 km of underground and 125 km of submarine cables. The wind energy feeds into a converter substation at Diele, near Papenburg, on the German mainland where the power is injected into the 400 kV grid. This project reduces CO₂ emissions by nearly 1.5 million t per year.

DolWin1

Another example of this type of solution is the 800 MW DolWin1 HVDC Light connection, which will bring power to the grid connection point at Dörpen West in Germany, about 90 km inland → 3. ABB is responsible for system engineering, including design, supply and installation of the offshore converter station, including the platform, 75 km of DC submarine cables, 90 km of underground cables and the onshore converter station. Scheduled to be operational in 2014, this network of offshore wind power parks is expected to reduce CO₂ emissions by 3 million t per year.

DolWin2

For the DolWin2 project, the wind power parks will be connected to an HVDC converter station installed on an offshore platform in the North Sea → 4. The generated power will be transmitted through a 45 km long DC submarine cable and a 90 km long underground cable to the HVDC onshore station at the grid connection point of Dörpen West.

The transmission system will have a total capacity of 900 MW at ±320 kV, which will make it the world's largest offshore HVDC system. This HVDC Light connection provides numerous environmental benefits, such as electrical losses of less than 1 percent per converter station and

4 The DolWin2 offshore platform for the North Sea



neutral electromagnetic fields. Compact converter stations will help reduce carbon dioxide emissions by more than 3 million t per year by replacing fossil-fuel-based generation.

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From far away

Efficient and cost-effective long-distance power transmission with HVDC

ABHAY KUMAR, ALF PERSSON – As the energy needs of the world increase, the demand for long-distance energy transmission also rises. Areas needing electrical energy are often located far away from the source of energy, be it water, solar or wind. ABB's HVDC Classic technology serves as a cost-effective alternative to AC transmission for long-distance and bulk-power transmission as well as for interconnecting asynchronous AC networks. For connecting remote and large-scale generation to load centers HVDC is an attractive solution with extremely low transmission system losses. ABB continues to create HVDC solutions to suit the many scenarios encountered in the transmission world.

HVDC technology uses thyristors for conversion and typically has a power rating of several hundreds of megawatts, though many are in the 1,000 to 3,000 MW range, and some even as high as 8,000 MW. HVDC is suitable for overhead lines as well as undersea/underground cables, or a combination of cables and lines. It can also be configured as back-to-back HVDC stations. This configuration enables two asynchronous grids to exchange power and ensures that in the event of a disturbance in one, the other supports it.

The interconnection through HVDC does not add to the short-circuit capacity of the networks. This allows for less-frequent replacement of the heavy-duty switchgear equipment, keeps grids immune from disturbances and minimizes affected areas. By controlling its power flow, an HVDC system stabilizes the grid in the interconnected networks and increases the security of supply. As HVDC systems cannot be overloaded, uncon-

trolled cascade tripping of lines is avoided. For example, during the massive 2003 blackout that affected the entire northeastern United States, the HVDC connections shielded the Quebec system in Canada from frequency swings.¹

HVDC lines use the right of way (m/MW) very effectively and can also be operated at reduced voltage in case some section of a line has issues with insulation withstand capability. HVDC technology enables long underwater transmission links with low losses. Traditional AC transmission systems with underwater cables cannot be longer than about 60 to 100 km as it would require massive reactive compensation en-route.

The configuration enables two asynchronous grids to exchange power and ensures that in the event of a disturbance in one, the other supports it.

Footnote

- 1 <http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf>

1 The NorNed station



2 A selection of ABB's HVDC commissions

- The Itaipu project in Brazil supplies 50 Hz power into a 60 Hz system and economically transmits large amounts of hydropower (6,300 MW) over long distances (800 km).
- The Leyte-Luzon project in the Philippines supplies bulk geothermal power across an island interconnection and improves stability to the Manila AC network.
- The Rihand-Delhi project in India transmits bulk thermal power (1,500 MW) to Delhi, ensures minimum losses, least amount of right-of-way, and better stability and control.
- The Garabi project in Argentina is an independent transmission project transferring power from Argentina to Brazil. The back-to-back HVDC system ensures a supply of 50 Hz bulk power (1,100 MW) to a 60 Hz system under a 20-year power supply.

The interconnection, which is based on market coupling, has led to power trading between the two countries and increased the reliability of electricity supply in both.

Sustainability showcase: NorNed

The 580 km NorNed HVDC monopolar transmission link with a 700 MW / ± 450 kV transmission capacity, is the longest underwater high-voltage cable in the world → 1. Commissioned in 2008, the converter stations are located at the Feda substation in Norway and at the Eemshaven substation in the Netherlands – a span of 580 km. The interconnection is jointly owned by the two state power grid companies, TenneT in the Netherlands and Statnett in Norway. The interconnection, which is based on market coupling, has led to power trading between the two countries and increased the reliability of electricity supply in both.

To optimize cable costs and cable losses, NorNed has two fully insulated DC cables at ± 450 kV although it is a monopolar link. This makes the DC current small and creates low cable losses, but requires a higher converter voltage and has a record voltage of 900 kV for a 12-pulse converter.

Scandinavia has a largely hydro-based production system whereas the Netherlands and surrounding countries have a system based largely on fossil fuels. Hydropower is easily regulated and stored in existing dams. This allows the

Dutch grid to be optimized by using hydropower to cover peak loads during the day. At night, power can be transported back to Scandinavia, thereby saving electric energy in the dams. The result is a more stable output from the fossil-fuel-fired plants, thus minimizing emissions. Additionally, the stabilized grid allows integration of new renewable generation in the form of wind power.

The security of supply has improved since production resources in a larger area are available as a backup in the event of network disturbances. The electricity market has benefitted as the link has enabled electricity trading between two distant, isolated markets.

The link demonstrates that HVDC technology offers the unique capability to build long underwater or underground cable transmission lines with low losses. The NorNed link has losses of only about 4 percent.

North-East Agra

ABB has built HVDC transmission projects all around the world → 2. A unique project is currently under construction in India. When commissioned in 2016, the North-East Agra HVDC link, officially known as ± 800 kV / 6,000 MW HVDC Multi Terminal NER/ER-NR/WR Interconnector-I, will