

ABB's tried and proven technologies meet the grid connection challenges of Europe's drive for renewable energy



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It's power delivery that really counts

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Renewable energy - inherently variable in its nature - is playing an ever-increasing role in meeting our energy demands. The creation of 'supergrids' of interconnected networks offers an attractive way of increasing reliability and security of supply, and smoothing out the peaks and troughs in both power usage and generation. The challenge is how to connect these grids in a reliable, efficient way, potentially over great distances, and crossing seas. High Voltage Direct Current (HVDC) transmission solutions are set to play a vital role.

Sustainable energy sources cannot be evaluated as 'stand alone' solutions; they are only as effective as the power grid to which they ultimately connect. What really counts is the efficiency of the total energy system.

There will need to be new approaches to living with variable generation sources, with more active demand response and smarter grid

technologies playing a very significant part. In parallel, we will also need to roll out new ways of managing and interconnecting electricity grids nationally and internationally. This is where supergrids will play a key role.

Supergrids make sense strategically because they enable potentially rich sources of energy - such as offshore wind farms, hydroelectric, geothermal and solar arrays - to be permanently connected to centres of demand, such as large cities, which may be hundreds of kilometres away.

Europe's proposed Offshore Supergrid (www.friendsofthesupergrid.eu) is a case in point. This ambitious project aims to address the impending energy crunch in Europe by interconnecting national electricity grids from Spain to the Baltic Sea in a seamless electricity transmission and trading network. It would smooth out demand and supply across a vast geographical area and population, and make

the most use of renewable energy sources wherever and whenever they are available.

The role of the supergrid is two-fold. First, it will carry electricity generated by offshore wind farms, and other renewable sources, to onshore grid connections. Second, it will carry electricity from all sources around Europe, making the region's electricity markets more efficient both in terms of meeting demand and in terms of energy trading.

The idea of harnessing solar power from North African deserts to provide emission-free electricity to Europe is the central proposition of the Desertec Industrial Initiative, inaugurated in July 2009. The Desertec vision (www.desertec.org) sees solar power generated in the Sahara eventually meeting 15 percent of Europe's energy needs, and a significant proportion of local demand in producer countries by 2050.

With improvements in the ef-



efficiency of power transmission, and in renewable energy technologies, most of the previous technical challenges involved have now been overcome.

Nonetheless, the construction of very large offshore wind farms presents some significant engineering challenges in getting large quantities of electrical power back to shore. Subsea supergrid interconnections demand a very robust electrical transmission system, with high availability and minimal maintenance requirements. They must not only meet strict national grid codes, but also relieve stresses from wind turbines and other renewable sources by isolating electrical transients from the mainland grid. Another important requirement is to design a system that can withstand the harsh and sometimes very hostile offshore environment.

HVDC (High Voltage Direct Current) technology is used to transmit electricity over long distances by overhead transmission lines or submarine cables. First made available on a commercial basis by ABB, it is a well-proven technology with over 50 years of operating experience. HVDC offers higher capacity per line but also lower transmission losses than traditional AC systems. It can be used to connect separate asynchronous power systems (operating on a different frequency or voltage) where traditional AC connections are not feasible. In addition, HVDC systems also provide rapid and accurate control of power flow and are therefore ideal for interconnecting power grids to facilitate market trading.

Now HVDC has emerged as a robust and economically feasible alternative for the subsea interconnection of offshore wind farms, especially

with the significant improvements that have been made in the performance of wind-conversion systems, which have enabled wind turbines to be connected to the transmission grid and be safeguarded against surges in power generation.

An excellent example of this new generation of HVDC is the HVDC Light system pioneered by ABB over the past 14 years. Based on VSC (Voltage Source Converter) technology it uses series-connected power transistors rather than thyristor valves. It is ideal for integrating dispersed, renewable generation, especially wind power, into existing AC grids. It is also used for smart transmission and smart grids due to its great flexibility and adaptability.

In offshore wind farm applications, VSC-based HVDC solutions use extruded polymer (XLPE) cables, which are a strong, flexible and cost-effective alternative for severe conditions and deep waters. This cable type has a copper or aluminium conductor surrounded by a polymeric insulating material, which is very strong and robust. The water sealing of the cable has a seamless layer of extruded lead and finally one or two layers of steel wire armouring to provide the mechanical properties.

Most grid codes today set requirements on 'fault ride-through' or 'low-voltage ride-through'. As the proportion of renewable power generation increases, grid codes requirements are becoming stricter. For example, wind turbines or farms must typically be able to survive sudden voltage dips down to typically 15 percent of the nominal grid voltage for up to 140ms.

The wind farm network is much

smaller than a typical utility grid and, as a consequence, weaker. Also, its rated generation normally matches the rated HVDC transmission capability. A fast reduction in the input power capability may therefore lead to a significant increase in the wind farm bus voltage - resulting in an over-voltage tripping of the VSC and/or the wind turbines.

The solution used is very robust, and leaves the wind farm unaffected during main grid faults. The DC chopper is a high-energy resistor in the DC circuit that evacuates the surplus of energy during network faults when power transmission is not possible. This means there will be no abrupt change in the output power from the wind turbines and the disturbance seen by the wind turbines will be minimised.

It is surely significant that the long-established US grid features just one to two percent of HVDC transmission. In China, which is currently building a truly national grid, designed from a blank sheet of paper, HVDC will comprise some 10 to 20 percent of the total transmission capacity. This allows the development of remote hydro resources, minimises the number of lines, increases reliability and also creates an infrastructure that allows full utilisation of production resources including additional remote renewables.

Renewables will make a significant contribution to Europe's power needs, but we must ensure that our grids are sufficiently developed to collect and deliver that power efficiently and reliably. The good news is that ABB has the technology to build these strong, reliable grids commercially available and ready to connect. ■

Building HVDC supergrids - challenges and possibilities

HVDC links are used for bringing offshore wind power to shore. As the number of these point-to-point HVDC connections grows, it would help to connect them directly, rather than through the broader AC grid. This is giving rise to plans for HVDC supergrids.

Wider use of DC grids is likely to involve challenges of a technical nature. However, the main challenge concerns adaption of international Regulatory frameworks to manage these new grids.

Plans to introduce wind power in the North Sea, solar power in North Africa (the Desertec initiative) etc, have created interest in HVDC grids. The value of these grids (offshore or onshore) is in their role as a facilitator for power exchange and trade between regions and power systems.

Moreover, an offshore grid will allow the aggregation and dispatch of power from offshore wind farms in different regions, resulting in power generation profiles of low variability.

The major motivation for an offshore grid topology is constituted by two policy drivers: the need for connectivity between countries and

power market regions, and the demand for economically efficient connection of offshore wind farms.

A reference project for constructing a regional grid with a limited number of nodes is already in place. The Québec-New England project completed in the 1990s has clearly demonstrated the feasibility of three-terminal HVDC systems.

HVDC Light provides better capabilities for operating regional multi-terminal systems as it has the advantage that the power direction is altered by changing the direction of the current, and not by changing the polarity of the DC voltage. The terminals can be connected to different points in the same AC network or to different AC networks. The resulting DC grids can be radial, interconnected or a combination of both.

An interregional DC grid is defined as a system that needs several protection zones. The following technology gaps need to be closed to create such a grid:

- DC breakers
- Power flow control
- Automatic network restoration
- DC/DC converters for connecting different regional systems

The basic technologies in these

fields are known although some further development is needed to fully meet all regulatory demands.

For HVDC supergrids to become commercially viable they may well need to be based on individual links of some 2GW. Currently, the maximum rating for a single building block of ABB's HVDC Light technology at +320 kV is 1150MW. However, technology is advancing and ABB is providing a monopolar 500kV, 700MW HVDC Light system for the fourth HVDC link between Norway and Denmark. So it is reasonable to expect that 2GW HVDC Light links will soon be achievable.

The subsea cables for such supergrids will need to operate in the region of 500kV. To date, no XLPE cables capable of this are commercially available. However, there have been rapid developments in XLPE cable technology for HVDC applications recently and the trend indicates that the required voltage levels will be achieved soon. Mass Impregnated subsea cable at 500kV already exists and several HVDC projects will be based on this technology in the near future.

Future transmission grids will be more international and will be operated and regulated by a range of international bodies as well as national agencies and system operators.

Establishing the ENTSO-E (a European TSO cooperative association) in 2008 was a major step towards the formation of rules and frameworks to support future grids.

ABB anticipates that, based on previous HVDC and cable technology development rates, the residual technology gaps will be closed to make the European Supergrid a reality. ■





HVDC Light goes offshore

The demanding environment and remote location makes power transmission from large offshore wind farms a considerable challenge. Oil exploration companies successfully met similar challenges when they first began to exploit offshore oil and gas reserves in the North Sea. ABB has followed their path by successfully delivering the first offshore HVDC schemes.

A remote wind power farm could be connected with either AC or HVDC. Depending on the size of the wind farm, along with grid conditions, the use of HVDC is applicable where the distance to the connecting AC grid exceeds 40-70km.

With the constraints placed on space and weight offshore, HVDC Light offers some key advantages, since it is compact and lightweight compared with other HVDC solutions. Other needs are as follows:

- safety is paramount
- salt and humidity place severe requirements on the choice of materials and surface treatment
- maintenance needs must be minimised
- extensive monitoring is needed.

Apart from the main transformers, all high-voltage equipment must be installed inside compact modules on the offshore platform. The ventilation system in the modules must protect the high-voltage equipment and the

electronics from salt-laden and humid air. The main circuit equipment is therefore exposed to lower environmental requirements than a normal outdoor installation that enables a more compact design. The ventilation must also take airborne losses into consideration. An advantage of being offshore in the North Sea, of course, is that cold (5-11°C) water for cooling is readily available.

VSC-based HVDC converter stations can be fully automated or remotely operated. The goal is to maintain high performance of the link throughout the whole operational lifetime.

HVDC Light's functionality in the offshore environment is shown by Statoil's Troll A power from shore project, set up in 2005. This 84 MW link was the world's first offshore HVDC transmission project. It enables the Troll A gas production platform to meet all its power requirements from onshore generation, via four 70km subsea cables.

The world's first HVDC link to connect an offshore wind farm with an AC grid is the BorWin 1 project. Based on HVDC Light technology, this 200 km link connects the Bard Offshore 1 wind farm located off Germany's North Sea coast to the HVAC grid on the German mainland.

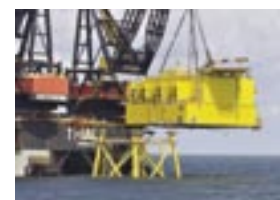
When complete, BARD Offshore 1 will consist of 80 wind genera-

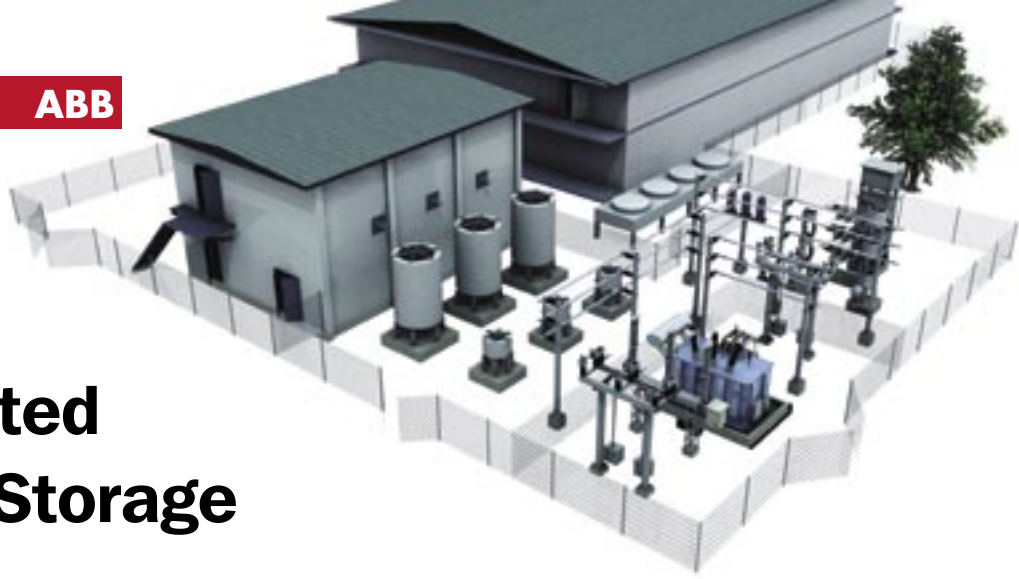
tors, each with a capacity of 5MW. These will feed their power into a 36kV AC cable system. This voltage will then be transformed to 1.55kV AC before reaching the HVDC Light converter station, located on a dedicated platform. Here the AC is converted to ± 150 kV DC and fed into two 125km sea cables, which then continue into two 75km land cables, transmitting 400MW power to the land-based converter station.

The German utility TenneT has awarded a contract to ABB to supply an 800MW transmission link to connect offshore wind farms located in the cluster DoWin 1 (Borkum West II wind farm, 400MW, plus future unnamed wind farms) in the North Sea to the German grid.

The wind farms will be connected with AC cables to the HVDC converter station based on an offshore platform situated in the North Sea and further through 75km of DC sea cable and 90km of land cable to the HVDC onshore station at the grid connection point at Dörpen/West.

The transmission system has a total capacity of 800MW at ± 320 kV. ABB oversees system engineering including design, supply and installation of the offshore converter, sea and land cable systems and the onshore converter station. The land cables will be laid underground, thus minimising environmental impact. ■





Distributed Energy Storage

ABB's Distributed Energy Storage (DES) systems serve a variety of different applications in transmission and distribution networks where they can improve the quality of the power at optimal cost.

In the past, networks only needed to handle a simple, passive flow of power from high-voltage generation and transmission to low-voltage consumption. Energy storage can enable networks to make the transition to handling complex, highly variable and multi-directional power flows to accommodate: increased levels of distributed generation; the potential transition of energy sources currently on the heat grid on to the electrical grid (for example, ground- and air-source heat pumps); and the growing demand for electric vehicles.

The main DES applications are:

-Load Shifting - Altering the pattern of energy use so that on-peak energy use is shifted to off-peak periods. To reduce the end user's electricity cost, the DES charges up with low-priced energy and is discharged when the energy prices are high.

-Peak

Shaving - Related to Load Shifting. Both contribute to demand management in which the ultimate goal is to increase the load factor. Peak shaving uses stored energy to eliminate the short-term peaks in the energy consumption pattern.

Benefits:

- Commercial and industrial customers can reduce their energy charges by improving their load factor
- Utilities reduce the operational cost of generating power at peak periods (reducing the need for additional generation equipment)
- Investment in infrastructure is deferred because the system has flatter loads with smaller peaks.

Renewable Energy Capacity Firming - Allows an intermittent electric supply resource to be used as a nearly constant power source.

Deferred infrastructure upgrades - DES modules placed electrically downstream from the congested portion of the transmission system can help to prevent overloads and defer potential upgrades.

Power Quality - DES can protect loads further downstream against short-duration events that affect the quality of power delivered to the load.

Voltage Support - Energy storage with reactive power capability can provide voltage support and respond quickly to voltage control signals.

Frequency Regulation - DES is an attractive alternative for this application with its rapid response.

Outage management - DES can provide power for short periods of time to a network, reducing the effect of a temporary fault.

ABB's latest DES development is the DynaPeaQ® system that enables dynamic control of active as well as reactive power in a power system, independently of each other. By controlling the reactive power, grid voltage and stability are safeguarded with high dynamic response. By control of active power, new services based on dynamic energy storage are added.

The system is based on SVC Light®, combined with Li-ion battery storage. SVC Light is based on Voltage Source Converters (VSC) connected in shunt to the grid at transmission as well as sub-transmission and distribution level. Insulated Gate Bipolar Transistors (IGBTs) are used as switching devices. DynaPeaQ is aimed at industrial, distribution and transmission level energy storage applications. The focus is on applications where the use of continuous reactive power control and short time active power support is needed.

We need a smarter grid that can receive power of all qualities from all sources, both centralised and distributed, and deliver reliable supplies, on demand, to consumers of all kinds.

Since the increased use of intermittent generation requires dynamic voltage control as well as balancing power, DynaPeaQ is a great Smart Grid enabler. ■





Enhancing ABB's UK centre of grid excellence

ABB has established its UK operations as a centre of excellence for the implementation of the very latest grid technologies. They include both HVDC and FACTS (Flexible AC Transmission Systems) that covers a number of technologies that enhance the security, capacity and flexibility of power transmission systems.

One of ABB's most important current projects in the UK is Eirgrid's East West Interconnector that will provide a 500MW link between the Irish and UK power grids using HVDC technology. The interconnector will strengthen the reliability and security of electricity supplies in each country, and enable Ireland to expand its wind power capacity.

The transmission link will run underwater for 186km and underground for 70km, with minimal environmental impact. The only visible parts will be

the converter stations at each end that switch AC (alternating current) to DC (direct current) and back. The XLPE cable will provide the strength and flexibility needed to endure the severe conditions of the Irish Sea.

Rated at 200kV, this will be the highest voltage HVDC Light link using this type of cable. The higher voltage enables a transmission capacity of 500MW, the highest ever for an HVDC Light underground cable. ABB is responsible for system engineering, including design, supply and installation of the sea and land cables, and both converter stations. The system is scheduled to be operational in September 2012.

ABB is pioneering the development of the UK's multi-terminal offshore supergrid by starting technical design work on an HVDC Light project, which will be the first link to incorporate a hub for the connection of

offshore wind farms.

There is a growing consensus that VSC (voltage source converter) based HVDC technology is the optimum approach for creating the effective power links to integrate offshore power into national grids. What is less clear is its status as a proven commercially available technology. The simple facts are that ABB pioneered VSC-based HVDC technology in its HVDC Light system launched over 14 years ago. Indeed, ABB has 16 HVDC Light projects either delivered or in delivery, with a total capacity of nearly 5,000MW - HVDC Light is a well-proven technology, ready to implement now.

ABB works hand in hand with the UK's leading power utilities to help them develop and maintain their vital electrical infrastructure and its growth has been outstanding - up by 30 percent in 2010. It has plans to grow even further and needs more people to help achieve its ambitious targets. In 2011, ABB is carrying out a major recruitment drive in the UK, with a particular focus on further enhancing its position as a centre of excellence for grid systems technology. This recruitment programme covers every level, from senior staff to the new technical apprenticeship scheme.

With its unique combination of advanced technology, skilled and experience staff and project delivery know how, ABB looks forward with confidence to helping create the modern, reliable and efficient electricity grids vital to make the best use of Europe's precious energy resources. ■

For information about careers with ABB please visit www.abb.co.uk/careers



Connect renewable power to the grid?

Naturally.

ABB's leading edge technologies and life cycle services ensure the effective integration of renewable power into electrical grids, even in the most challenging conditions and over long distances. Our focus on harnessing green energy is making power networks smarter as well as more efficient and reliable, helping to protect the environment and fight climate change. www.abb.com/hvdc

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