

Clean and invisible

by Gunnar Asplund and Bo Normark, ABB

When electric transmission technology was developed more than one hundred years ago, local fossil-based energy sources in remote areas were replaced with renewable energy in the form of hydro power. At that time, transmission development was purely driven by the need to find new sources of energy rather than by environmental issues.

Hydro power contributed 18% of the 17 450 TWh of electricity produced globally in 2004. Maintaining this share, even when consumption grows, is possible thanks to developments in hydro power technology. From a global perspective, the electricity generated from wind power is still marginal. However this renewable energy source is technically and economically exploitable, and its contribution to the overall total is growing at an impressive 30% per year.

It's all about location and transmission

Location is a key factor in making renewable energy more competitive. In other words, areas with an abundance of wind and sun and those with access to a never-ending supply of water are ideal for the production of renewable power. In reality, the best locations are those that are remote from the consumers. However, remoteness raises another issue: efficient transmission from the source to the consumer.

Transmitting electricity costs between 5% and 15% of what it takes to produce it. Production costs could be reduced by as much as 50% if the electricity is generated in locations rich in renewable sources. However, these locations, especially in the cases of hydro and solar power sources, could be thousands of kilometers away from their intended destination, while large wind parks may be hundreds of kilometers offshore. Therefore, finding the best means of transmitting the electricity over these distances with the least amount of losses becomes more of a technological rather than a financial issue.

Technical development

High voltage direct current (HVDC) transmission can transmit more power per line than AC, and is much more efficient and cost effective over large distances. In addition, the losses are quite low. Today's HVDC transmission schemes can carry up to 3000 MW of power over distances of between 1000 and 1500 km. A typical scheme consists of two stations that convert AC to DC and vice versa. It uses overhead lines or cables with only two conductors, one carrying +500 kV and the other carrying -500 kV, giving a total of one million volts.

A new transmission technology known as HVDC light has been developed in the last few years. It utilises transistors instead of thyristors for the conversion process, and rather than overhead lines, HVDC light uses underground cables between stations.



Fig. 1: Illustrating the long-term testing of 800 kV HVDC equipment at the high-voltage test institute STRI in Sweden.

Currently, HVDC light is used to transfer power from offshore wind parks, for example, and to strengthen the electrical grid in areas where over-head lines are either not permitted or where the time taken to obtain permission takes too long.

Connecting to remote hydro power

Because of its ability to efficiently transmit power over long distances, HVDC transmission has been used primarily to connect cities, such as Boston, Montreal, Sao Paolo, and Shanghai to remote hydro power.

However, increasing demands and strict environmental regulations mean that more and more remote hydro power plants are being considered. While the evidence suggests that sufficient hydro power resources exist around the world to partly meet these demands, their availability heavily depends on an economic transmission technique. For example, an estimated 320 GW of renewable hydro power could be made available to consumers in Africa, Latin America and East Asia if investments in transmission were made. The addition of an extra 120 GW in Latin America is equivalent to 80% of the total electricity produced on the continent today. As well as hydro power, these areas would benefit enormously if solar power could be fully exploited. But the problem is these resources are located between 2000

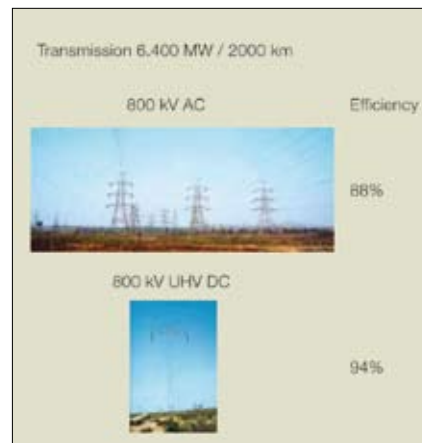


Fig. 2: The 800 kV UHVDC transmission system has an efficiency rating of 94% and uses significantly less land than traditional technologies.

and 3000 km from the load centres. New technology is required if these resources are to be successfully utilised.

This challenge has already been addressed by the development of an 800 kV ultra high-voltage direct current (UHVDC) transmission system. This transmission system is characterised not only by its large power carrying capacity, but when compared to traditional technologies, it occupies significantly less land and uses much less material. In addition, it has an efficiency rating of over 94% (See Fig. 2).

ABB's HVDC Light technology will connect a wind farm 128 km offshore with a substation 75 km inland. The first 800 kV UHVDC systems are already under construction in China. The largest, built by the State Grid Corporation of China, will transmit 6400 MW of power over a distance of 2071 km from the Xiangjiaba hydro power plant in the southwest of China to Shanghai.

Connecting to offshore wind power

Wind power is rapidly becoming a mainstream production resource for electricity. In 2007, wind power accounted for 40% of all new installed generated power. But if it is to be further developed, especially in Europe, an increasing share of new wind power plants will have to be built offshore. In fact it is foreseen that up to 40% of all new installations in the next few decades will be offshore primarily for environmental reasons. The higher cost of building offshore plants can be partly offset by higher production. But yet again, connecting to the grid becomes a major challenge. Traditional AC transmission is only suitable for installations within 50 km of the shoreline.

In larger offshore installations, clustering many wind farms and building fewer but larger transmission systems has proven to be very beneficial. The use of HVDC Light technology is ideal for these installations because the converters are relatively compact, making them easier to install on offshore platforms. The converters can also provide the necessary electrical functionality to give the desired performance as well as voltage and frequency stability during fault conditions.

The German energy company, E.ON, is currently constructing the first major transmission system of this type in the North Sea. With a carrying capacity of 400 MW, it will connect a wind farm 128 km off the coast with a substation located 75 km inland (Fig. 3). The entire transmission system is invisible and there are no electromagnetic field (EMF) emissions, making it a very attractive solution. In total, four clusters are planned in the area, each with a capacity to generate at least 1500 MW of wind power.

As more wind power installations are developed, there is an increasing need to balance power when winds are low. The HVDC Light system solves this problem by interconnecting offshore wind power plants with different countries and markets. Several such schemes are planned in Northern Europe. HVDC Light currently supports a power level of 1100 MW with a cable voltage of ± 300 kV. Additionally, because a cable has a controlled environment compared to an overhead line, the risk of flashover is significantly reduced.

Connecting remote solar power

Is it possible to have a totally renewable

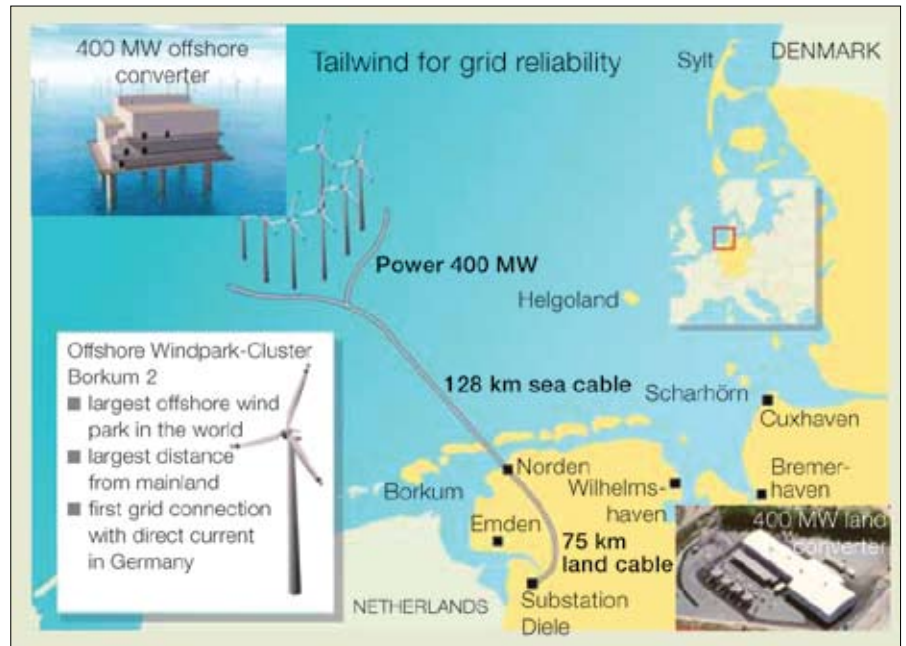


Fig. 3: E.ON is currently constructing a HVDC Light transmission system in the North Sea, which will have a carrying capacity of 400 MW.

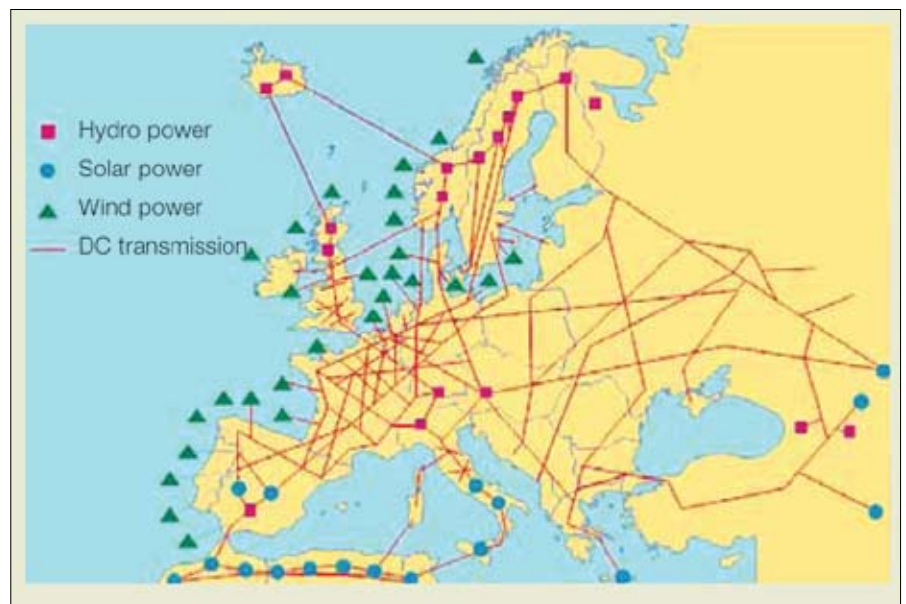


Fig. 4: A totally renewable electrical system is possible if solar power could be harnessed properly and combined with hydro, wind and pump storage.



Fig. 5: A computer-generated illustration of an 800 kV converter station.

electrical system in Europe? The answer, in a nutshell, is yes. There is an almost unlimited source of solar power. If it could be harnessed properly and combined with hydro, wind and pump storage, then the dream of many could be turned into reality (Fig. 4). In fact, building the required grid is technically and economically feasible. So what would it therefore cost to build the required transmission system and what efficiency would it have?

Using the current conditions in China and India as a reference, an HVDC transmission system transmitting 6400 MW of power over a distance of 3000 km would cost less than \$2,8-billion. This figure includes the cost of the line losses, which would be rated at just over five% (See Fig. 6).

Extending current limits

Some years ago, the idea of a renewable energy system was technically out of reach and economically unthinkable. Since then, dramatic developments in renewable generation and transmission technologies is turning the unthinkable in to the very likely. Today, it is possible to transmit at least 6000 MW of power per line from the Sahara dessert to central and northern Europe. To transmit 700 TWh, a transmission capacity of around 150 GW, requiring around 25 lines, would be needed at a total cost (using current European conditions) of approximately €100-billion, or roughly €0,01/kWh (Fig. 7). With accelerated research and development, cable developments can significantly reduce this figure. If, as expected, the power and voltage rating of HVDC Light cables increase significantly within the next few decades, then it will be possible to cost effectively transmit several GW of power completely underground (Fig. 8). However, the DC voltage needs to be raised to 1200 kV to achieve the same power transfer capability as overhead lines. If current cables impregnated with oil can withstand 500 kV, is it realistic to expect this

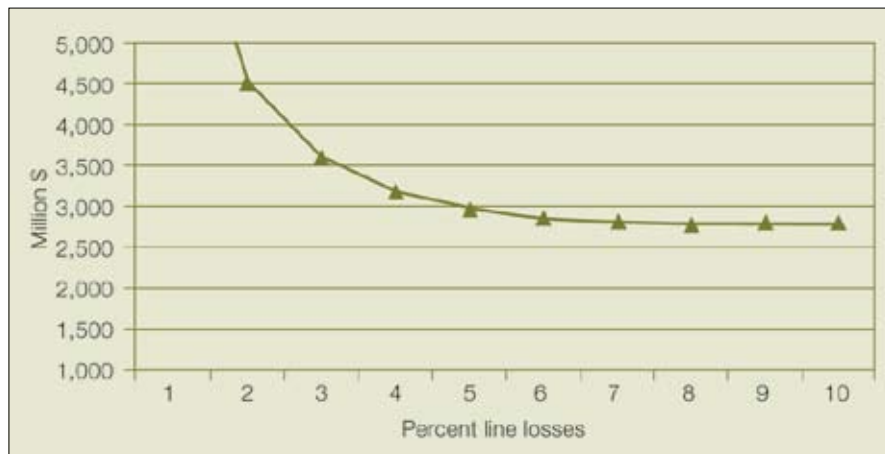


Fig. 6: The estimated cost of a system (lines, stations and losses) that would transmit 6400 MW a distance of 3000 km.

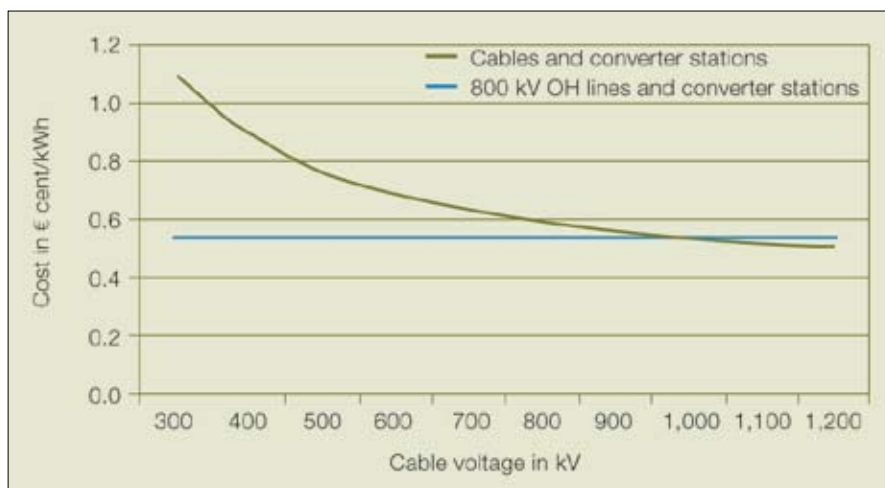


Fig. 7: To transmit 700 TWh, a transmission capacity of around 150 GW would be needed at a total cost of approximately €100-billion, or roughly €0,01/kWh.

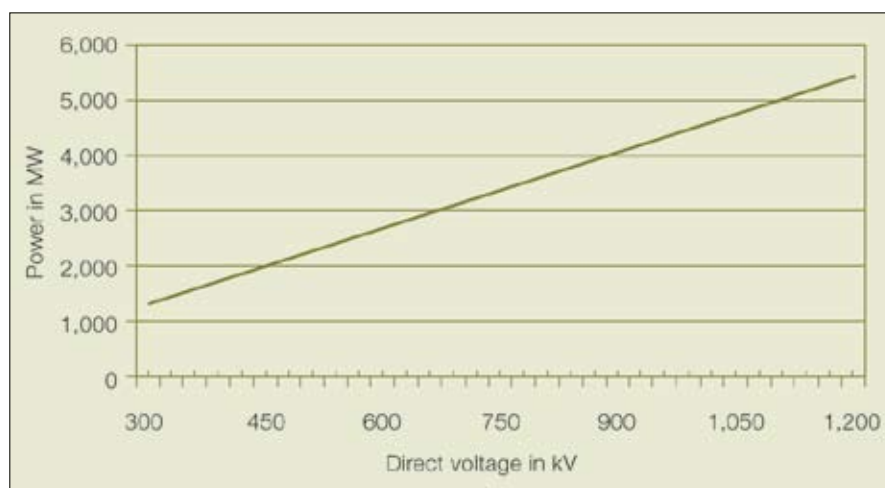


Fig. 8: Research and development will enable a significant increase in the power that can be transmitted in a pair of HVDC light cables.

level to rise by almost a factor of three? In theory, yes, because when compared with cables, capacitors have an insulation system that can withstand much higher voltage stresses. If the same stresses could be applied to cables, they would withstand up to 4000 kV.

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Contact Gunnar Asplund
ABB Power Systems,
gunnar.asplund@se.abb.com ❖