Clean and invisible

New transmission technologies are a valuable link to a clean and sustainable future

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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. Fast forward one hundred years and the situation looks quite different. Climate change combined with the need to reduce green house gas emissions, primarily CO_2 levels, mean that environmental issues have now become the main driving force behind transmission technology development.

While electricity (and heating), with its present production and distribution methods, is the largest contributor to green house gases, it also represents the greatest potential in combating climate change. Fossil fuels still produce much of the world's electricity. However, the generation of renewable energy from hydro, wind and solar power sources is steadily increasing. This, combined with transmission technology developments over the past 20 years, is key to finding a solution that not only significantly reduces CO_2 levels, but in a cost effective way.

The solution is to connect renewable electric energy generated by hydro, wind, or solar power to the consumer using currently available ABB technologies.

The need for electric power has increased in many countries over the past two decades or so. This, combined with the requirement to reduce CO_2 levels, has made coal-fired plants less attractive and forced countries to look for alternative or renewable sources of energy.

Of the 17,450 TWh of electricity produced globally in 2004, fossil fuel sources contributed to approximately 65 percent of that total.[1)] Of the renewable electric energy sources discussed, hydro power contributes a further 18 percent. 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, because this renewable energy source is technically and economically exploitable, its contribution to the overall total is growing at an impressive 30 percent per year.

However, the ultimate generation resource for renewable electricity is solar power. To explain this further, consider that 1,366 W/m² of solar energy reaches the earth. This translates into 174 million GW or 60,000 times the total installed electric generation! Compare this with today's thermal technology, which manages to achieve a peak electric power of around 190 W/m², or 460 kWh/m² per year. This means an 80 square kilometer area in a desert with a peak capacity of 1,200 GW of power can produce 3,000 TWh of electricity per year. There is no doubt that solar power is expensive and the development of installed MW trails wind power by about 10 years, but there are realistic plans to drastically reduce this cost so that solar power becomes competitive with the alternatives.

It's all about location and transmission

Location is a key factor in making renewable energy more competitive. In other words, areas prone to a lot 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 percent of what it takes to produce it. Production costs could be reduced by as much as 50 percent 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.

Today a transmission line is capable of transporting millions of kilowatts over thousands of kilometers.

Over the years, new transmission technologies have been developed that manage "to kill two birds with the one stone." In other words, not only has the long distance challenge been addressed, but environmental issues have also been covered. New transmission technologies can be used to link different electricity markets together, which in itself is a big step towards lower emissions. In addition, the market mechanisms of connected free markets increase the efficiency of production.

The Stern Report estimates that one percent of global GDP – equivalent to $ 1 trillion of the estimated total of $ 100 trillion in 2050 – is needed to stabilize CO_2 emissions at 550 ppm. However, this cost may be significantly reduced if energy companies continue to focus on increasing transmission, the transmission of electricity from renewable sources, and increased efficiency through market coupling.

Technical development

At the end of the nineteenth century, one transmission line could transmit only a few kilowatts over tens of kilometers. Today, a transmission line is capable of transporting millions of kilowatts over thousands of kilometers. A typical transmission power line has voltages a thousand times that of a regular household grid, because for successful transmission over long distances, the electricity needs to be transformed into high voltages.

There are two ways of transmitting electric power: using alternating current (AC) and direct current (DC). Because AC transmission is characterized by a constant change of voltage, it is more suited to local networks with

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

Converters

many different access points rather than for the efficient transmission of power over distances greater than 500 km.

DC power transmission is better suited to transport power from remote power plants.

On the other hand, high-voltage direct current (HVDC) transmission can transmit more power per line, 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 3,000 MW of power over distances of between 1,000 and 1,500 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 utilizes transistors instead of thyristors for the conversion process, and rather than overhead lines, HVDC Light uses underground cables between stations. Currently, HVDC Light is used to transfer power from offshore wind parks, for example, and to strengthen the electrical grid in areas where overhead 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 mega cities, such as Boston, Montreal, Sao Paolo, Shanghai and Johannesburg 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 percent 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 2,000 and 3,000 km from the load centers. New technology is required if these resources are to be successfully utilized.

This challenge has already been addressed by the development of an 800 kV ultra high-voltage direct current (UHVDC) transmission system.[2)] This transmission system is characterized not only by its large power carrying capacity[3)], but when compared to traditional technologies, it occupies significantly less land and uses much less material 1. In addition, it has an efficiency rating of over 94 percent!

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 6,400 MW of power over a distance

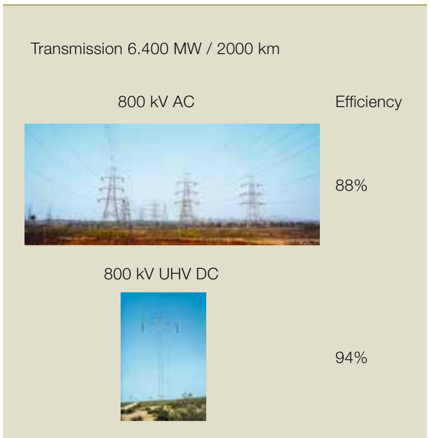
Footnotes

1) It takes nature a year to recreate the fossil fuels that are consumed in only 10 seconds.

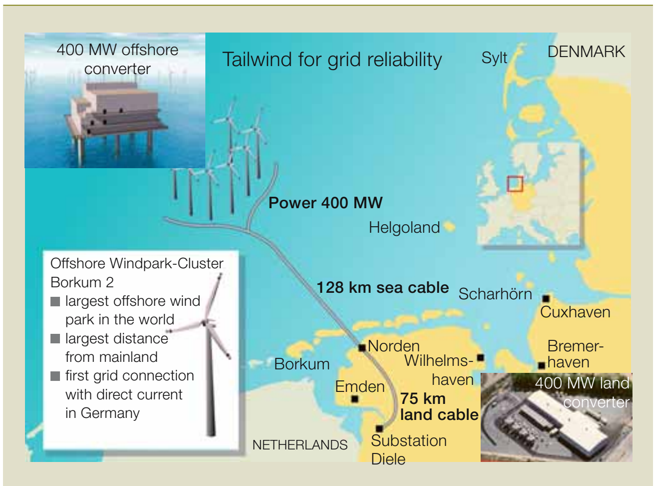
2) The voltage between the conductors is 1.6 million volts.

3) A UHVDC transmission system requires an extremely reliable control system with built-in redundancy. For this purpose, ABB has further enhanced its well-known MACH 2™ system to create the DCC 800 control system.

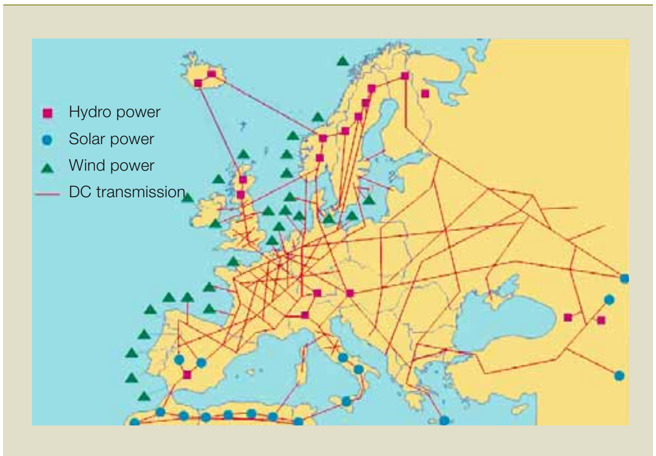
1 The 800 kV UHVDC transmission system has an efficiency rating of 94 percent and uses significantly less land than traditional technologies.



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



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



of 2,071 km (1,286 miles) 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 percent 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 percent 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 2. The entire transmission system is invisible and there are no electro-magnetic 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 1,500 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 1,100 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[4] is significantly reduced.

Developments in renewable generation and transmission technologies make it possible to have a totally renewable electrical system in Europe.

Connecting remote solar power

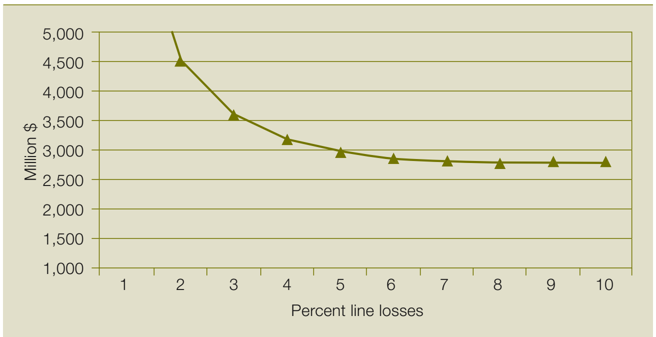
Is it possible to have a totally renewable electrical system in Europe? The answer, in a nutshell, is yes. There is an almost unlimited source of solar power. If it could be harnessed prop-

A computer-generated illustration of an 800 kV converter station

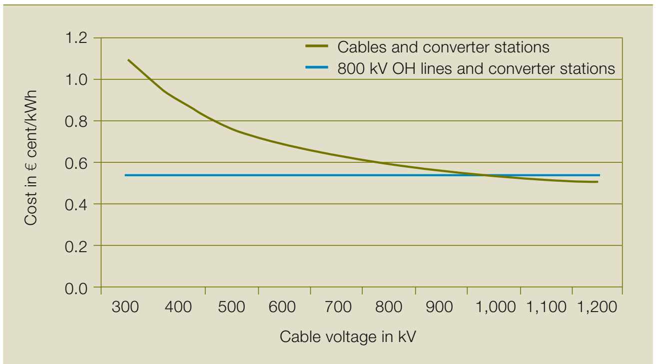
Converters

erly and combined with hydro, wind and pump storage, then the dream of many could be turned into reality 3. 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?

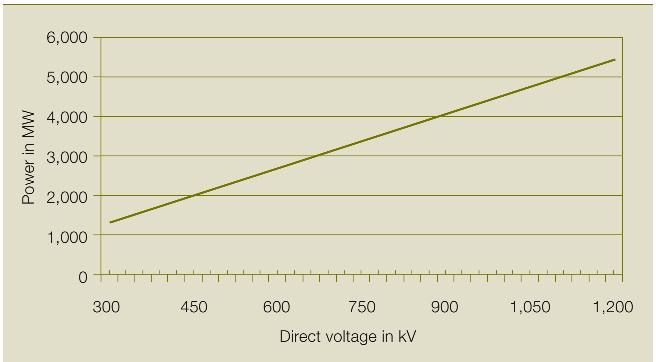
4 The estimated cost of a system (lines, stations and losses) that would transmit 6,400 MW a distance of 3,000 km



5 To transmit 700 TWh, a transmission capacity of around 150 GW would be needed at a total cost of approximately 100 billion euros, or roughly 1 euro cents/KWh.



6 Research and development will enable a significant increase in the power that can be transmitted in a pair of HVDC Light® cables.



Using the current conditions in China and India as a reference[5], an HVDC transmission system transmitting 6,400 MW of power over a distance of 3,000 km would cost less than $ 2.8 billion 4. This figure includes the cost of the line losses, which would be rated at just over five percent.

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 6,000 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 euros, or roughly 1 euro cents/KWh 5.

With accelerated research and development, cable developments can significantly reduce this figure. If, as expected, the power and voltage rating of HVDC Light cables[6] increase significantly within the next few decades, then it will be possible to cost-effectively transmit several gigawatts of power completely underground 6. However, the DC voltage needs to be raised to 1,200 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 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 4,000 kV.

In any case, the prospects of radically reducing CO_2 emissions from electricity are technically at hand and economically within reach. Several new technologies for generating and storing electricity, as well as using electricity for cleaner transportation and industrial processes, are evolving. More sophisticated market mechanisms foster efficiency and change. The key to all these positive developments is transmission – the need to "cleanly" transport electricity from where it is generated to where it is consumed.

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Footnotes

[4] A flashover is an unintended high-voltage electric discharge over or around an insulator, or arcing or sparking between two or more adjacent conductors. Source: http://en.wikipedia.org/wiki/Flashover, (May 2008).

[5] The cost of overhead lines varies from country to country.

[6] This should be possible without having to increase the insulation thickness.