

Electric transmission system in change

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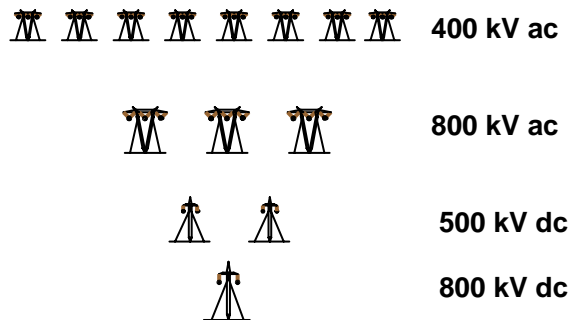
Background

The energy consumption in the world is growing at the same time as environmental concerns make the use of fossil fuels less desirable. The solution for electric generation can be to use renewable resources such as hydropower; wind and sun. The problem is that the most efficient location for generation are normally far or very far from consumers why the need for electric transmission of very large quantities of electric power is needed. This puts new challenges to the electric transmission system. Luckily, new technologies make it possible to transmit more power over longer distances in a more environmental acceptable way than ever before. Some of these technologies are already in operation but the development is very fast and within short we will see quite new system solutions for electric transmission.

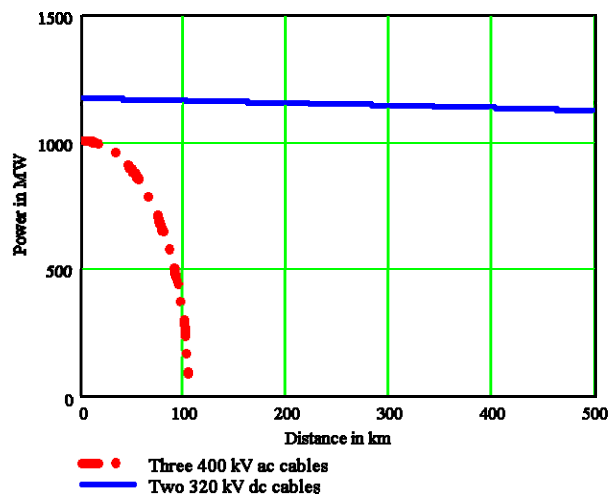
HVAC or HVDC transmission

HVAC is very good for transforming the voltage and thereby reduce the losses in transmission over longer distances. As the current passes zero each cycle in HVAC breakers are relatively easy to make and it is possible to construct big meshed ac grids that can connect large number of generators and consumers.

HVDC on the other hand makes it possible to connect ac networks that are not synchronous or have large differences in phase angle. HVDC is also more economical when large amounts of power shall be transmitted long distances on overhead lines.



If there is a need for using cable transmission HVDC is the only technical solution even at relative short distances (50-100 km).



The picture shows the power that can be transmitted on ac cables compared to dc cables. The capacitances need to be charged each cycle in the ac cable thereby reducing the active power in long cables.

The picture shows the number of lines needed to transmit 7000 MW over a distance of 2000 km. Higher voltage reduce the number of lines and dc can handle more power than ac.

HVDC

HVDC was originally developed with mercury arc valves in the early 1950s. These valves could be switched on and the current was extinguished by the ac net. This type of converters are called “current source converters” as they operate with a stiff dc current.

As soon as thyristors were powerful enough the mercury arc valves were replaced by thyristor valves which operate with the same principle as mercury arc valves.

A large number of HVDC projects have been delivered during the years all over the world but only around two percent of all electric transmission is done by HVDC. However, in countries where the electric transmission grid is now being expanded, HVDC plays a much bigger role than in the past when the technology was new.

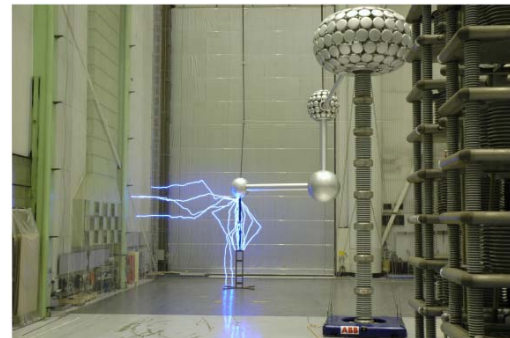
One big reason for the increased interest in HVDC is that more power can be transmitted than by ac and thereby fewer lines are needed saving both money and land. Higher voltage means higher voltage of the line. Therefore an effort started five years ago to develop the next voltage level of HVDC. Earlier the highest voltage level was 600 kV and maximum power on one bipole line was just above 3000 MW. The development goal was 800 kV dc and 6400 MW on one bipolar line. All the equipment that is exposed to 800 kV dc had to be developed. Some equipment could linearly be extrapolated to the higher voltage, but other equipment had to be redesigned from the beginning. Transformer bushing, wall bunching and the converter transformer were the equipment that needed most development efforts.

When all equipment had been designed and tested according to the normal criteria they were all installed in a long term test circuit for a one year test to ensure that no unforeseen phenomena occurred.



The picture shows the 800 kV HVDC long term test circuit

In order to design the valve halls and the screens of the thyristor valves special high voltage tests were performed to ensure that the margins are sufficient.



Test of 800 kV valve electrodes

The first HVDC project of 6400 MW, 800 kV is already under construction in China between Xiangjiaba and Shanghai. According to the plans many such projects will be built in both China and India and discussions are ongoing regarding projects also on Southern Africa and Barazil. These projects will transmit power from very distant hydro resources to the consumers. Totally hydro resources of at least 500 GW are available in these countries.

HVDC Light

HVDC has been very successful, but it has some limitations that could be overcome by a newly developed type of HVDC called HVDC Light.

HVDC Light utilize voltage source converters (VSC) which instead of using a stiff current use a stiff voltage. The advantage with this is that the converter creates an ac voltage electronically which can be changed in amplitude and phase very fast. Another

advantage is that the power direction is changed by changing the direction of the current and not by changing the polarity of the dc voltage. This makes it easier to build systems of more than a few terminals.

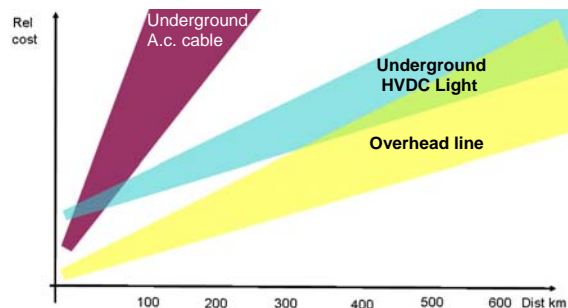
The reason that this technology was not developed from the beginning is that it need components that can be switched off. The component most suitable for this is the IGBT (Isolated Gate Bipolar Transistor) that has been available only around 20 years while the thyristor was invented fifty years ago.

The impact on the converter is that less equipment is needed and the footprint can be considerably smaller. Performance is also superior.

So far HVDC Light has lower power rating. Maximum power of a bipole is presently 2400 MW with overhead lines and 1200 MW with cables. Also losses have been higher in HVDC Light although considerable reductions have been made during the last ten years.

The cables used together with HVDC Light are extruded as are most ac cables today. This has great advantages when cables are laid on land and many joints are needed due to the limitation in the amount of cables that can be transported one cable drum. Joints of extruded cables are prefabricated and the time to make a joint is in the order of one day. Work can also be done in parallel to reduce the time further.

HVDC Light with extruded cables has made it possible to change the present cost of transmission. Until now it has only been possible to build low cost transmission ac by overhead lines. AC cables are quite expensive and can only be used for shorter distances as shown above.



The figure shows that for distance of 200 km HVDC Light with cable transmission cost

around twice that of overhead ac- lines. At 400 km cost is almost equal.

Wind

HVDC is essential for the development of distant hydro power as we have seen above. Also wind power at sea in larger scale will benefit from HVDC. In this case HVDC Light is the most appropriate due to the small footprint which makes it possible to locate big converter stations far out in the sea.



The picture shows the converter station at sea in the NordE.ON 2 project where 400 MW wind power will be transmitted from the North Sea to Northern Germany, a distance of 200 km.

Future

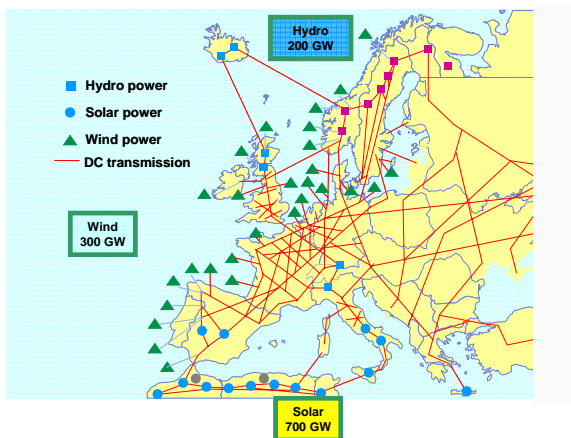
HVDC and HVDC Light could play a very important role in the future global energy supply as big renewable energy resources that are located in inconvenient places are still accessible at reasonable cost. Biggest of all these resources is solar energy. If only a small fraction of the worlds deserts would be covered by solar generation plants (thermal or photovoltaic) all the world energy demands could be met.



The picture shows the surfaces needed to supply all European and all the World energy by solar generation in the Sahara desert.

One problem with solar power (as with wind power) is that it is not controllable. When it is not blowing or when it is night no power is available. In this case hydro, wind and solar power is a perfect combination. When wind and solar power is small compared to the hydro power it is sufficient to reduce the hydro power when wind and sun are available. Some reinforcement of the generators might be needed. Later it would be necessary to use pumped hydro in a large scale.

Also in this case transmission is very essential as good locations for pumped hydro are normally not close to neither the generators nor the consumers.



The picture shows a scenario where Europe gets its power from renewable resources, hydro, wind and solar which is distributed to

the European ac grid by an overlay dc cable net.

Conclusion

HVDC is today a very mature technology that is developing very rapidly into higher voltages and higher power and more flexibility. The world faces tremendous challenges regarding supply of energy to a growing population. If this energy should be supplied without damage to the environment new types of generation will be needed such as distant hydro, wind at sea and solar generation in the deserts. All this require transmission of big amounts of electric energy over long distances and HVDC is the most suitable technology for this task. We believe that HVDC will have a big role in the future to create a more sustainable world.