800 kV HVDC – Alternative Scenarios for long distance bulk power transmission

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1 Background

The energy consumption in the world is growing and more and more far distance energy resources are used.

Use of renewable resources such as hydropower, wind and sun is normally not possible without the use of electric transmission since these resources, at least new ones, are normally located far away.

2 AC transmission

AC is by far the most used way to transmit electric power and has been so since very early in the development of electricity.

AC systems have normally been developed from lower voltages to higher voltages. This means that there are several layers of grids with higher and higher voltage in most countries.

The highest ac voltage that is used commercially in the world is 800 kV. However, due to the need of increasing the strength of the ac grids an overlay net of 1000 kV or even 1200 kV is considered in some countries.

![Power transmission on 1000 kV ac](image)

The figure shows transmission capability of one 1000 kV transmission line with max 70 percent compensation and 30 degrees angle between the terminals.

The strength of ac is very good when it is used in a net where the distances between stations are relatively short. For transmission over longer distances even 1000 kV ac has problems to transmit very high power.
3 HVDC transmission

Below a cost comparison has been made between transmitting 12000 MW over a distance of 2000 km with ac and with HVDC.

The figure shows the cost of stations, lines and losses as a function of the line losses. This makes it possible to see which line loss gives the lowest total cost.

HVDC gives lower cost for transmission of bulk power over long distances. The longer the distance and the bigger the power is the more important it is to have sufficiently high dc voltage. For distances of 2000 km and 6000 MW 800 kV HVDC seems to be the optimal solution.

3.1 Configurations

For 800 kV HVDC several converter configurations are possible as can be seen below.

One important issue when selecting configuration should the size of power block that could be lost without severe impact on the connected ac- nets. By
using series connected converters or parallel converters only one quarter of
the power is lost by the loss of one converter.

3.2 Technical achievements

Development of 800 kV HVDC has been going on at ABB since several
years and all equipment that is exposed to 800 kV dc has been designed,
manufactured and type tested. As a final proof that 800 kV HVDC will
work all equipment has been operated at 855 kV in a long term test circuit
for more than a year.

800 kV HVDC long term test circuit at STRI, Ludvika, Sweden

To the 800 kV, 6400 MW, 2000 km Xiangjiaba - Shanghai HVDC link in
China, ABB will supply system engineering including design, supply and
installation of the two converter stations including 800 kV HVDC power
transformers and switchgear, valves provided with newly developed 6 inch
thyristors and advanced control equipment.
The system is scheduled to go into operation in 2011.

4 Combined AC and DC transmission

The main disadvantage with HVDC is the high cost of tapping power along
the line. However, a combination of low cost bulk power HVDC
transmission in parallel with a lower voltage ac network could in many
cases be the optimal solution to give both low cost and high flexibility to
supply customer along the route.

There are however some technical problems with the combined dc and ac
solution. Disturbances in the dc transmission will in many cases trip of the
ac connection as the phase angle difference becomes to big. This problem
could be solved in various ways as is shown in the following picture:
Alternative 1 has a quite strong ac connection that can withstand most disturbances in the dc connection without having to disconnect.

Alternative 2 has two networks operating asynchronously and each feeding half of the customers along the route. In this case there will be no stability problems as the systems are asynchronous.

Alternative 3 is the same as alternative 2 but use an HVDC back to back station to increase the flexibility of power supply without needing to synchronize the two systems. Preferably this back to back is a Voltage Source Converter (HVDC Light) which will stabilize the voltages and increase the power transfer of the ac lines.

5 Conclusions

In order to transmit bulk power over long distances 800 kV HVDC is a very cost efficient alternative. The biggest draw back of HVDC is the high cost of tapping power along the route, but a combination where the bulk power is fed by HVDC and the power needed along the rout is fed by ac seems to be the most cost effective and flexible solution.