WM0908TU - Technics and Future

FUTURE OF HVDC POWER GRID IN EUROPE

Technology forecast

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Introduction

In this paper, I would like to outline the perspective of possible existence of HVDC power grid in Europe. You just maybe ask yourself, why should there be a demand to build some new transmission network, when we had already build a huge AC grid, which interconnects the whole continent..? Well I hope You will find some cogent arguments here later.

The whole work is divided in two parts:

In the firs place, I explain what exactly is HVDC technology in the area of transport of electrical energy (transmission systems), how does it work and explain present technological development and possible future movement.

In the followings is my humble forecast of application of HVDC transmission systems in Europe in close and distant future and I discuss eventual impacts on the power grid, network operators, but also on environment, society etc.

My research question then stands:

What is the possible future of HVDC power grid in Europe?

I would like to thank dr.ir. P.H.F. Morshuis from the department of High-Voltage Technology & Management for his support in my studies and assistance in answering my questions for this paper.

High Voltage DC technology

History

Electric power transmission was originally developed with direct current. The availability of transformers and the development and improvement of induction motors at the beginning of the 20th Century, led to greater appeal and use of AC transmission. Through research and development in Sweden at Allmana Svenska Electriska Aktiebolaget (ASEA), an improved multi-electrode grid controlled mercury arc valve for high powers and voltages was developed from 1929. Experimental plants were set up in the 1930's in Sweden and the USA to investigate the use of mercury arc valves in conversion processes for transmission and frequency changing. DC transmission now became practical when long distances were to be covered or where cables were required...

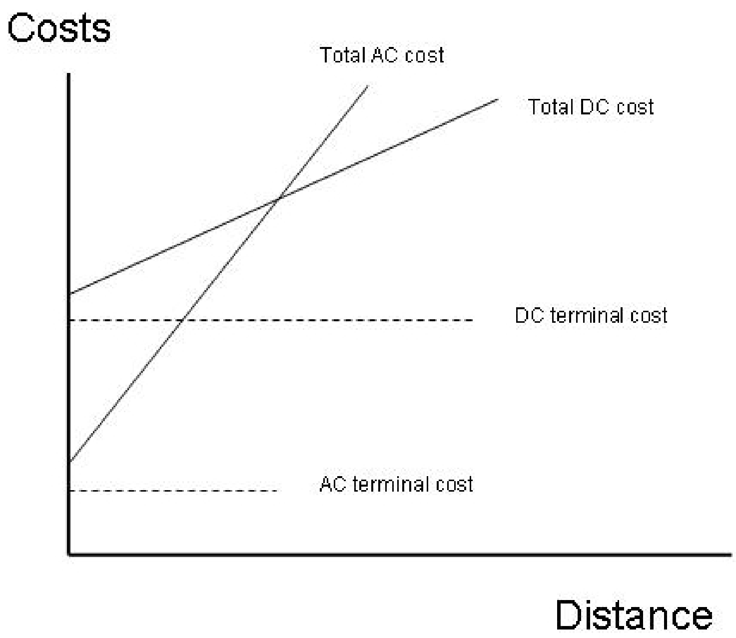
The first commercial HVDC line built in 1954 was a 98 km submarine cable with ground return between the island of Gotland and the Swedish mainland. Thyristors were applied to DC transmission in the late 1960's and solid state valves became a reality. In 1969, a contract for the Eel River DC link in Canada was awarded as the first application of sold state valves for HVDC transmission. Today, the voltages used for transmissions reaches up to +- 800 kV over thousands of kilometres.

Why use HVDC?

The question is often asked, "Why use DC transmission?" One response is that losses are lower, but this is not correct. The level of losses is designed into a transmission system and is regulated by the size of conductor selected. DC and AC. conductors, either as overhead transmission lines or submarine cables can have lower losses but at higher expense since the larger cross-sectional area will generally result in lower losses but cost more.

When converters are used for DC transmission in preference to AC. transmission, it is generally by economic choice driven by one of the following reasons:

1. An overhead DC transmission line with its towers can be designed to be less costly per unit of length than an equivalent AC. line designed to transmit the same amount of electric energy over the same (long) distance. However the DC converter stations at each end are more costly than the terminal stations of an AC. line and so there is a breakeven distance above which the total cost of DC transmission is less than its AC. transmission alternative.



Comparison of cost between AC and HVDC

The DC transmission line can have a lower visual profile than an equivalent AC. line and so contributes to a lower environmental impact. There are other environmental advantages to a DC transmission line through the electric and magnetic fields being DC instead of AC.

2. If transmission is by submarine or underground cable, the breakeven distance is much less than overhead transmission. It is not practical to consider AC. cable systems exceeding 50 km but DC cable transmission systems are in service whose length is in the hundreds of kilometres. It is basically the only way how to effectively connect distant energy sources (seabased wind farms) to the network.

3. Some AC. electric power systems are not synchronized to neighbouring networks even though their physical distance between them is quite small. This occurs in Japan where half the country is a 60 Hz network and the other is a 50 Hz system. It is physically impossible to connect the two together by direct AC. methods in order to exchange electric power between them. However, if a DC converter station is located in each system with an interconnecting DC link between them, it is possible to transfer the required power flow even though the AC. systems so connected remain asynchronous. The terminal of HVDC in fact looks for the AC grid as a power plant with certain production.

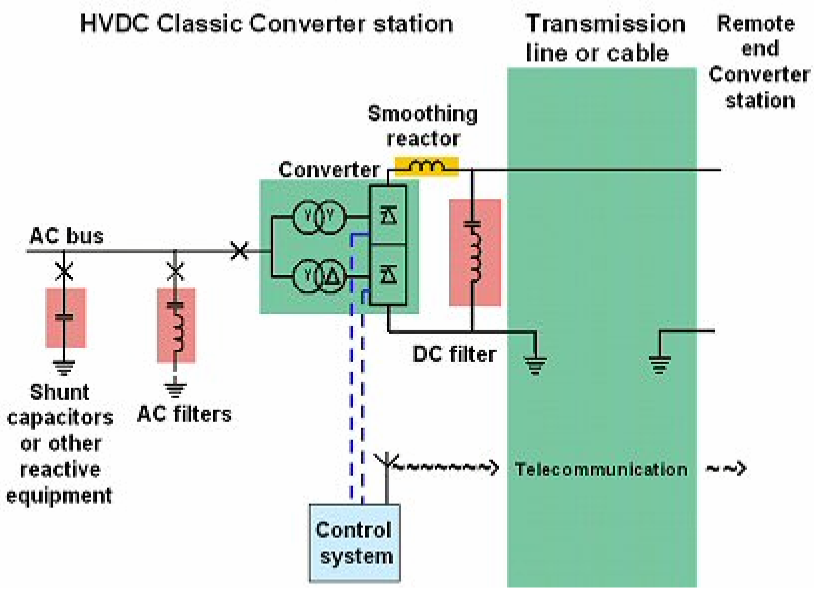
4. Among other advantages belong easy operation, simple control and operation, the systems can be fully autonomous and have less maintenance.

How does it work?

The basic principles are very simple. There are three major categories of HVDC transmissions:

1. Point to point transmissions

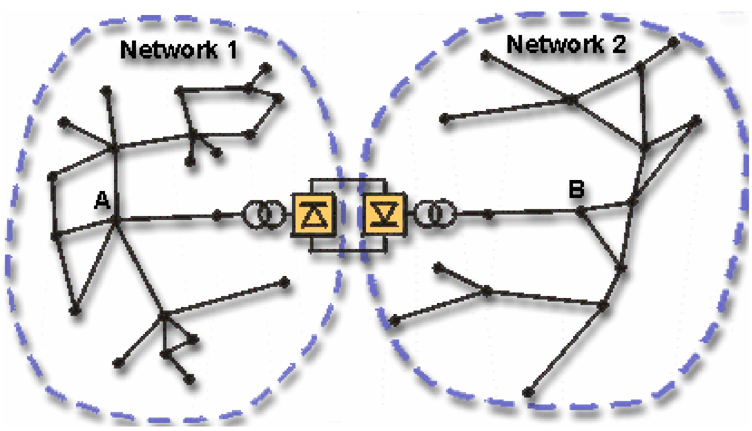
Is the simplest model. It consists of a cable, usually mass impregnated paper oil, which interconnects only two points. At every point, the cable ends in the DC/AC converter, which is backed with safety circuit breakers. Then, because of the phenomena of inverting, where vacant higher harmonics occur, the AC filters are applied. After the harmonics are suppressed, the current flows normally to the AC grid. The scheme is shown on the picture below:



Scheme of one cable terminal, ABB

2. Back-to-back stations

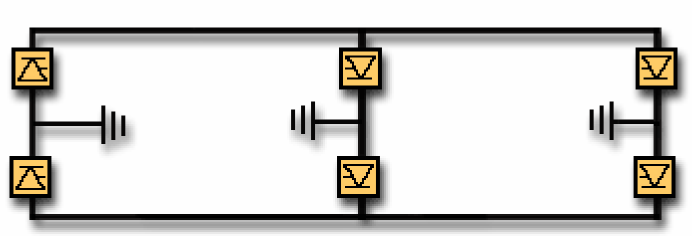
Are used for connecting of two separate AC grids. There is no transmission cable and both the rectifier and the inverter are located in the same station and are normally used in order to create an asynchronous interconnection between two AC networks



Back-to-back connection, ABB

3. Multi-terminal systems

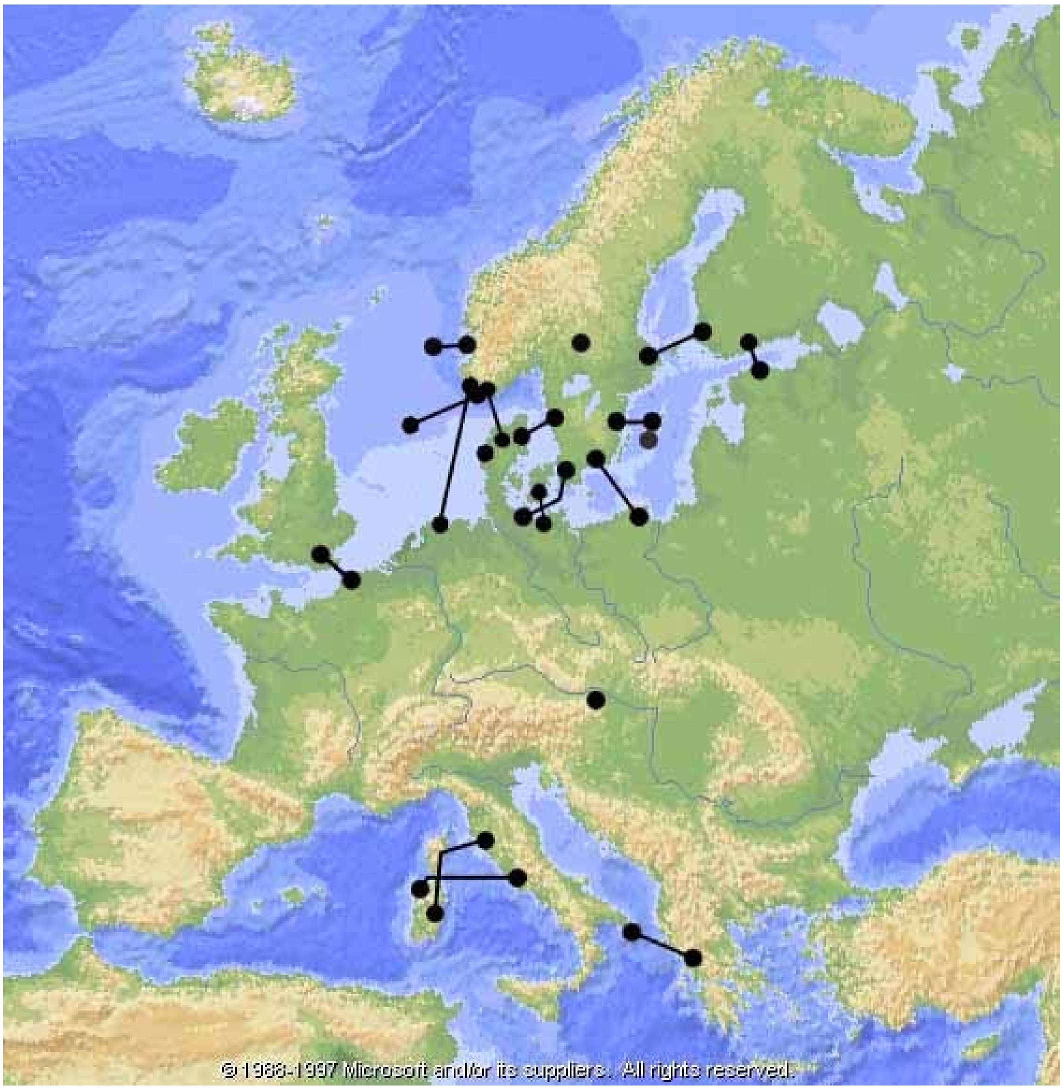
Is a bit more complex system, which can connect several converter stations on the same voltage level, creating connected network. The communication between stations and coordination of action is more complicated.



Multiterminal scheme, ABB

Present HVDC installations in Europe

The picture below shows the HVDC installations in Europe, in which the company ABB participated. There are some other connections made by Siemens, for example between Spain and Morocco, Sicily and Tunisia and some others.



HVDC interconnections in Europe, ABB

Future in Europe

As we can see, the number of HVDC connections is not so small, the number of lines will surely grow, starting with undersea connections, but later on even with longer overhead lines. Germany for instance have to find a solution how to transport their wind electricity from the north to the south of the country. I am convinced that many, many more connections will be made to fulfil the future demand for energy in Europe. The reasons I see for it are as follows:

Liberalisation of energy market

In the end of the 20th century, the EU proposed to liberalise whole energy market, theoretically allowing everyone in the grid to buy energy from anyone who is selling. That is great idea, but facing one major problem: the present AC transmission grid almost reached its transport capacity and every large transport of electricity through the grid leads to stability problems, resulting in outages and blackouts.

Renewable energies

The next issue is renewables. The sources of wind or strong sun are usually far from the populated areas and industry regions, and therefore you need some way to connect the wind farms (project Airtricity) and solar farms to the customers. If you use standard AC grid as seen today, you can see on German example that it is again resulting in stability problems not only in Germany, but everywhere in the whole connected grid!

Decentralisation and control

In the more distant future it is obvious that the mankind will run out of fossil fuels, and the structure of electricity generating system will fundamentally change. With HVDC, the operators will have effective instrument how to easier regulate the flow of energy in the region. It might also protect the separate AC networks from uncontrolled spreading of disturbances and overvoltages.

Pan-European HVDC power grid

The only possible solution for the problems mentioned above in the long term future is the HVDC network connecting the whole continent. This solution, which is technologically possible, will transport electricity over very long distances, when and where necessary, allowing:

- Connection of large remote wind farms on the see or coast in to the continent.

- Connection of large solar farms in south of Europe, or even the north of Africa.

- Effective electricity market, allowing massive transportation of energy over long distances.

- Effective utilization of regional sources – daytime/nighttime supplies. For instance, in the day, the electricity produced in Spain from the sun can power large water pumps in Norway, pumping water into reservoirs. Later in the night, the reservoirs are running water turbines and generating electricity which may be delivered back to Spain. The same way with multiple sea located wind farms.

- Less overall reserves are needed, because the area covered by HVDC grid is large and there will be always somewhere an excess of energy. This will result in lower environmental burden (pollution, CO2...), because these reserves are mainly based on fossil fuels.

- To be a virtual energy storage utility

Benefits

The number of benefits given from the described HVDC structure is optimistic. The society has a chance to get very reliable, mostly clean energy almost everywhere in Europe. The power lines are either „invisible“ (cables), or with much less profiler compared to standard AC lines. Connection with renewable sources will result in less conventional power plants, theoretically none! For the operators, the system will be easy to control and operate. With connection to west and east Africa, the possible source of solar power might be almost undepletable. That is the vision.. now comes the tricky question, which is..

What stands in the way?

Well, the vision of future looks always bright, but at closer look, there is usually some work to do. The problems, or maybe better challenges of proposed idea are, as I assume, follows:

Technological issues:

There are still many issues in HVDC technology, where intensive research takes place:

- cables (higher voltage levels, lower and operating – switching - stresses, reverse of polarity, use of XPLE and similar materials, nanotechnology)

- converters (efficiency, control of power conversion, improved application of GTO, IGBT’s and other specialised power electronics, it is usually the most expensive part of the whole project, the press on costs is inevitable)

- Communication and control systems (the multiterminal concept demands more complex control and monitoring systems)

- Protection (DC circuit breakers and other safety installations, breakdown must be localised, cleared and line back operational with minimum maintenance, costs and time)

Governmental, enterprise issues:

Creating such a large industrial and strategic network is always related with interests, politics and of course money in the first place.

- Governments are likely to control their state energy policy by themselves, and are not willing to be dependent on supplies from other countries, especially the developing ones (African problem). On the other hand, AC systems partitioned with DC joints and connections might be interesting for them, because neigbours would not be able to use their part of the grid as seen today. It is for sure, that consensus about unified energy policy and various guarantees and treaties must be accepted in the EU to make progress.

- Energy companies and network operators will hold with present AC grid as long as possible, building of large HVDC grid is expensive, and every company is willing to avoid making unnecessary investments. Next bad new is that huge financial resources will have to go in repair or replace of present installations in the AC grid to maintain its function because of aging of the system.

Conclusion

So what is the future of HVDC grid in Europe? I am optimist. Sole HVDC technology is (or will be) capable of such installation, however, more sides from large industrial and public spectra will have to be involved to get real and maximum profit both for the companies and the society.

In the close future, the states will continue in connecting with their neighbours. On the other hand, more and more new or present large power plants will be sooner or later connected to HVDC (as seen today in India, China, Brazil...). Finally, I hope that whole EU will be „interlaced“ with HVDC lines, and then the next step will take place – connection of these separate lines in one complex system.

When will this happen? I don’t know. Too many factors are involved, and when I see the painful process which accompanies almost every decision and negotiation within the EU, it will not be easy...however, I am convinced, that sooner or later the deals will be made, because there are problems which need to be solved and HVDC power grid is one (and maybe the only one) of the solutions.

References

[1] http://www.abb.com
[2] http://www.siemens.com
[3] http://www.wikipedia.org
[4] http://www.milestep.no/norned/
[5] http://www.tennet.org
[6] High Voltage Direct Current (HVDC)Transmission Systems, Technology Review Paper (technology_abb.pdf)
[7] Trends for future HVDC applications, conference presentation (Trends_in_HVDC_CEPSI06_V_1.pdf)
[8] The European power grid - the need for regulatory changes (Grid+Issues+in+Europe.pdf)
[9] F.H. Krueger, Industrial High DC Voltage
[10] Multiterminal HVDC for High Power Transmission in Europe (cepex99.pdf)
[11] Three Gorges - Changzhou HVDC : Ready to Bring Bulk Power to East (3GC HVDC Ready to Bring Bulk Power to East eng.pdf)