

Bulk Power Transmission at ± 800 kV DC

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1 Summary

ABB is a market and technology leader on the HVDC market with installations up to ± 600 kV. Recent discussions, particularly in China, but also in other countries, have shown a benefit for higher voltage levels in order to reduce investment for the power lines, save land and reduce losses for the transmission of bulk power (e.g. 6 GW) over long distances. As an example, until now all big HVDC projects in China have been built for 500 kV. The development of the hydro rich regions in South West China about 2000 km away from the load centers in East China calls for increasing this voltage level, with 800 kV being a frequently discussed option.

ABB has been continuously developing its HVDC capabilities in an ongoing R&D program so that the technology challenges at these voltage levels are well understood. ABB has already been discussing 800 kV DC solutions for a number of years. This allows ABB to actively pursue discussions on requirements and time plans for commercially introducing such voltage levels to the HVDC marketplace.

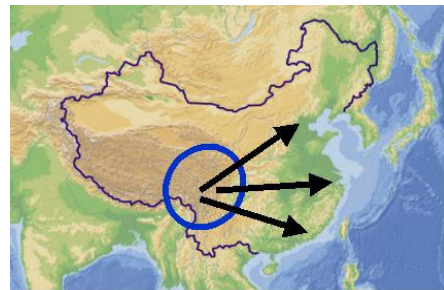
2 Introduction

Bulk power transmission was on the agenda during the 70's and many research programs were launched (USA, Canada, former Soviet Union, Brazil, Italy, Venezuela, Korea and Japan) all over the world to develop UHV systems for AC. However, the oil crises and the general slow down of the world economy put an end to most plans.

The recent sharp increase of the Chinese economy has created a two digit increase of the electricity consumption every year over the last 10 years. The installed capacity has gone from 225 GW 1995 to 450 GW 2004, by 2020 it is planned to have 1000 GW installed. In order to meet the demand, the Chinese government has launched a program to develop China's huge untapped hydro power potential in the south-west part of the country. The load centers are located along the east coast (Beijing, Shanghai, Guangzhou) and thus there is a need for highly efficient bulk power transmission systems.

One example is the Xilodu –Xiangjiaba hydropower plant that is located 1000 km up-stream from the Three Gorges Dam. The size is 18 600 MW and the transmission distance is 2000 km.

Other parts of the world where high bulk power transmission requirements are discussed, include India, Africa (Congo – South Africa) and Brazil.



South West China is rich in hydro power resources which will be developed in order to meet the demand from the load centers in the East.

3 Present experience

To distinguish the various voltage levels, in the rest of this paper we'll use the term EHV (extra high voltage) for AC voltage levels above 700 kV and up to 800 kV, for which installations exist in various parts of the world. We'll use the term UHV (ultra high voltage) for AC voltage levels above that range, e.g. for 1000 kV AC, as well as for DC voltage levels of ± 800 kV.

3.1 EHV and UHV AC

The first 735 kV AC system was commissioned in Canada in 1965. Since then, voltage levels up to 765 kV AC have been introduced in Russia and its neighboring countries, U.S.A, South Africa, Brazil, Venezuela and South Korea.

Most EHV AC investments were made during the 70's and 80's. Since the 90's, hardly any new projects have been built, even though existing installations have been refurbished. Plans are under way for a future introduction of 800 kV AC in India and China.

The introduction of even higher AC voltages in the UHV range has been cancelled or postponed in several countries, e.g. in Russia, Italy and U.S.A. Future 1000 kV AC lines are, however, considered in Japan and China.

Tokyo Electric Power Company (TEPCO) completed in 1999 a 1000 kV AC transmission line route that links a nuclear power station on the Sea of Japan to the metropolitan region and the other route linking power sources on the Pacific Ocean. These transmission lines are now operated at 500 kV and are planned to be upgraded to 1000 kV AC around 2015.

State Grid Corporation of China has recently started a program which aims for a 1000 kV AC line to be in operation by 2008. Based on its experience in delivering EHV AC equipment like switchgear (LTB, DTB and GIS) and transformers in a number of countries, ABB is well-positioned for developing its product portfolio towards UHV AC.

3.2 UHV DC

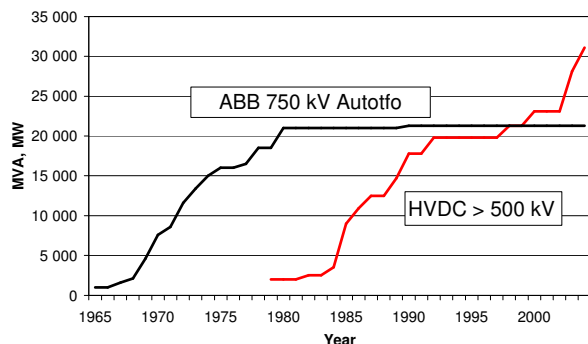
The first HVDC system for ± 500 kV and above was the Cabora Bassa project (± 532 kV), commissioned in 1979. The Brazilian Itaipu project is operating at ± 600 kV since 1984.

The major HVDC investments at these voltage levels were made in the late 80's and early 90's.

However, an increasing interest in high-capacity HVDC links has been noted in recent years.

ABB together with the research institute CEPEL in Brazil conducted basic research in HVDC 800 kV systems in 1987-1995 and some equipment was designed and manufactured. Since then design work has continued within ABB.

Several studies and meetings confirmed that 800 kV HVDC transmissions are a feasible voltage step (IEEE and Cigré in the late 80's, Cigré 2002, Powergrid Company of India Ltd. Workshop in Delhi, February 2005).

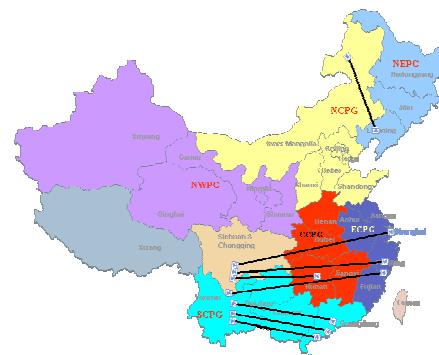


The graph shows the increase in HVDC projects while the EHV AC market stagnated

4 The Chinese UHV DC market

The Chinese market for Bulk Power Transmission is by far the biggest in the world. China is planning for approximately 10 UHV DC projects, each rated 5000-6000 MW, to be in operation before 2020, with transmission distances in the range 2000 –3000 km. The first project is scheduled to be in commercial operation already by 2010.

The reason for selecting HVDC 800 kV is that alternative methods for transmission are more expensive (+20 %), have higher losses (+ 20 %) and require more land for Right-Of-Way (+50 %).



The map shows the ± 800 kV DC projects that are planned to be in operation before 2015

5 R&D for UHV DC

The potential market for UHV DC in China, India, Brazil and South-Africa has reinforced R&D for UHV DC. The target is that UHV DC equipment should be type-tested and ready for commercial delivery when needed by customers. ABB has arranged or attended UHV seminars with customers like State Grid Corporation of China, China Southern Power Grid and Power Grid Company of India. ABB also established numerous contacts with electrical design institutes and research institutions.

5.1 Environmental Stress

There are two areas of co-operation that have been identified as essential for UHV DC. One area is ultra high voltage combined with pollution and high altitude, the other area is external insulation. For the converter station equipment, the conditions can be well defined but for the transmission line, the conditions can and will vary along the route since the distances might be in the range of 2000 – 3000 km and the line will pass through all kinds of terrain, including polluted areas and high altitudes > 2000 m.

ABB has a pollution test station (PTS) that is now installed at a 110 kV substation in Southern China. The station is operated by Chinese and ABB experts in co-operation. The aim is to collect pollution data at high altitude to be used in the design of the converter station and the transmission line.



ABB has opened a research center in Beijing with focus on government priorities: power supply and energy savings

For the converter station equipment the internal design and the external insulation are the two most important issues. The mechanical design considering high seismic requirements together with high structures may lead to unconventional solutions

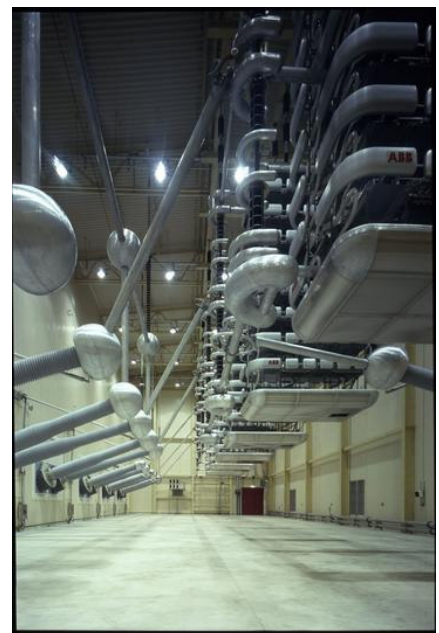
5.2 Equipment for UHV DC

The R&D program for the converter station equipment can be divided in two major areas:

- Equipment with DC voltage grading and linear voltage distribution
- Equipment with oil/paper insulation and non-linear voltage distribution

For the equipment in the first category, which includes the thyristor valves, the design may be scaled since the voltage distribution is linear. R&D focuses on reducing remaining risks and on identifying requirements on crucial components like thyristors. ABB can leverage its advantage to produce such components internally.

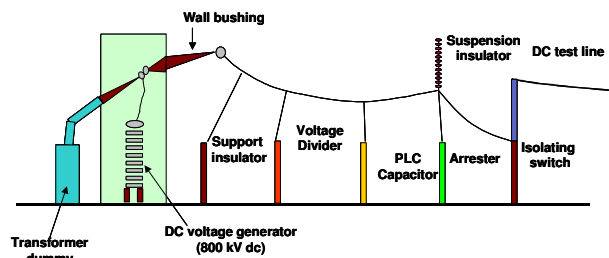
Equipment in the second category includes the wall bushings and the converter transformers and requires major R&D and extensive testing. This work requires scientific research coupled with solid design experience. In this field, ABB can draw on its corporate research centers working closely together with design specialists.



Interior from the Valve hall in the Three Gorges – Guangdong HVDC project

5.3 Equipment Testing

All equipment that will be exposed to 800 kV will have to be type tested at the factories to ensure that all requirements are met. In addition, ABB envisions a test circuit to be built with the purpose to demonstrate the capability of the equipment to withstand ± 800 kV for a longer time. The equipment to be installed in the test circuit should in principle be all DC switch-yard equipment exposed to 800 kV, but should be agreed upon between ABB and the end user.



Circuit for long term verification of ± 800 kV DC equipment

6 Transmission lines

Because of the location of the hydro power resources, the transmission lines will be very long and exposed to extreme ambient conditions such as high altitude, severe pollution and weather conditions above normal. This will require a robust and reliable line design in order to have a safe operation of the line when exposed to such tough conditions.

Even though the transmission lines are not supplied by ABB, ABB experts are supporting the Chinese Design Institutes with knowledge in line insulation and mechanical design to facilitate progress on the complete system design.

7 Conclusion

In order to meet the sharp increase of power consumption, developments are ongoing to increase HVDC transmission voltages. As an example, the Chinese government has decided to develop the hydro rich region in South West China. The load centers are located 1500 – 2000 km away and a more effective transmission system is needed to keep investment costs down, save land and reduce losses. In international studies and panels, no roadblocks to the feasibility UHV DC transmission were identified.

ABB, as the HVDC market pioneer, continues its R&D to prepare for a market in UHVDC, ± 800 kV. R&D work is and will be done in co-operation with customers and partners to meet the tough requirements put forward for bulk electricity transmission. Manufacturing issues will have to be taken into account as well.