800 kV HVDC – a big technological step

Basic research

More than twenty years have passed since the voltage used for high-voltage direct current (HVDC) transmission was last increased. The reason it took so long is that this development step required further basic research in a number of fields:

- The development of new materials for insulators in an outdoor environment. Using a higher voltage also means that there must be a wider gap between voltage and ground in order to isolate live parts with respect to ground. For the past 100 years, insulators to provide these gaps were primarily made of porcelain. However, the past 15 years have seen the development of new plastics which have made it possible to abandon porcelain, primarily for silicone rubber. This material has been shown to possess very favorable properties for outdoor insulation.
- Advanced computer-aided design tools for three-dimensional field calculations, primarily for transformer design.
- Refined measurement methods using advanced laser technology to determine the characteristics of insulating materials and insulation systems.
- Advanced control systems that control the entire installation. This calls for an extremely high calculation capacity, exploiting state-of-the art computer processors and information technology to the limit. For this, the Mach2 system developed in-house by ABB is used.

There was a development project aimed at raising the voltage to 800 kilovolts (kV) in the mid-1990s, but the basic research needed to achieve this was not finalized at the time. While the project was in progress, the market lost interest and the project was abandoned.

The 800 kV project

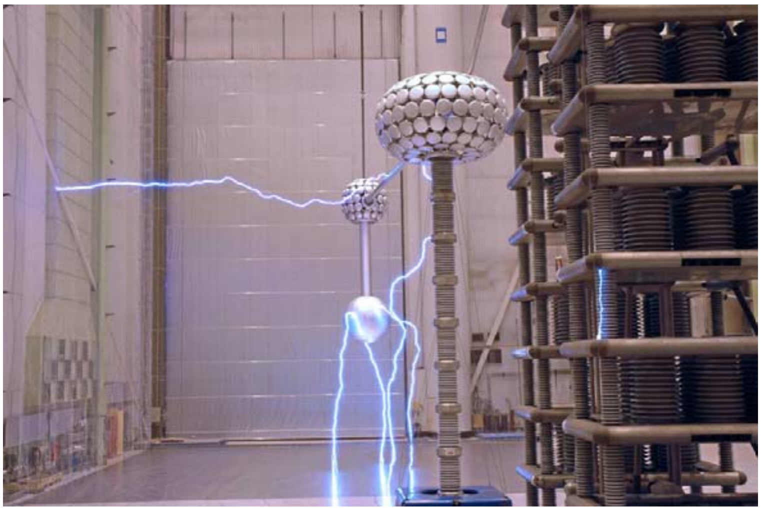
When the basic research above was in place, extensive product development was carried out over the past two years. Most of this development work has been done at ABB's facility at Ludvika, Sweden, backed by the central research laboratory at nearby Västerås.

The central parts of the project

1. With up to 9,000 megawatts (MW) being carried on a line, extreme reliability is obviously essential, so a completely new station design has been produced to make it possible to meet these requirements. The line must not fail more than once every 25 years. Increased availability is achieved by extensive sectioning of both the main circuit and the auxiliary systems. In addition, all control and safety systems are duplicated, as are auxiliary systems such as auxiliary power and emergency battery systems.
2. New types of all the high-voltage devices subject to DC have been developed and fitted with newly developed polymer insulating materials. Examples of such devices are potential dividers, bypass switches, radio interference suppression capacitors, disconnectors and post insulators.
3. One of the main aims of the project was to develop a new transformer and a new bushing for 800 kV. The foundation for this was the basic research mentioned above. Prototype bushings were produced and type-tested. For the transformer, a mock-up was

built to simulate the parts of the transformer subject to high DC voltages. The photo below shows the transformer and wall bushing during tests.

4. New calculation models to assess the required insulation gaps have been developed. Extensive tests were done at extremely high, previously untried voltages. The picture below shows a discharge flash at over 2 million volts. These flashes are more than ten meters long. The photo below shows an insulation gap test in one of the high-voltage laboratories in Ludvika.



5. The Mach2 control and protection system has been developed further to satisfy the extreme reliability demands.
6. A new thyristor and thyristor valve have been developed to handle the increased voltage and current.
7. Finally, all critical devices undergo endurance testing in a special endurance testing station built by ABB at STRI[*] in Ludvika. The elevated voltage test extends over a year. The purpose of the test is to verify the long-term characteristics of the components used.

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[*] STRI is an independent technology consulting company and accredited high-voltage laboratory located in Ludvika, Sweden. www.stri.se

Financial benefits and built-in advantages

Two main driving forces justify the use of 800 kV HVDC.

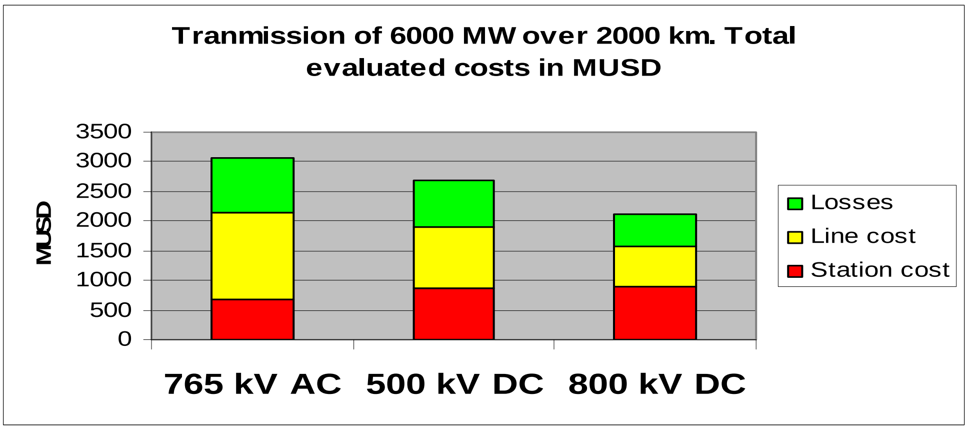
- First, the installation, including the power transmission line, is significantly cheaper for the customer.
- Second, this technology takes up significantly less space. This argument is at least as important as the simple capital cost.

Financial

There are three main aspects to the financial evaluation:

- Power line losses
- The investment cost for the line
- The investment cost for the converter station and associated AC switchgear

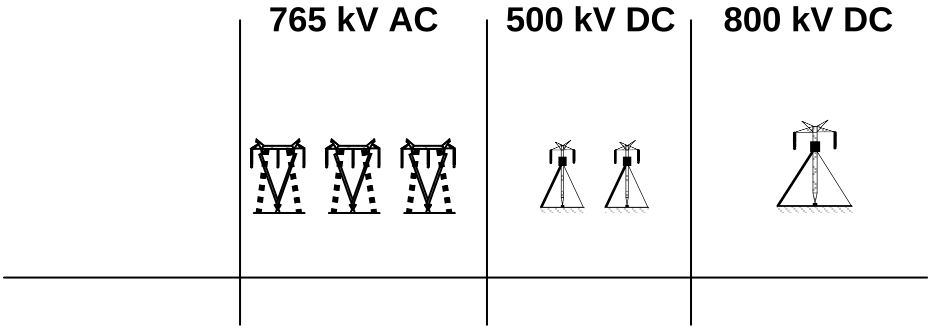
The diagram below illustrates the cost differences between 765 kV AC, 500 kV DC and 800 kV DC. The example is for a 2,000-kilometer (1,240 miles) line to transmit 6,000 MW.



Inherent environmental advantages

Narrow tracks

With 800 kV HVDC the width of the power line track is minimal. Where alternative means of transmission are used, two or more lines are needed and in most cases the track for each will be wider. The sketch below shows the approximate differences:



Low losses

As mentioned under "*Financial*" above, the line losses are significantly lower with HVDC than with AC.

Low magnetic fields

Contrasted with normal AC transmission lines, HVDC lines have an almost negligible oscillating magnetic field. This means that HVDC lines, unlike AC lines, can easily satisfy the stricter magnetic field requirements (<0.4 µT) increasingly being enforced in the west.

The market today and tomorrow

In China and India, the demand for energy is growing dramatically. Every year, China installs new power-generating capacity equivalent to the entire installed capacity of Sweden. A major expansion of hydropower will be needed to satisfy this demand.

For China, this means exploiting large reserves of hydropower in the west of the country. However, the power is needed in the east and south, so the electricity needs to be transmitted 1,500 to 2,000 kilometers .Up to now, 500 kV DC has been used for long-distance transmission of electric power, over distances of as much as 1,000 kilometers.

With the introduction of 800 kV DC it will be possible to transmit power as far as 3,000 kilometers with reasonable transmission losses. China is currently planning to build one 800 kV DC line per year over the next ten years, with a capacity of between 5,000 and 6,400 MW per line.

India has plans to expand hydropower in the north-eastern part of the country. As in China, the demand for power is far from the source, so here too the power will need to be transmitted as far as 2,000 km. India is currently planning to build one 800 kV DC line every two years over the next decade, with a capacity of 6,000 MW per line.

Apart from China and India, there are plans to install 800 kV lines in southern Africa and Brazil.

So it can be said that 800 kV DC will account for a significant part of world growth in power transmission capacity over the next ten years.

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