History of High Voltage Direct Current Transmission (HVDC)

To transmit electrical energy over long distances – or to connect asynchronous AC networks, the application of HVDC systems offers both technical and economic benefits over traditional AC technology. However, it has taken about 50 years of continuous development to transform the early promise of HVDC into today’s reliable and economic product.
The Beginnings of DC Transmission

Siemens has been involved in power transmission since its infancy. Indeed the invention of the dynamo by Werner von Siemens in 1866 is often seen as the beginning of the Electrical Power Age. At the Paris World’s Fair of 1867 von Siemens envisioned an electrical power transmission system “to transmit powerful electric currents from the nearby coalfields for use in the city of Berlin”. By 1882 a transmission system featuring the characteristics of HVDC was unveiled at the 1st. German Electro-technical Exhibition. The system connected Munich to Miesbach, some 57 km distant, at a voltage of 2000V.
Further Development of Energy Transmission Technologies

By the latter part of the 19th century the AC power transformer had progressed to a practical reality and when combined with Tesla’s work on 3-phase systems the transformer became the catalyst for the development of efficient power transmission. Because, at that time, static converter equipment did not exist, the DC technology could not benefit from this breakthrough and its use as a transmission medium lapsed.

But engineers never forgot the advantages of DC and by the 1930s the appearance of the mercury-arc valve led many to contemplate the return of DC transmission. In this era Siemens engineers were again at the fore and by 1945 were actually ready to commission a 115 km mercury-arc based link with 120 MW / ± 200 kV ratings in partnership with the AEG. But fortunes of war intervened and the equipments were taken as reparations by Soviet forces. By 1950 some equipment was re-installed for the 200 kV link between Moscow and Kashira. Western Europe also had its first mercury-arc DC link in 1954 when Gotland was connected to Sweden.

For the next two decades progress with HVDC was slow. Steady improvements were made to the control systems and valve technology but the reliability and maintenance issues of the mercury-arc valves limited the spread of HVDC.
The Re-naissance of HVDC

By the 1970s the emergence of a high power semiconductor device, the thyristor, transformed the fortunes of HVDC. Converter technology was revolutionised providing a far more reliable, economic and maintainable product than was possible with the old mercury-arc valves. Siemens now renewed interest in HVDC and by 1977 had commissioned the converters for the huge Cahora Bassa project in Mozambique.
Today’s HVDC Transmission Systems

Continued development of semiconductor technology has led to dramatic increases in both the current and voltage ratings of the thyristor. Therefore, fewer devices are now required for a given power/transmission voltage rating resulting in reduced costs and higher reliability.

As an example the Cahora Bassa scheme (1977) with a rating of 1920 MW required 48,384 thyristors, whereas the HVDC Transmission System of East-South India (2003) used just 3,888 thyristors for a rating of 2000 MW.
Light-triggered Thyristors - an Innovation

The heart of a HVDC Transmission System is truly the electronic power converter valves. These valves are built around the thyristor device and they convert AC into DC at the Rectifier station and DC into AC at the Inverter station. Originally, the thyristors were triggered with an electrical current pulse, but since 1995 Siemens has pioneered an innovative use of Laser technology. Glass-fibre cables are fed into the thyristor device to allow direct light triggering of the device with just 10 mW of Laser power.
Light-triggered Thyristors in Use

The slim valve towers - as illustrated for the HVDC transmission stations at Moyle (UK) - are equipped with light-triggered thyristors. When compared with electrical triggering an 80 % reduction in the valve electronic components is achieved – leading to higher reliability with reduced maintenance costs.
HVDC Projects Worldwide

Today the economic and technical advantages of HVDC are universally accepted with HVDC stations now found worldwide. From the very beginning of HVDC’s history Siemens engineers have been involved in the technology’s development. Many innovations relating to HVDC were the ideas of Siemens engineers and technologists.

In the early days Siemens shared projects with other partners (e.g. Cahora Bassa, Nelson River, etc.), but gradually the Siemens scope of supply increased. An example is the turnkey HVDC – Moyle project with a connection via sea cable between Northern Ireland and Scotland, shown in the picture.
Continuous Enhancements

More recent projects including Welsh (USA) shown in the picture and Virginia Smith (USA), Tiansheng-Qiao (China) and Gui-Guang (China), East-South (India) and Basslink (Australia /Tasmania) have been turnkey Siemens projects.

Today in the field of HVDC Siemens stands for worldwide experience, innovative technology and a concentrated knowledge base.
Future Prospects

The future prospects for HVDC are bright since alternative technologies find its advantages hard to match:

Transmission of energy economically and efficiently over huge distances  
Connection of unequal networks  
Stabilisation of existing 3-phase networks by fast converter control  
Increase of transmissible power

It’s feasible that the 1,500 MW rating (per pole) which is often used today could be increased to 3,000 MW giving a total power rating of 6,000 MW for a Transmission Bipole. This would mean an increase in DC voltage above +/- 500 kV.

The picture illustrates a converter station from the recent Thailand-Malaysia project showing the valve-hall (centre), smoothing reactors (right) and valve cooling plant (bottom left).