



# China showcases UHVDC technology

## Introduction

High voltage direct current (HVDC) technology is well suited to connecting existing networks. With rising energy price, power exchange between large grids will become more commonplace.

An HVDC back-to-back link can easily combine two different AC networks, even when they are operating at different frequencies. It allows both network users to balance varying load and outputs caused by different time zones or usage patterns. For example, an area (A) with abundant hydropower in a cold region may rely on another area's (B) coal fired power in winter since frozen river cannot produce power. Conversely, during the rest of the year, region B may rely on region A to meet the peak demand in summer. HVDC are ideal in such scenarios and ultimately help customers strengthen and optimise their networks.

## New challenges

In today's society it is important to find reliable power sources that allow us to meet increasing power demand while at the same time protecting the environment.

Yet while generating power in a sustainable and ecologically responsible way is one thing, it is equally important that the energy can be transported to the centres of consumption in an efficient and environmentally sound manner. For the past 30 years, 500 kV DC transmission has been the most efficient means of transmitting bulk power over long distances; but as power transfer capacity needs and distances increase, we are beginning to see limitations in the power transfer capability of 500 kV DC lines.

In China for example, the distance between the hydropower plants in the centre of the country to the mega cities along the coast is almost 2000 km. It is a distance over which the large state-owned utilities need to transmit more than 5000 MW of power – enough for 2 million households. Realizing the limitations of existing technology, Siemens' utility customers asked Siemens to develop a system that is able to handle their requirements.

As a world-leading manufacturer, systems integrator, and provider of complete solutions, Siemens was able to offer a 630 kV HVDC transmission system. However, even as the R&D departments were still finalizing the solution, the Chinese customers decided that 800 kV would be the solution of choice.



## 800 kV DC converter transformers for China

In 2007, Siemens received the first two Chinese +800 kV UHVDC (ultra high voltage DC) projects: Yunnan – Guangdong at 5000 MW and part of Xiangjiaba – Shanghai at 6400 MW.

Case study: transformer for 800 kV HVDC Transmission

Answers for energy.

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With the pilot contract in hand, Siemens' transformer experts began the design of an 800 kV DC converter transformer. Compared to the previously used 500 kV level, 800 kV represents a 60% increase in rated voltage – an unequaled rise in voltage level.

Developing an 800 kV UHVDC transformer is a major milestone in electrical power engineering and transformer technology and presents many challenges.

The key challenge is to control external and internal insulation requirements. External insulation refers to all insulation exposed over distances of air or surfaces of insulators exposed to pollution. Internal insulation relates to all insulation inside oil or solid insulation material, e.g. in an oil-insulated transformer tank.

In the UHV range, some insulation characteristics become highly non-linear. For example the distance in air (air clearance) required between HV parts and ground can be approximately 4–5 m for 500 kV HVDC systems. For 800 kV systems, however, the 60% increase in voltage level means the necessary air clearance nearly doubles to approximately 10 m.

To achieve this clearance, the most straightforward approach would have been to increase the size of components and the distance between components to achieve sufficient insulation strength. However, this would have resulted in an extremely large design, and the equipment in many instances would no longer be producible or transportable.

The selected approach was therefore to re-design all main equipment exposed to the 800 kV voltage level to ensure an optimum balance between electrical fields and dimensions.

There were a number of major challenges during development:

- New insulation techniques had to be developed to enable optimum balance of electrical and mechanical designs of the high voltage equipment. This was a big challenge to material and manufacturing processes
- Completely new valve side bushings and barrier system were required
- Generating test voltages was a challenge since only a few test labs can provide voltages in this range
- Setup of a partial discharge-free test
- A special transformer setup was required to stay within the limits of the Chinese railway transport system (this meant limiting transport dimensions)

The complexity of the entire production process and quality requirements increased tremendously. New production equipment and processes had to be set up in order to ensure the highest quality as well as meet the tough delivery deadlines. In fact, an entirely new production facility had to be built by bushing supplier HSP to handle the dimensions of the bushings. The task was all made more difficult because of a lack of international (design) standards covering this new technology.

A coordinated R&D program was set up to involve experts from various business units. This broad in-house experience, combined with well-proven equipment and components, provided the basis for success.

#### Potential for success

The 800 kV UHVDC technology guarantees economical transmission of large-scale bulk power over very long distances.

Compared to other solutions, an 800 kV UHVDC system has significant advantages when transmitting 5000 MW over a distance of 1400 km. Over such long transmission distances, the use of UHVDC technology is clearly a much cheaper option than AC technology. Overhead transmission line costs are reduced since only one bipole is needed. Further, when compared to existing 500 kV HVDC, overall costs of the new 800 kV system could be up to 25% lower.

Power losses in the new 800 kV systems are also extremely low, which means power can be increased to 7000 MW and above, per system. Taking the reduction in losses into account, UHVDC in this application can save in the region of 33 million tonnes of CO<sub>2</sub> emissions each year.

The reduced footprint size can also be an advantage in meeting right-of-way requirements.



800 kV UHVDC Transformer

**Customer collaboration**

The successful development of the system can be attributed to the faithful cooperation between Siemens and their lead customers. The key expert working group finalized the joint design of technical requirements and features in less than two and a half years. The lead customers have always believed in Siemens' concept and technological capabilities.

When China Southern Grid awarded the +800 kV transformer contract for both terminals to Siemens in the summer of 2007, Siemens committed to help the local suppliers build the low voltage end as well as the HVDC transformers in China. At the end of 2007, China State Grid awarded part of the first order for the +800 kV DC transformers to Siemens. This demonstrates the confidence that two of China's major utilities have in Siemens technology.

Compared to the very first project in China (Gezhouba – Shanghai), the rated power of these projects has increased from 1200 MW to 6400 MW. The number of transformers has increased from seven to 28 units (including both high-end and low-end) in one terminal, and DC voltages have risen from +500 kV to +800 kV. This shows that Siemens is without doubt an acknowledged leader in this technology.

The changing energy environment provides more and more opportunities for UHVDC solutions, and Siemens is prepared to provide its customers with either our solution or with converter transformers as a standalone component.



500 kV HVDC Transformer

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