**<http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/#content=Description%20>**

# Siemens Ultra HVDC Transmission System in China

In June 2010, State Grid Corporation of China commissioned the 800 kV HVDC Xiangjiaba-Shanghai transmission system. The high-voltage direct-current transmission link (HVDC) is the most powerful and longest transmission of its kind to be implemented anywhere in the world at that time, transmitting 6,400 MW of power over a distance of nearly 2,000 kilometers. Siemens Energy has equipped the sending converter station Fulong for this link with ten DC converter transformers, including five rated at 800 kV. Apart from that, Siemens provides the power electronics (6-inch thyristor valve towers and interfaces) together with its partner XD Xi’an Power Rectifier Works.

The HVDC transmission link transmits 6,400 MW of hydro power from South-Western China to Shanghai on China's East Coast over a distance of about 2,000 kilometers. The Xiangjiaba-Shanghai link also operates with a transmission DC voltage of 800 kV to further minimize transmission losses. Thanks to the use of [environmentally friendly](http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/references.htm) hydro [power generation](http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/references.htm) and low-loss HVDC transmission, the new system will save up to 44 million metric tons of CO2 p.a. ***versus local*** [***power supply***](http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/references.htm) ***with energy-mix***.

The ten HVDC transformers which Siemens has supplied for the Fulong converter station in Sichuan close to the Xiangjiaba hydro power plant were built at the company's transformer facility in Nuremberg. This applies in particular for the newly developed 800 kV HVDC transformers that are in the highest voltage class at the present time. Last year Siemens became the world's first manufacturer to supply and commission 800 kV converter transformers.

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| **Customer**  | State Grid Corporation of China andXD Xi’an Power Rectifier Works (XPR)  |
| **Project name**  | Xiangjiaba  |
| **Location**  | Xiangjiaba to Shanghai  |
| **Type of plant**  | Long-distance transmission,2070 km  |
| **Power rating**  | 6400 MW, bipolar  |
| **Voltages levels**  | ± 800 kV DC, 525 kV AC  |
| **Type of thyristor**  | Electric-triggered thyristor, 8 kV (6 inches)  |

# Description

Throughout the world, the demand for power keeps growing at a scale and speed never imagined in the past. For various reasons we also witness a strong push for [renewable energy](http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/) sources (RES) with [power generation](http://www.energy.siemens.com/co/en/power-transmission/hvdc/hvdc-ultra/) becoming increasingly distributed and a growing number of generation facilities located far away from load centers. At the same time, demanding economic objectives as well as obligations to reduce greenhouse gases have to be met.

To meet all these demands precisely, Siemens has taken great efforts to overcome the hitherto limitations in the technology available for high-voltage direct current (HVDC) power transmission. Thanks to Siemens Ultra HVDC (UHV DC) long-distance power transmission at a voltage level of 800 kV providing power capacities of up to seven gigawatts and more has now become technically as well as economically feasible for the first time ever. The first 800 kV UHV DC system, ordered by the China Southern Power Grid Co. in Guangzhou, is scheduled to commence commercial service by mid-2010. It allows the country to tap more hydropower instead of adding new coal plants. The CO2 emissions offset amount to a whopping 33 million tons at the Yunnan-Guangdong project alone.

**Benefits**

The most economic solution for long-distance bulk power transmission, due to lower losses, is transmission with High Voltage Direct Current (HVDC). A basic rule of thumb: for every 1,000 kilometres the DC line losses are less than 3% (e.g. for 5,000 MW at a voltage of 800 kV). Typically, DC line losses are 30–40% less than with AC lines, at the same voltage levels, and for long-distance cable transmission DC is the only solution, technically and economically.

Siemens UHV DC is a newly developed system that provides the key to increased performance and robustness of the transmission grid, to keeping pace with the steadily growing energy demand, and to a highly economical way of CO2 emissions reduction:

* single bipole power transmission capacity of more than 7 gigawatts at a voltage of ± 800 kV
* 60 % reduction in transmission losses and CO2 emissions with UHV DC compared with standard ± 500 kV HVDC
* significantly smaller footprint and lower OHL costs compared with 800 kV AC solutions
* deally suited for bulk power transmission over very long distances of 2,000 km and more for infrastructure upratings
* capable of interconnecting large grids and of stabilizing parallel AC systems
* advanced high-speed system control with Win TDC



UHV DC – More than 50 % Reduction in Right-of-Way Requirements

Siemens UHV DC will be the bulk power energy highway and security backbone of the future power grids



UHV DC – A significant reduction in Transmission Losses

**Layout**

The next level of HVDC technology, Siemens UHV DC, is characterized by its innovative 800 kV voltage level, its transmission capacity of up to 7,200 Megawatts, and a substantial loss reduction. Thanks to thorough R&D efforts, Siemens is able to produce the entire range of components required for 800 kV DC power transmission itself and supply complete UHV DC systems from a single source. An example of the station Layout and the converter arrangement with two 400 kV systems in series in each pole for n-1 redundancy is given in the following figures.

 

**Example of a Bipolar Station Layout with two 400 kV Converters in Series**

A converter station links the DC transmission line at each end to the AC grids. It consists of a number of components which have reached a high degree of maturity. However, for UHV DC application, innovative solutions have been implemented to fully meet the extended requirements for ultra-high voltage bulk power transmission, ref. to the figures

**Tomorrow’s Power Grids | HVDC Transmission**

**China’s River of Power**

**How do you supply five million households with hydroelectric power from a distance of 1,400 km? The answer is: with high-voltage direct-current transmission. Siemens is building the world’s most powerful such system in China.**



With the help of high-power [transistors](http://www.siemens.com/innovation/en/publikationen/pof_fall_2009/energie/hguechina.htm), rectifier modules, and smoothing reactors, a new HVDCT line is able to transmit 5,000 MW over the 1,400 km from Lufeng to Guangzhou



**I**t takes a jarring ninety-minute ride to cover the distance from Kunming, the capital of Yunnan province in southwestern China, to Lufeng. Lush green paddy fields and herds of water buffalo flash by the car window. Then, at long last, deliverance comes. Our driver turns in at a blue sign bearing lots of Chinese characters and "800 kV" in Western script and lets us out just beyond a rolling gate. In front of us is a site measuring around 700 by 300 m that looks like something from another world. Gigantic pylons dripping with cables soar into the cloudy sky, while workers below toil with spades and wooden wheelbarrows to finish the last of the landscaping. The air is alive with a sonorous hum. "That’s from the testing," explains Jürgen Sawatzki, who is in charge of the installation of equipment from Siemens at the site.

The high-voltage overhead lines coming from the hills to the left of the fence are already carrying power, but the shiny new one that crosses the fence to the right and disappears over the mountain is still dead. It will go into operation in 2010 as a bipolar line transmitting power to Guangzhou in Guangdong province, over 1,400 kilometers away. From there it will supply five million households in the megacities Guangzhou, Shenzhen, and Hong Kong on China’s southeastern seaboard. This will reduce the country’s annual emissions of CO2 by some 33 mill. t a year, as the electricity comes from a dozen hydroelectric plants on the Jinsha ("Golden Sand") River, one of the headwaters of the Yangtze, which provide carbon-free power.

The overhead lines arriving from the left of the site are carrying conventional alternating current (AC) that has been generated by hydroelectric plants, some of which are located as far as several hundred kilometers away. The 1,400-km transmission line to Guangzhou, however, will carry direct current. High-voltage direct-current transmission (HVDCT) is not a new invention; as long ago as 1882, a transmission line of this type carried electricity from Miesbach in Bavaria to an electricity exhibition in Munich, 57 km away. That, however, is where the similarities end. Back then the voltage was a mere 1,400 V; in China, the line will transmit at a record 800,000 V. "The HVDCT line in China is the ultimate example of this technology. It will carry 5,000 MW; that’s the output of five large power plants," explains Prof. Dietmar Retzmann, one of Siemens’ top experts on HVDCT.



Hydroelectric generation capacity on the Jinsha River is being expanded. The resulting electricity will be transmitted to major cities on China’s southeastern coast by the world’s most powerful HVDCT line

**Low-loss Power.** Regardless of whether power is transmitted as an alternating or a direct current, the goal is to ramp up the voltage as much as possible. For both types of transmission, physics dictates that for a fixed amount of transmitted power, the current is inversely proportional to the voltage. In other words, the higher the voltage, the lower the current, thus reducing the energy losses that result from the conductor heating up. When transmitting over long distances, however, HVDCT is superior.

"With our power highway in China, as much as 95 % of the power reaches the consumer," says Wolfgang Dehen, CEO of Siemens Energy. With AC transmission lines, this falls to 87 %, which in this case would amount to a loss of 400 MW—the output of a mid-sized power plant or 160 [wind generators](http://www.siemens.com/innovation/en/publikationen/pof_fall_2009/energie/hguechina.htm). As a result of these reduced transmission losses, the HVDCT link will cut emissions by a further three million metric tons of CO2 a year.

In theory, it would be possible to build AC transmission lines over similar distances. A voltage of 800 kV will transmit an alternating current over a distance of 1,500 km. The problem is, however, that over long distances the voltage waves at the beginning and the end of the transmission line are shifted relative to one another—the technical phrase here is "phase angle"—and this necessitates the installation of large banks of capacitors every few hundred kilometers for the purposes of series compensation. This drives up the price of such installations. And in spite of such compensation, the losses over long distances would still be significantly higher than with HVDCT.

Sawatzki leads us into a hall the size of an aircraft hangar, where workers are installing a power stabilization system onto long poles suspended from the 20-m-high ceiling—a measure designed to minimize the chances of a short circuit and associated electrical outage even in the event of an earthquake. The devices look like a stack of huge plant trays and could well have been inspired by the legendary Hanging Gardens of Babylon. Each tray contains a total of 30 shiny golden cans that are carefully connected in series and wired to control circuits with fiber optic cables ([*HVDCT Converters*](http://www.siemens.com/innovation/en/publikationen/pof_fall_2009/energie/hvdctconverters.htm)).



Giant 800 kV transformers were tested in Nuremberg (left) before being shipped to China for installation (center). The control room of the transmission station in Lufeng (right)

Inside the tins are thyristors—converter valves made of silicon, molybdenum, and copper—which are activated optically by means of a laser beam 50 times a second, exactly in phase with the current as it switches polarity. This occurs so precisely—to within a millionth of a second—that the negative waves of the alternating current are "flipped" so as to create a direct current. Because this current still has a high ripple content, it next goes to the so-called "DC yard" right behind the valve hall. There, capacitors temporarily store charge, which they "inject" into the ripples, and coils filter out interference signals emanating from the rectifiers in the hall. All this is standard circuitry, as found in any mains-operated electrical appliance, but the dimensions are gigantic here in the DC yard.

**Bipolar Transmission.** In another hall right next to the first one, the screed floor is being poured. Sawatzki draws a circuit diagram on a piece of cardboard and explains: "The rectifiers and the DC yard are in duplicate." The advantage here is that one conductor is operated as an 800 kV positive pole and the other as an 800 kV negative pole, thus giving a total of 1.6 mill. V between them. In other words, the power is divided between two conductors in order to minimize transmission losses. At the same time, this is a precaution in the event that one pole should go down.

A number of tests are scheduled for the coming months. Eight Siemens engineers, accommodated in an office above the valve hall, sit in the control room, gradually ramping up the voltage onscreen. This is designed to push the components to their very limits and reveal any weaknesses before the system enters service. A blackout in one of China’s large coastal cities would be a nightmare.

The left half of a large control screen displays the operating load of the transmission station in Lufeng as "0 MW." The right side of the screen shows the status of the receiving station in Guangzhou, where the direct current will be converted back into alternating current and fed into the public grid. Here a default reading of "9.999 MW" is displayed. Were the station in operation, the screen would show a power of 5,000 MW as well as a raft of other data from Guangzhou, all of which will be transferred in real time via a fiber optic cable that is laid along the HVDC transmission route.

**Know-how from East and West.** Whereas the AC part of the system was built entirely by Chinese firms, the DC part contains a lot of Siemens know-how. Yet that doesn’t mean that all the components were made in Germany. Half of the 48 transformers are of German production, while the others were manufactured in China under the supervision of Siemens.

Sawatzki has been in China for ten years now. The HVDCT system in Lufeng is his fourth for network operator China Southern Power Grid. All in all, the project will take three years, from the award of contract in June 2007 to full commissioning in June 2010.

In the first project with China Southern Power Grid, Siemens handled 80 % of the total contract volume, in the second 60 %, and in the third 40 %. In the fourth project this share has fallen a bit further, coming in at around €370 million out of the €1 billion that the system is costing. China Southern Power Grid has stipulated that most of the components to be supplied by Siemens must be manufactured in China by subcontractors. So whereas Siemens is still responsible for the engineering of the thyristors, for example, these components and all the ancillary equipment are being manufactured under Siemens supervision by two Chinese firms.



A gate at the Guangzhou receiving station alerts visitors to its world-record transmission voltage. Hydropower and HVDCT are cutting China’s CO2 emissions by 33 mill. t a year

**Profiting from Innovation.** It will not be possible, however, to build future systems of this kind without Siemens’ know-how, since innovation is continuously advancing the state of the art in this field. "There’s a lot of new know-how in the 800 kV technology, which is being used here for the first time," explains Susanne Vowinkel, who works at Siemens’ Energy Sector as a commercial project manager in the field of contracts, issuing invitations to tender to suppliers, and customer relations.

Innovations from Siemens include silicone-covered insulators that repel water and provide better insulation when dirty. Meanwhile, engineers are already looking beyond the 800 kV mark, as higher transmission voltages promise even lower line losses. The move from 500 kV to 800 kV has already reduced costs over 30 years by around one quarter. The name of the game, as Vowinkel points out, is to stay one step ahead.

Siemens has just landed a major contract in India and tendered bids for further HVDCT projects in China, India, the U.S., and New Zealand. What’s more, HVDCT has already become the cornerstone of major projects for the future, such as Desertec, which will transmit power from North Africa and the Middle East to Europe ([*Solar Energy*](http://www.siemens.com/innovation/en/publikationen/pof_fall_2009/energie/desertec.htm)).
                                                                                                                  *Bernd Müller*