

A Quantum Leap for Power Transmission

One of the greatest challenges in providing a secure and efficient power supply is the transmission of electricity from the plant to the consumer. Siemens has a new solution for long-distance transmission. The breakthrough technology had its world premiere in China in June 2010.

By Justus Krüger

Efficient Transmission Connects Chinese Provinces

Rural Yunnan Province is a long way from the urban centers in the Pearl River Delta. Siemens' breakthrough UHV DC technology bridges the 1,400-kilometer gap between the place where the hydro-power is and energy-hungry megacities in the Delta, thus supplying five million households with clean energy. Apart from its main strength – hugely superior transmission efficiency – UHV DC has various additional advantages. The small footprint of its overhead lines is one of them. The pylons supporting the UHV DC transmission cover less than half the space required by conventional AC systems with comparable capacity.



Trial by Lightning for Crucial Element

Testing novel components specifically designed to handle ultrahigh voltage of 800 kV posed a special challenge. The huge size of the wall bushings – no less than 21 meters long – required new testing facilities specially designed for the 800-kV project. The wall bushings are a key part of the new technology. They conduct the current from the valve towers to the transmission line and vice versa. During the tests, the pillar-sized bushing (above) is exposed to different types of high voltage such as direct and alternating current and lightning impulse voltage of up to 2,420 kV.



Carrying Transformer Units to Distant Project Site

The remoteness of the site is one of the challenges for the Yunnan–Guangdong project. “We specially designed the transformer units to fit through the mountain tunnels,” explains Marcus Häusler, Technical Director of the 800-kV project. The connector arms – the transformer bushings – and parts of the windings are then installed on-site. In total, 24 transformers are installed at each station with one spare for each type. “If one of the transformers needs to be replaced, it could take months to get a new one out here, so we chose to keep one for each type in reserve on-site.”



Current Conversion in the Hall of Towers

The valve hall is the heart of the ultrahigh voltage DC transmission. This is the place where AC current from the conventional grid – in this case in Yunnan – is converted into DC for transmission to Guangdong, where it gets transformed back into AC. The conversion takes place in valve towers suspended from the ceiling in the hall. The valve towers receive the alternating current from converter transformers outside the hall through the bushings on the left side of the picture and, after transforming it into DC, feed it into the transmission line via the wall bushings to the right.



The Chuxiong Substation – the DC yard is situated in the left part of the installation.

Most people, even in China, have never heard of Chuxiong Prefecture. Its chief city, also called Chuxiong, has a mere 130,000 inhabitants, almost a village by Chinese standards. The next city – Kunming, the provincial capital of Yunnan – is nearly 200 kilometers away. From the perspective of the highly urbanized east and south of the country, from megacities such as Beijing, Guangzhou, and Shanghai, Yunnan Province in southwest China is a remote, almost mythical place. Artists from Beijing who have had enough of city life sometimes go there to get in touch with nature. Yunnan is famous in China for its tea plantations, for its ancient cities such as Dali – exotic even for Chinese travelers –, and for its marvelous alpine landscapes. Chuxiong town is enclosed by mountain ranges in a plateau region at an altitude of roughly 2,000 meters. This is where the Chuxiong hydro-power plant is located, which feeds the

5,000-MW DC transmission system. A coal plant of this capacity would expel approximately 33 million tons of carbon dioxide (CO₂) into the atmosphere every year. The hydroplant, of course, produces none. The catch, however, is that Yunnan, like most places that are fit for water-powered plants, is far away from the megacities that need the electricity. The nearest large industrial center is the Pearl River Delta in Guangdong Province. It is the greatest production hub in China – and about 1,400 kilometers away from the hydroplant in Chuxiong. Unlike Chuxiong, the cities in the Pearl River Delta such as Shenzhen, Guangzhou, and Dongguan have an enormous appetite for energy. But the natural conditions for hydro-power are lacking in the Delta, which is why coal is the dominant source of energy there. This is a problem, because the air quality in the huge industry zone is already suffering from

the exhaust of countless factories. Thus, the green energy from Yunnan is perfect for serving the energy-hungry region in Guangdong. The problem lies in getting the electricity from Chuxiong to the Delta. It may look simple to the layman – just install a power line and pipe the energy to the end user. But there is a serious impediment: Conventional AC power lines guzzle substantial amounts of energy. At relatively short distances and moderate amounts of electricity, these “friction losses” are annoying, but still tolerable. The bigger the distance, though, the more substantial the loss. On the 1,400-kilometer route between Chuxiong and Guangzhou, the leakage would amount to roughly 15 percent of the energy. That would be like an oil tanker carrying 300,000 tons of crude losing 45,000 tons of oil on its way from the Suez Canal to Piraeus. Needless to say, such a tanker would never be allowed at sea due to

economic, not to mention environmental considerations. A conventional AC power transmission from Yunnan to Guangzhou – although not as dirty as the leaking tanker, but still equally wasteful – would be similarly unfeasible.

But now there is a solution to this challenge. Siemens has developed a new technology for the long-distance transmission of large amounts of power with minimal losses.

Surge for Power Markets

Commissioned by China Southern Power Grid, the electric power transmission and distribution company in charge of China’s five southern provinces, it will have its world premiere in China, connecting the Chuxiong hydroplant with the megacities in the Pearl River Delta. Starting in June 2010, the system transports 5,000 MW of power over a distance of 1,400 kilometers.

Photo: Siemens

Instead of working – as is conventional – with an alternating current, the facilities employ a new kind of direct current transmission technology known as ultrahigh-voltage direct current (UHV DC). Its key new features are its extremely high voltage level of 800 kV, its transmission capacity of up to 7,200 MW, and a substantial reduction in transmission losses. The connection between Chuxiong and Guangzhou is the world’s first and presently the most powerful long-distance high-voltage DC link ever built. With the UHV DC system, Siemens has entered a new level of high-voltage transmission technology. This is significant not only for the link between Yunnan and Guangdong. Because of the rapidly growing demand for energy, power markets worldwide will undergo enormous changes within the years to come: Many of the existing AC transmission systems are about to reach their capacity limits.

New transmission technologies are required for long-distance transmission of bulk power from power generation installations to energy-hungry load centers that grow at breathtaking speed. This is exactly what Siemens UHV DC does.

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 can supply complete UHV DC systems from a single source. “The success of the Yunnan–Guangdong transmission system shows that our efforts to get 800-kV UHV DC technology ready for concrete projects have paid off,” says Udo Niehage, CEO of the Power Transmission Division of Siemens Energy. Previously, the market for DC transmissions had leveled off at a voltage of 500 kV. Significantly higher levels were considered unfeasible since the 1980s – the last time the matter had

been researched in earnest. The voltage level, however, is central for the efficiency of transmission. The higher it is, the less power is lost along the way. A rise from 500 to 800 kV – an increase of 60 percent – translates directly into a 60 percent efficiency gain compared to 500-kV DC. A conventional AC transmission at 500 kV would even lose almost one-sixth of the energy along the way from Chuxiong to Guangzhou. The new 800-kV technology by Siemens reduces the losses to a mere 3.5 percent. That development not only saves a lot of money, it is also a major contribution to reducing CO₂ emissions. It is only with the Siemens UHV DC technology that a connection between the remote hydroplant in Yunnan and the Pearl River Delta becomes feasible. Without this link, construc-

tion of additional coal plants with emissions of well above 30 million tons of CO₂ in the Delta would have been unavoidable.

A Quantum Leap

The new, efficient approach to power transmission, however, confronted Siemens engineers with significant technological challenges. “Compared to AC technology, DC is a different world,” says Simon Balbierer, Project Manager at Siemens for the Yunnan–Guangdong transmission.

“The step from 500 to 800 kV is a quantum leap,” adds his colleague Professor Dietmar Retzmann, Technical Director at UHV DC global marketing. “With regard to power transmission, this represents a whole new order of magnitude.”

Among the critical core components in high-voltage DC transmission are so-called converter transformers. One of the main research and development efforts was meeting the exceptionally high standards required for the insulation systems of these high-tech transformers, which operate at an extra-high voltage of 800 kV. With UHV DC, transformers show very impressive dimensions. For example, because of the necessary insulating clearances in air, the two valve bushings through which the current flows from inside the transformer into the converters are 14 meters long. Another important consideration was the factory’s testing facility, which had to be adapted to handle the huge increase in the voltage necessary to test this new kind of transformer.

“Siemens is the technology leader in this industry. With UHV DC, we have entered a new dimension.”

Udo Niehage, CEO, Siemens Power Transmission Division

In 2005, during the early phase of the project, Siemens started to discuss the possibilities and requirements of future UHV DC transmissions together with representatives of Chinese power grid operators.

Why UHV DC Will Premiere in China

“The Chinese interest in this technology really drove the development,” says Marcus Häusler, Technical Director of the 800-kV project. “The facilities and components for a project like this are so expensive that you will only want to build prototypes once you can assume that there will be a commission.” Step two in the development consisted of theoretical studies and simulations. Finally, prototypes of the critical components were built. They passed the relevant tests in 2007. In the same year, the order was formally placed.

“That was when development began in its full extent – while the deadline was 2009–2010,” says Häusler. The transmission project ran its first test at half capacity in December 2009. As scheduled, it was fully operational in June 2010. “The time frame was extremely tight,” adds Häusler, “and I must say, getting it done was a tour de force that we can be proud of.” There is a reason why the Chinese authorities are particularly interested in the Siemens technology. “It is really under conditions such as in China that UHV DC can play out its full potential,” says Häusler. “That pertains both to the distances covered and to the amounts of energy transferred.” China’s territory is more than twice as large as that of the European Union, and so the distances to be covered are

naturally much greater than in Europe. Future UHV DC connections in China are already in the pipeline: Over 20 projects are expected from China alone between 2010 and 2020, some of which are projected to cover routes of 2,000 to 3,000 kilometers – equivalent to the distances from Lisbon to Vienna and from Lisbon to Kiev, respectively. Austria does not import energy from Portugal, however, nor is Lisbon connected to Ukrainian power grids. One reason for this is that European power grids are less centralized and have more interconnections than the Chinese grids. That also means that individual transmission lines typically carry lower energy loads than the main connections in China.

It is the high efficiency in the transmission of large amounts of electricity over long distances, however, that constitutes the main strength of UHV DC connections. They are thus ideally suited for China and countries with similar conditions such as India and, potentially, the Americas and Russia.

The Next Step

Apart from their high efficiency, however, UHV DC transmission links have numerous additional advantages. One of them is the strikingly small footprint of overhead lines. Moreover, compared to AC lines, the electric current can be much better controlled in DC transmissions. Thus, they are employed as a kind of firewall to stabilize AC networks – a feature that caters especially to high demands for power supply security in Europe and the USA. UHV DC technology can also play an important role in future transmission projects in Europe such as Desertec,

which is to bring solar power from North Africa to the European Union. China, however, is the first country to build a UHV DC transmission line – and the first to switch increasingly to the new technology. Apart from the Yunnan–Guangdong connection, more than 20 UHV DC transmission projects are planned. Moreover, the next step – further increasing the voltage level from 800 to 1,000 kV – is already in the making.

“We have taken over the role of technology leader in this industry,” says Udo Niehage. “With UHV DC, we have entered a new dimension.”

Justus Krüger is a freelance journalist based in Hong Kong. He has written for the Financial Times Deutschland, Geo, the South China Morning Post, the Berliner Zeitung, and Mck Wissen.

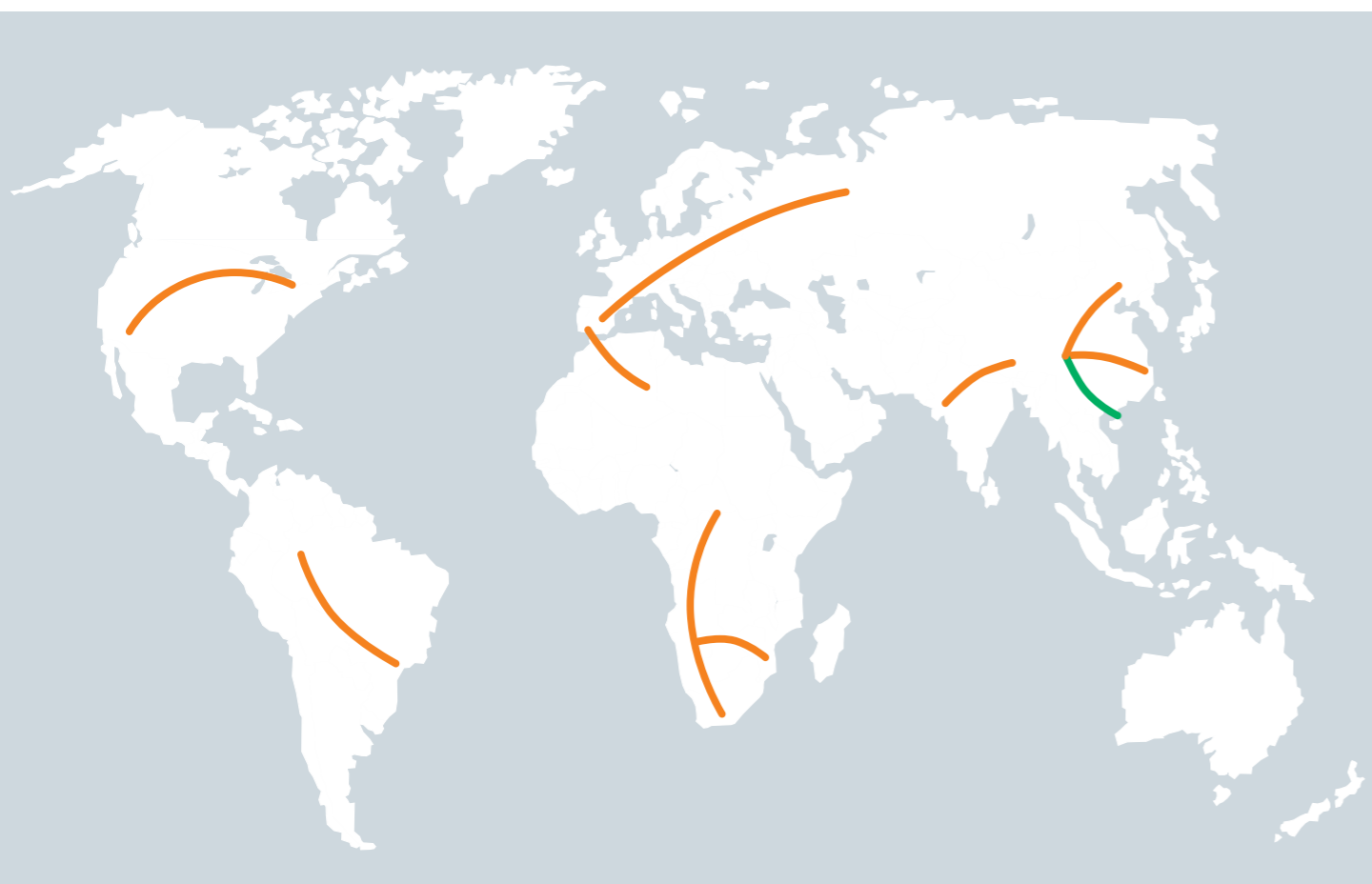
Further Information

www.siemens.com/energy/hvdc

Glossary

■ **UHV DC:** Ultrahigh-voltage direct current is marked by very low transmission losses and high energy efficiency, allowing remote power plants and load centers to be linked and great amounts of electricity to be carried across long distances in the most efficient, economical, reliable, and environmentally compatible manner possible today.

For further glossary terms, see: www.siemens.com/energy/living-energy



Global prospects of UHV DC long-distance bulk power transmission: There are many options for handling the growing demand for power appropriately. Above: A selection of potential UHV DC projects.

Graphic: Siemens