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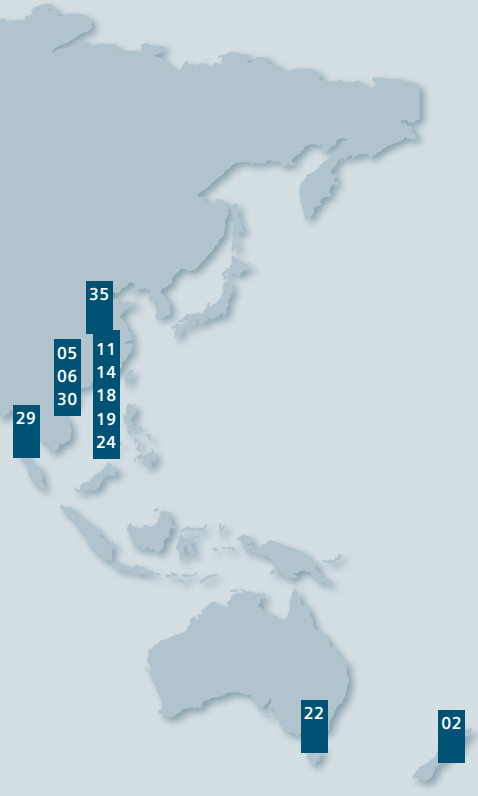
HVDC – High Voltage Direct Current Transmission

Unrivaled practical experience

Answers for energy.

HVDC – High Voltage Direct Current Transmission often is the best Strategy



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Direct current – direct success!

AC technology has proved very effective in the field of generation, transmission and distribution of electrical energy.

Nevertheless, there are tasks which cannot be performed economically or with technical perfection by this method.

For instance:

- Economical power transmission over very long distances, power transmission via cables
- Power transmission between networks operating asynchronously or at different frequencies
- Input of additional power without increasing the short circuit ratio of the network concerned.

For all these tasks High Voltage Direct Current Transmission is not only a realistic technical and economical alternative to AC technology, but also the only possible transmission method.

The plants listed in the following pages show the power ratings and technical standards of our HVDC equipment installed throughout the world.

Western HVDC Link, United Kingdom

In February 2012 the NGET/SPT Upgrades Limited, a joint venture between National Grid and Scottish Power awarded the contract to Siemens in a consortium with the Milan-based leading cable company Prysmian to build a submarine DC interconnector in the Irish Sea.

The grid connection between Scotland and England, designed as a low-loss HVDC transmission system, will have a rating of 2,200 MW up to 2,400 MW. World's first submarine interconnector with 600 kV DC voltage level. The Western HVDC Link project will provide much needed additional power transmission capacity on Britain's transmission system as the UK heads toward a low carbon economy. The power link will help to balance supply and demand within the grid sections in light of the continued growth of remote and fluctuating renewables. The link is scheduled to be operational by late 2015.

Technical Data

Customer	NGET/SPT Upgrades Ltd.
Project name	Western HVDC Link
Location	Hunterston – Deeside, UK
Power rating	2,200 MW, bipolar
Type of plant	Submarine cable transmission, 420 km
Voltage levels	± 600 kV DC, 400 kV AC, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Inter Island Connector Pole 3, New Zealand

On 30th October 2009 Transpower New Zealand Limited awarded Siemens Energy the contract for the New Zealand Inter Island HVDC Pole 3 Project.

To ensure a reliable power supply with minimal losses and to further stabilize New Zealand´s grid, Wellington-based Transpower New Zealand Ltd, the national grid owner and operator, has decided to replace the existing 46 year old Pole 1, upgrade the control & protection system of the existing Pole 2 to state-of-the-art technology and add a Static Var System (SVC Plus). This major upgrade will expand the power transmission capacity of the link and ensure reliable energy transmission between the country's North and South Islands. The power transfer of the link will be increased from today's capacity of 900 MW to up to 1,200 MW.

Siemens supplies the pole 3 in two converter stations (rated at 700 MW continuous and an overload capacity of 1,000 MW for 30 minutes) in the first section of the project. Following that the aging control & protection system of Pole 2 will be replaced with advanced technology.
In the final section of the project Siemens will supply a ±60 MVar SVC PLUS system as part of the Pole 3 project.
All these works on the New Zealand Inter Island HVDC Pole 3 project will be completed in 2014.

After commissioning the Basslink Project in 2006, a high-voltage direct-current link between the Australian mainland and Tasmania, the Inter Island Connector Pole 3 is the second major power transmission project Siemens is executing in this region.

Technical Data

Customer	Transpower New Zealand Limited
Project name	Inter Island Connector Pole 3
Location	Haywards (North Island) to Benmore (South Island)
Power rating	700 MW, bipolar
Type of plant	Long-distance transmission, 649 km including 40 km submarine cable across Cook Strait
Voltage levels	± 350 kV DC, 220 kV AC, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

EstLink 2, Finland – Estonia

In December 2010 Fingrid and Elering, awarded the contract for the EstLink 2 Converter Stations, using HVDC Transmission System.The system, with a transmission capacity of 650 megawatts at a DC voltage of ± 450 kilovolts, will increase the capacity for transmission between the Baltic and Nordic countries from 350 MW to 1,000 MW. It will also make the power supply more reliable. The output between the two stations will travel over a 14-kilometer overhead line, a 145-kilometer submarine cable across the Gulf of Finland, and a 12-kilometer land cable.

The customers are the Fingrid power utility in Helsinki and the Estonian power network operator Elering, in Tallinn. The EstLink 2 HVDC connection will not only triple the power transmission capacity between Finland and Estonia, but also make a significant contribution toward the planned integration of energy markets between the Baltic and Scandinavian countries.

For EstLink 2, Siemens is responsible for designing the entire classic HVDC system as a monopolar connection, using a IRC cable as the metal return conductor. The contract includes a turnkey delivery, installation and commissioning of both complete HVDC converter stations in Anttila (Finland) and Püssi (Estonia). The converter stations are planned to go into operation early in 2014.

Technical Data

Customer	Fingrid, FIN/Elering, EST
Project name	EstLink 2
Location	Anttila, Finland to Püssi, Estonia
Power rating	670 MW, monopolar
Type of plant	Submarine cable transmission, 171 km
Voltage levels	450 kV DC, 400 kV/330 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

INELFE, France – Spain

In December 2010 Rte and REE, awarded the contract for the INELFE Converter Stations, using HVDC PLUS Voltage Source Converters (VSC) to Siemens. INELFE is the worlds first VSC HVDC with 2 x 1,000 MW.

The INELFE/Siemens transmission links 1 and 2 between Baixas, west of Perpignan in France, and Santa Llogaia, south-west of Figueras in Spain, is an important component of the trans-European electricity network. The installation can transmit rated power of 1,000 MW per link with minimal transmission losses. The converter stations use HVDC PLUS voltage-sourced converters in a modular multilevel converter arrangement (VSC-MMC) with a transmission voltage of ± 320 kV DC. The power will be transmitted over a distance of about 65 kilometers with underground cables in trenches and in a tunnel through the Pyrenees for about eight kilometers. The project illustrates the unique capability of VSC technology to meet special technical demands. The independent exchange of reactive power for each network, as well as the black-start capability, which enables the HVDC system to restart a collapsed network, are particularly worth mentioning.

The converter stations are scheduled to be ready for tests by the end of 2013. The commercial operation is scheduled for 2014.

Technical Data

Customer	INELFE (Rte and REE)
Project name	INELFE
Location	Baixas, France to Santa Llogaia, Spain
Power rating	2 x 1,000 MW
Type of plant	HVDC PLUS 65 km underground cable
Voltage levels	± 320 kV DC, 400 kV, 50 Hz
Type of semiconductor	IGBT

Xiluodu – Guangdong, China

In January 2011, China Southern Power Grid awarded Siemens the contract for key components of the 500 kV HVDC Xiluodu-Guangdong transmission system in double bipolar scheme southern China. Xiluodu-Guangdong will have an overall capacity of 6,400 MW at a DC voltage of ± 500 kV and provide electricity to the megacities in the Guangdong region.

The project is a double 500-kV bipole system with a transmission capacity of twice 3,200 MW. For this project Siemens together with Chinese partners will supply the converter valves for the sending station in Zhaotong, which is located in the vicinity of the Xiluodu hydro power plant in the Yunnan/Sichuan region, and for the receiving station in Conghua of Guangdong province. The transmission distance of this project is 1,286 kilometers. Siemens will also supply key equipment for the system's DC section. Commissioning of the system is scheduled for 2013.

Technical Data

Customer	China Southern Power Grid
Project name	Xiluodu-Guangdong
Location	Zhaotong-Conghua
Power rating	6,400 MW, bipolar
Type of plant	Long-distance transmission, 1286 km
Voltage levels	± 500 kV DC, 525 kV AC, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Nuozhadu – Guangdong, China

In January 2011, China Southern Power Grid awarded Siemens the contract for key components of the 800 kV HVDC Nuozhadu-Guangdong transmission system in southern China. Nuozhadu-Guangdong will have a transmission capacity of 5000 MW at a DC voltage of ± 800 kV and provide electricity to the megacities in the Guangdong region.

For the Nuozhadu-Guangdong 800 kV HVDC bipole system Siemens together with its Chinese partners will supply the converter valves with direct light-triggered power thyristors both for the sending station in Pu'er in the province of Yunnan and for the receiving station in Jiangmen, Guangdong Province. The transmission distance of this project is 1451 kilometers. The order also includes key components for the HVDC system instrumentation and controls, the 800 kV components for the stations' DC switchgear, supply of key materials for converter valves and the supply of eight 800 kV converter transformers, which are specially designed and proved to fit through the train profile of the west Chinese mountains, produced at the company's manufacturing plant in Nuremberg. Commissioning of the system is scheduled for 2013.

Technical Data

Customer	China Southern Power Grid
Project name	Nuozhadu-Guangdong
Location	Pu'er to Jiangmen
Power rating	5000 MW, bipolar
Type of plant	Long-distance transmission, 1451 km
Voltage levels	± 800 kV DC, 525 kV AC, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Hudson Transmission Project, USA

In May 2011 Hudson Transmission Partners, LLC awarded the contract to Siemens to connect the power supply networks of New Jersey and New York for a 660 MW back-to-back HVDC system in New Jersey, USA.

In the future it is estimated that an additional 660 megawatts (MW) of controlled electric power will be transmitted via a high-voltage ac cable link across the Hudson River from New Jersey to boost the power supply of the megacity New York. Siemens' scope on a turn-key basis includes the contents engineering, civil works, delivery of all components, and installation and commissioning of the complete back-to-back HVDC System.

The converter station with the HVDC back-to-back link will be built in Ridgefield, New Jersey, where it will be connected at Bergen substation with New Jersey's 230-kV power supply network. A 345-kV high voltage ac cable spanning a total distance of eleven kilometers, part of which will be laid under water in the Hudson River, will provide the connection to the point where the power is fed into New York's system. The infeed point is located on W49th Street in Manhattan.

The HVDC technology with its fast control function will also contribute toward stabilization of the connected systems, which is a key benefit in the event of grid disturbances or blackouts. Furthermore, this high capacity power link will play a significant role in relieving bottlenecks in the power supply for New York. Commercial operation is planned in July 2013.

Technical Data

Customer	Hudson Transmission Partners, LLC
Project name	Hudson Transmission Project
Location	Ridgefield (New Jersey), USA
Power rating	660 MW, monopolar
Type of plant	Back-to-back tie
Voltage levels	180 kV DC 345/230 kV, 60 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Black Sea Transmission Network Project, Georgia

In August 2010 Energotrans Ltd. awarded the contract to Siemens for two 350 MW back-to-back HVDC systems in Georgia. The HVDC converter station will connect the Georgian power supply network with the grid system in Turkey with two back-to-back links. Each link transmits 350 MW eco-friendly electric power, which is adjuvant for Turkey's growing power demand. The HVDC technology offers the opportunity to control the transmission of electric power to Turkey, too. Because of its rapidity the connected grids can be stabilized, which is a major advantage in times of system disturbances and blackouts. At the substation in Akhaltshire, southern Georgia on the Turkish border, the systems will be connected via overhead transmission lines with Georgia's and Turkey's high-voltage networks to enable hitch-free transport of electric power between the two countries. HVDC back-to-back links are necessary when two power supply networks with varying technical parameters (frequency, phasing) are to be interconnected.

As there is the challenge to interconnect two varying technical parameters, HVDC back-to-back links are necessary. The three-phase alternating current of the one network is converted in the converter substation into direct current and transmitted directly via a DC link to the inverter station. There, the direct current is converted back into three-phase current with simultaneous adjustment to the parameters of the network into which it is to be fed. This enables hitch-free interconnection of the two networks. Furthermore, the HVDC back-to-back link provides protection against cascading grid disturbances because it acts like an automatic firewall, which can control stop and restart the transport of electric power. Therefore Siemens will prospectively be represented in the former CIS states with the first HVDC Interconnection. The first HVDC back-to-back link is on line since May 2012, with the overall project scheduled for completion in May 2013.

Technical Data

Customer	Energotrans Ltd.
Project name	Black Sea Transmission Network Project
Location	Akhaltsikhe, Georgia
Power rating	2 x 350 MW, monopolar
Type of plant	Back-to-back tie
Voltage levels	96 kV DC 500/400 kV, 50/50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Back-to-Back, Bangladesh

In March 2011 the Power Grid Company of Bangladesh Ltd. awarded the contract to Siemens to connect the power supply networks of Bangladesh and India with a 500 MW back-to-back HVDC system in Bheramara, Bangladesh. The system can be extended by an additional 500 MW pole in the future.

Siemens' scope on a turnkey basis includes engineering, civil works, delivery of all components, installation and commissioning of the complete back-to-back HVDC System. The converter station will be built in Bheramara, Bangladesh where it will be connected via a new overhead line to Ishurdi, 230 kV substation in the grid of Bangladesh. A new 400 kV high voltage overhead line will provide the connection to the 400 kV substation Baharampur in the grid of India.

This is the first HVDC project in Bangladesh. It is being set up under India-Bangladesh Power exchange program and is being funded by ADB. Commercial operation of the system is planned for 2013.

Technical Data

Customer	Power Grid Company of Bangladesh Ltd.
Project name	Back-to-Back Bangladesh
Location	Bheramara
Power rating	500 MW, monopolar
Type of plant	Back-to-back tie
Voltage levels	158 kV DC, 230 kV/400 kV, 50/50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Mundra–Haryana, India

In April 2009 Adani Power Ltd. awarded the contract to Siemens for a 2500 MW HVDC converter system.

This is the first HVDC contract being awarded by a private sector company in India. The power transmission system will transport electrical energy with low loss from Mundra in Gujarat, Western India to Mohindergarh in Haryana, Northern India, through a DC line length of 960 km. This link supports the Adani Group's Green Initiative to transmit power with minimized loss of energy thanks to most modern technology.

The bipolar DC system is rated for a continuous power of 2500 MW (±500 kV, 2500 A) at the DC terminals of the rectifier/converter station. The HVDC scheme can be operated in bipolar and monopolar mode with ground return or metallic return. Both Poles are ready for operation since December 2011. Commercial operation started in July 2012. The new long-distance HVDC transmission link will be the third system that Siemens has built in India in succession.

Adani Power is the first private sector player setting up the HVDC line under the United Nations Framework Convention on Climate Change UNFCCC, Clean Development Mechanism.

Technical Data

Customer	Adani Power Ltd.
Project name	Mundra–Haryana
Location	Gujarat province to Haryana province
Power rating	2,500 MW, bipolar
Type of plant	Long-distance transmission, 960 km
Voltage levels	±500 kV DC, 400 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Jinping–Sunan, China

In February 2011, Siemens received the order for supply of the key components for the sending station Jinping of the Jinping-Sunan HVDC transmission system.

This HVDC System transmits eco-friendly hydropower 2,059 km from Jinping in the province of Sichuan to Sunan in the eastern province of Junan. As the key component of the system, the thyristor valve technology provided by Siemens converts 7.2 GW of power, the equivalent of seven large conventional power plants, for efficient delivery to the energy hungry coastal region near Shanghai.

The Siemens thyristor valve technology is responsible for conversion of alternating current into direct current to a transmission voltage of 800 kilovolt (kV). Transmission of power using direct current and high voltage dramatically reduces transmission line losses over long distances. The HVDC link can be operated in overload mode continuously at 7.6 GW and even at 7.92 GW for two hours under emergency conditions.

Following the world's first two 800 kV projects, Yunnan-Guangdong at 5 GW and Xiangjaba-Shanghai at 6.4 GW in China, this new power highway continues the drive forward in the trend to higher power levels with the low-loss HVDC technology.

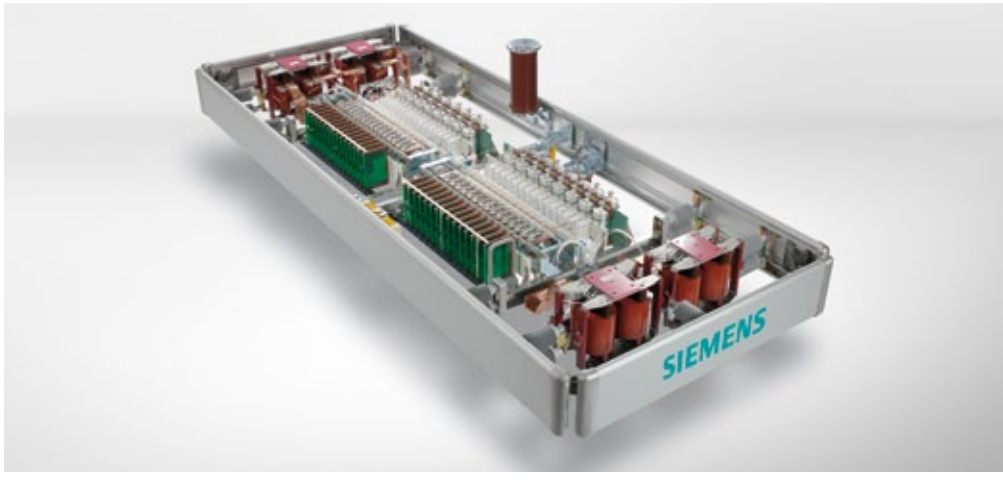
Siemens thyristor valves have the demonstrated capability to handle a record power level of 8 GW over one bipolar 800 kV HVDC link.
This is currently a new world record!

Commercial operation of the system is scheduled for 2012.

Technical Data

Customer	State Grid Corporation of China
Project name	Jinping
Location	Yulong–Tongli
Power rating	7200 MW, bipolar
Type of plant	Long-distance transmission, 2059 km
Voltage levels	± 800 kV DC, 525 kV AC, 50 Hz
Type of thyristor	Electrically-triggered, 8 kV (6 inches)

6-inch thyristor



COMETA, Spain

Red Eléctrica de España signed the contract with Siemens in October 2007 for design, delivery, and construction of 2 x 200 MW HVDC bipole converter stations. Commercial operation started in March 2012. The COMETA HVDC project, under the responsibility of Red Eléctrica de España, connects the Spanish peninsula with the Ballearic island of Mallorca in order to meet the increasing demand of electric power on the island.

The transmission system is designed as a bipolar interconnector with metallic return conductor. One converter station is located near the city of Valencia on the Spanish peninsula, where an existing power plant will be connected to the HVDC via a HIS Switchgear and HVAC cables (also supplied by Siemens). The other converter station on Mallorca is located at Santa Ponsa near the capital city, Palma de Mallorca.

The COMETA submarine link crosses the Mediterranean Sea in a maximum depth of 1,500 meters, has a length of approximately 250 km and consists of three sea cables, one HV cable per pole and one cable as metallic return conductor.

Technical Data

Customer	Red Eléctrica de España
Project name	COMETA
Location	Spain–Mallorca
Power rating	2 x 200 MW, bipolar
Type of plant	Submarine cable transmission, 250 km
Voltage levels	±250 kV DC, 400 kV/230 kV AC, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

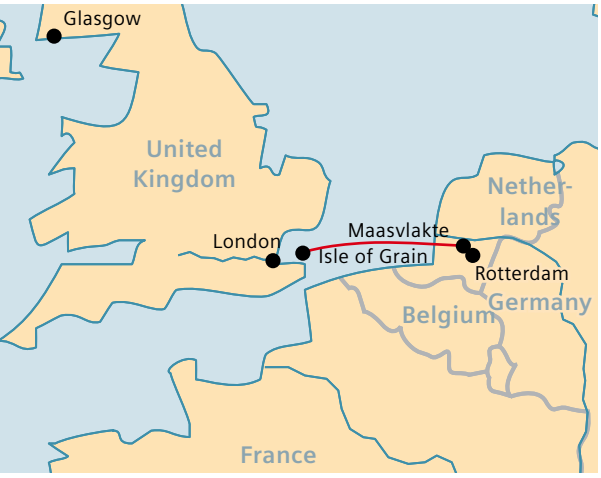
BritNed, Great Britain, Netherlands

In May 2007 BritNed Development Limited (owned by the TSOs National Grid International and TenneT) awarded the contract for the BritNed HVDC converter stations to a consortium of Siemens and BAM Civiel BV. The BritNed HVDC transmission system connects the grid in the UK with the Dutch part of the UCTE grid. It is a 1,000 MW HVDC interconnection across the southern part of the North Sea, linking the 400 kV substations on the Isle of Grain, on the southern bank of the Thames Estuary, and Maasvlakte near Rotterdam.

The HVDC system is designed as a bipole with fast bypass switches without metallic or ground return. The converter uses quadruple thyristor valves in a double tower configuration, single-phase three-winding converter transformers, air core smoothing reactors, indoor DC switchgear, and double branch AC filters with triple-tuned branches. Commercial operation of the interconnection started in 2011.

Technical Data

Customer	BritNed Development Limited
Project name	BritNed
Location	Isle of Grain on the southern bank of the Thames Estuary in the UK, and Maasvlakte west of Rotterdam in The Netherlands
Power rating	1,000 MW, bipolar
Type of plant	Submarine cable transmission, 260 km
Voltage levels	± 450 kV DC, 400 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV



Xiangjiaba–Shanghai, 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 hydro power generation and low-loss HVDC transmission, the new system will save up to 44 million metric tons of CO_2 p.a. **versus local power supply 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.

Technical Data

Customer	State Grid Corporation of China and XD Xi'an Power Rectifier Works (XPR)
Project name	Xiangjiaba
Location	Xiangjiaba–Shanghai
Power rating	6,400 MW, bipolar
Type of plant	Long-distance transmission, 2070 km
Voltage levels	±800 kV DC, 525 kV AC, 50 Hz
Type of thyristor	Electrically-triggered, 8 kV (6 inches)

Trans Bay Cable Project, USA

Trans Bay Cable, LLC, awarded Siemens a contract to construct a submarine High Voltage Direct Current (HVDC) transmission link between San Francisco's city center and a Pacific Gas & Electric substation near Pittsburg, California.

The Trans Bay Cable Project transmits 400 MW active power and ± 170 Mvar reactive power (statcom function) and is the first order for the innovative HVDC PLUS technology by Siemens. This project is a milestone of the HVDC PLUS technology in terms of providing densely populated areas with new transmission capacity.

Siemens HVDC PLUS System is based on a multilevel Voltage Sourced Converter Technology. Its innovative design offers technical and economical advantages. HVDC PLUS enhances the performance of the transmission grid, improves reliability, and reduces maintenance costs. HVDC PLUS is the preferred solution in space-constrained environments, as you will find them in San Francisco.

The heart of the HVDC PLUS converter stations is the multilevel converter where the conversion from AC to DC transmission, and vice versa, takes place. In comparison with line-commutated converters based on thyristor technology, the HVDC PLUS system operates with powered semiconductors with turn-on and turn-off capability (IGBT). After commissioning in 2010, the Trans Bay Cable Project is anticipated to meet the California Independent System Operator's (ISO) planning and reliability standards.

Technical Data

Customer	Trans Bay Cable, LLC
Project name	Trans Bay Cable Project
Location	Pittsburg, California, and San Francisco, California
Power rating	400 MW
Type of plant	HVDC PLUS 85 km submarine cable
Voltage levels	± 200 kV DC, 230 kV/138 kV, 60 Hz
Type of semiconductor	IGBT

© Hawkeye Photography

Storebælt, Denmark

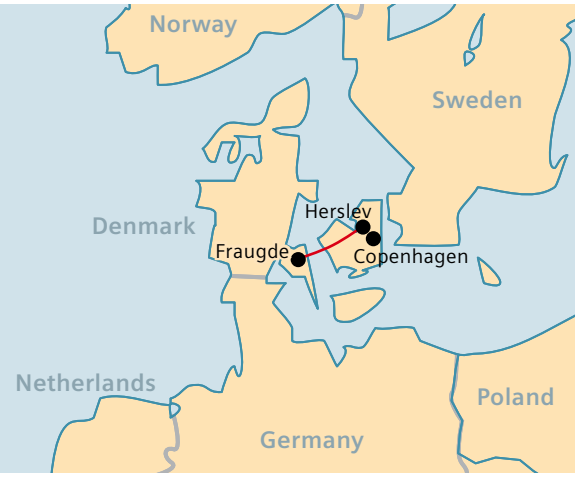
In May 2007 the Danish TSO, Energinet.dk, awarded the contract for the Storebælt HVDC converters to Siemens.

The Storebælt HVDC transmission system connects the grid in Jutland/Funen (a part of the UCTE system) with the Zealand Grid, which is a part of the NORDEL system.

It is a 600 MW HVDC interconnection across the Storebælt Strait, linking the 400 kV substations Fraugde near Odense on the island of Funen and Herslev near Kalundborg on the island of Zealand. The HVDC system is designed as a monopole with metallic return. Approximately half of the 56 km DC cable route is a land cable. The converter uses quadruple thyristor valves in a single tower configuration, single-phase three-winding converter transformers, air core smoothing reactors and triple-tuned AC filters. Commercial operation of the interconnection started in 2010.

Technical Data

Customer	Energinet.dk
Project name	Storebælt
Location	The islands Funen (Fyn) and Zealand (Sjælland) in Denmark
Power rating	600 MW, monopolar
Type of plant	Submarine cable transmission, 56 km
Voltage levels	400 kV DC, 400 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV



Ballia–Bhiwadi, India

In March 2007 Powergrid of India awarded the contract for the largest HVDC system in India to a consortium formed by Siemens and Bharat Heavy Electricals Ltd. (BHEL). The project will transmit power from the Ballia Power Pool in Uttar Pradesh to the Bhiwadi Substation in Rajasthan, only 80 km from Delhi.

The HVDC system will improve the power supply of the fast-growing Delhi metropolitan region without the need for installation additional power plants in this highly urbanized area. The contract includes the engineering, supply, installation, and commissioning, as well as all civil works on a turnkey basis.

Siemens is responsible for design, supply of foreign equipment (including 8 converter transformers), civil works, installation and commissioning. BHEL will supply 8 converter transformers as well as all material from India.

The commercial operation of the project started in 2010 in order to meet the increasing power demand.

Technical Data

Customer	Powergrid Corporation of India Ltd.
Project name	Ballia–Bhiwadi
Location	Uttar Pradesh province to Rajasthan province
Power rating	2,500 MW, bipolar
Type of plant	Long-distance transmission, 800 km
Voltage levels	± 500 kV DC, 400 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Yunnan–Guangdong, China

The long-distance transmission system of the Yunnan–Guangdong DC Transmission Project transmits 5,000 MW from the Chuxiong substation in Yunnan to the load center of the Pearl River delta in Guangdong. The contract was awarded in June 2007. Commercial operation of the first 800 kV pole started in December 2009, the complete bipole is in operation since June 2010. The system, with a transmission voltage of ±800 kV DC, sets a new dimension in the development of HVDC systems.

The bipolar system uses two series valve groups per pole: one 12 pulse valve group is rated 400 kV; the other is rated 800 kV. Apart from the converter valves, the other major components with insulation levels of 800 kV are the single-phase two-winding converter transformers and air-insulated smoothing reactors. The modular converter groups are equipped with direct light-triggered thyristors with water cooling. The 800 kV equipment in the DC Yard, e.g. bushings, support insulators, switches, and arrester are of composite type with silicone rubber external insulation to offer improved operation under severe environmental conditions. DC harmonic filtering is achieved through triple-tuned filters, whereas for AC harmonic filtering double-tuned filters together with a special low-order filter are used.

Technical Data

Customer	China Southern Power Grid
Project name	Yunnan–Guangdong
Location	Chuxiong City/Yunnan–Zengcheng City/Guangdong
Power rating	5,000 MW, bipolar with series valve groups
Type of plant	Long-distance bipole, 1418 km
Voltage levels	±800 kV DC, 525 kV, 50 Hz
Type of thyristor	Direct-light-triggered (LTT), 8 kV

Guizhou–Guangdong II, China

The DC Transmission Project (the long-distance transmission system of the Guizhou-Guangdong II line ±500 kV) transmits 3,000 MW power from the Xingren substation in the Guizhou Province of Southwest China to the load center of Shenzhen in the Guangdong Province. The system has a long-term overload capability of up to 115 %. Power transmission in the reverse direction is also possible. The project is carried out in cooperation with Chinese partners supported by Siemens. The bipolar system is designed for a ceiling suspended 12-pulse converter bridge arrangement with single-phase two-winding converter transformers and oil-insulated smoothing reactors. The 500 kV DC converter groups of modular design are equipped with direct light-triggered thyristors with water cooling. Most of the DC equipment is provided with composite housings improving the performance of operation under severe environmental conditions.

For harmonic filtering triple tuned AC and DC filters are used. The design considers the installation at 1450 m above sea level (Xingren converter station). The interconnection of the neutrals of both stations is implemented by means of ground electrodes. The contract was awarded in May 2005.

After successful completion of the test phase, Siemens Energy commissioned the "Guizhou-Guangdong II" high voltage DC transmission link (HVDC) on schedule at the beginning of January 2008.

Technical Data

Customer	China Southern Power Grid
Project name	Guizhou–Guangdong II Line ±500 kV DC Transmission Project
Location	Xingren/Guizhou–Shenzhen/Guangdong
Power rating	3,000 MW, bipolar
Type of plant	Long-distance bipole, 1,225 km
Voltage levels	±500 kV DC, 525 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

East-South Interconnector II Upgrade, India

In April 2006 Power Grid Corporation of India Ltd. awarded the contract to Siemens to upgrade the power transmission capacity from 2,000 MW to 2,500 MW on the existing Talcher Kolar HVDC Long Distance Transmission system. Since 2003, the 2,000 MW High Voltage Direct Current (HVDC) System "East-South Interconnector II" links the power generation centre of Talcher in the eastern part of India with the rapidly developing industrial and high-tech area of Bangalore in the south over a line length of nearly 1,400 km. The conventional method to increase the power of a transmission system is to increase the transmission voltage or to increase the current flow through the DC-line. Both measures require extensive and cost-intensive modifications of the system.

Siemens experts have developed an innovative solution not usually used for HVDC systems. With the aid of software systems known as Relative Aging Indication (RAI) and Load Factor Limitation (LFL), a first-time-introduced forced air cooling system for the DC smoothing reactors and other additional measures, it is possible to utilize the overload capacity of the system more effectively without installing additional thyristors connected in series or in parallel to increase the DC transmission voltage or the DC current respectively.

Technical Data

Customer	Powergrid Corporation of India Ltd.
Project name	Upgrade of Talcher Kolar HVDC Project from 2,000 MW to 2,500 MW
Location	Orissa province to Karnataka province
Power rating	2,500 MW, bipolar
Type of plant	Long-distance transmission, 1,450 km
Voltage levels	± 500 kV DC, 400 kV, 50 Hz
Type of thyristor	Electrically-triggered-thyristor, 8 kV (100 mm)

Neptune RTS, USA

The Neptune HVDC project connects the TSO Long Island Power Authority to the competitive PJM market and provides power to a fast-growing load center on Long Island.

The system is a monopolar cable transmission link with a DC voltage of 500 kV and a continuous power transmission rating of 660 MW. The cable stretches from First Energy Inc.'s substation in Sayreville, N.J., to Uniondale, N.Y.-based LIPA's Newbridge Road substation in Levittown. Siemens, as the leader of the consortium for this turnkey project, was responsible for the installation of two converter stations. Furthermore, Siemens is to operate the link for a five-year period. The consortium partner Prysmian (formerly Pirelli) delivered and installed the cable package including a 82 km DC submarine cable section from New Jersey to the landfall at Jones Beach followed by a 23 km DC land cable section to the Converter Station as well as the AC cable connections from the two converter stations to the grid. The project was developed by Neptune RTS over a period of several years. The EPC contract was awarded on July 15th, 2005. Execution time of the project was 24 months.

Technical Data

Customer	Neptune RTS
Project name	Neptune RTS
Location	USA/New Jersey–New York
Power rating	660 MW continuous, up to 750 overload for 4 hours
Type of plant	Submarine cable transmission, 105 km
Voltage levels	500 kV, 230/345 kV, 60 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Basslink, Australia

The Basslink cable link, which went into operation in 2006, represents the first interconnection between the states of Tasmania and Victoria. Both states benefit from this link, which operates in both directions. Tasmania relies entirely on hydroelectric plants to generate electricity; Basslink allows the import of base load from Victorian coal-fired power plants, thus improving supply reliability in periods of drought. On the other side, Victoria is able to improve its peak load supply with green energy from Tasmania.

Tasmania's first-ever access to the National Energy Market (NEM) has also increased competition within Australia. The transmission system is designed as a monopolar interconnector with metallic return. As consortium leader, Siemens augmented two existing AC substations and provided 5 km of AC overhead line, the HVDC converter stations, and 66 km of DC overhead line. Basslink now represents one of the longest submarine power links in the world, with a submarine cable length of approximately 295 km that crosses the Bass Strait. The EPC contract was awarded in the year 2000, and authorities approved the project in the second half of 2002 after extensive environmental impact studies.

Technical Data

Customer	National Grid Australia
Project name	Basslink Interconnector
Location	Loy Yang/Victoria to George Town/Tasmania
Power rating	500 MW continuous, up to 626 MW overload for 8 hours/day
Type of plant	Submarine cable transmission, 295 km
Voltage levels	400 kV DC, 500 kV 50 Hz (Victoria) 220 kV 50 Hz (Tasmania)
Type of thyristor	Direct-light-triggered, 8 kV

Lamar, USA

In February 2003 Xcel Energy awarded the contract to Siemens for the design, procurement, construction, and commissioning of the Back-to-Back DC Converter station located in Lamar, Colorado. The tie connects Xcel Energy's Southwestern Public Service Company system in the East (345 kV AC) with its Public Service Company of Colorado system in the West (230 kV AC), and has a bidirectional power transfer capability of 210 MW (nominal).

As one of its main features, the converter station provides continuously adjustable voltage control on the weak AC System.

The Eastern part and the Western part of the United States is not electrically synchronized. The dividing line is roughly down the eastern borders of Montana, Wyoming Colorado, and New Mexico. The Lamar project has been commercial operation since January 2005. The Back-to-Back DC converter station is highly cost-efficient due to a new grounding concept of the DC circuit. This concept allows the use of standard distribution transformers instead of special HVDC converter transformers. Standardized components result in shorter delivery time, and allow for high local manufacturing content.

Technical Data

Customer	Xcel Energy
Project name	Lamar
Location	Lamar/Colorado/USA
Power rating	210 MW, continuous
Type of plant	Back-to-back tie
Voltage levels	63.6 kV DC, 230 kV AC, 60 Hz (West Lamar/Colorado) 345 kV AC, 60 Hz (Easy Finney/Kansas)
Type of thyristor	Direct-light-triggered, 8 kV

Guizhou–Guangdong, China

The HVDC long-distance transmission system of Gui-Guang transmits 3,000 MW of power from the Anshun substation in Guizhou Province in southwest China to the Zhaoqing converter station in Guangdong Province near the load center of Guangzhou. It is a bipolar system, each pole comprising a 12-pulse converter bridge suspended from the ceiling. The thyristors are water-cooled and direct-light-triggered. The converter transformers are of the single-phase two-winding type. Triple-tuned filters are used for filtering harmonics on the DC- and AC-side of the converters. The smoothing reactors are of the oil-immersed type. The contract was awarded in October 2001. Commercial operation started in October 2004 (six months ahead of scheduled time).

Technical Data

Customer	China Southern Power Grid
Project name	Gui-Guang
Location	Guizhou–Guangdong
Power rating	3,000 MW, bipolar
Type of plant	Long-distance transmission, 980 km
Voltage levels	±500 kV DC, 525 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Nelson River Bipole 1, Canada

In 2002 Siemens received the contract to replace 36 mercury arc valves (MRVs) with thyristor valves. Bipole 1 of the Nelson river scheme had been in operation since 1970. Both poles were equipped with mercury arc valves designed for service life of 20 years. The old valves of Bipole 1, Pole 1 were replaced by thyristor valves 10 years ago. By using the best valves as spare parts for Pole 2, operation for 10 more years was possible. In 2001 Manitoba Hydro decided to also replace the MRVs of Pole 2 with thyristor valves to increase the reliability of the whole scheme. To minimize the outage time of this highly utilized scheme, replacement was performed in 3 lots.

For each lot 12 thyristor valves and 2 cooling units as well as new surge arresters are supplied. The overall completion time for the replacement was 27 months with a delivery time for the first lot of 13 months. Siemens delivered light-triggered thyristors, the same type as supplied for the Moyle Interconnector and the Celilo project. For future upgrading of the system the thyristor valves are rated for 500 kV with 2,000 A nominal current.

To meet the customer's demand for a short outage time the thyristor valves were designed to fit on to the existing support structure and therefore no time-consuming changes involving civil works are necessary.

Technical Data

Customer	Manitoba Hydro (Winnipeg)
Project name	Bipole 1, Pole 2 Valve Replacement
Location	Radisson Converter Station on Nelson River Dorsey Converter Station near Winnipeg, both in Manitoba, Canada
Power rating	1,000 MW
Type of plant	Long-distance transmission, 900 km
Voltage levels	±500 kV DC, 230/138 kV, 60 Hz
Type of thyristor	Direct-light-triggered, 8 kV

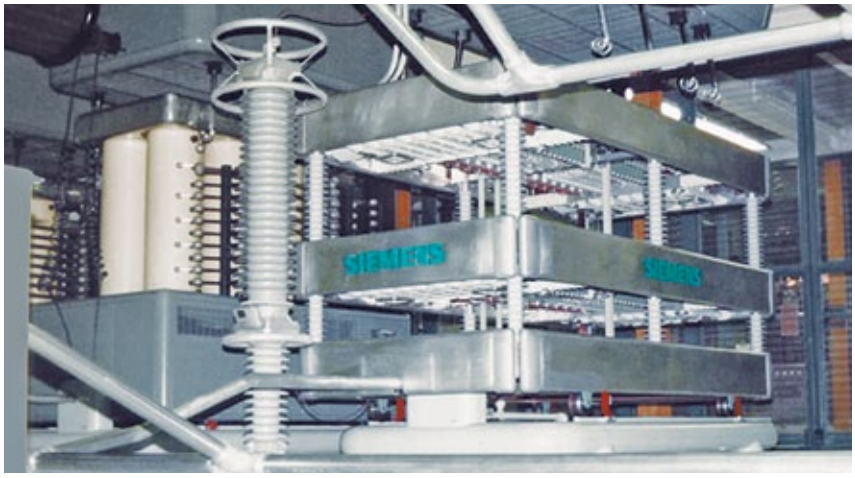
Celilo, Mercury Arc Valve Replacement, USA

In December 2000, Bonneville Power Administration (BPA) in Portland, Oregon, USA had to decide how to proceed with the Celilo Converter Station which was 30 years old meanwhile, and considering that the Pacific Intertie is a major contributor to satisfying California's electrical energy needs. The critical components were the mercury arc valves: they had been designed for a service life of 20 years; they require high maintenance efforts, are very unreliable, and the manufacturer had stopped supplying spare parts long ago. Based on the decision, BPA awarded Siemens a contract for the supply of 36 HVDC thyristor valves with direct-light-triggered thyristors for the Celilo Converter Station of the Pacific Intertie, to replace the mercury arc valves – representing a converter rating of 1,600 MW. The delivery in three phases was completed within 20 months.

In addition, all cooling towers in the 3,100 MW converter station were replaced by dry-type cooling towers. In 1997 Siemens provided BPA with a thyristor valve including the newly developed technology of direct-light-triggered thyristors for commercial demonstration during a period of two years. It was replacing a mercury arc valve. Due to the excellent performance, BPA purchased the valve already after 11 months of operation. It has been in service ever since without any fault or failure.

Technical Data

Customer	Bonneville Power Administration (BPA)
Project name	Celilo Mercury Arc Replacement Project
Location	The Dalles, Oregon, USA
Power rating	3,100 MW, bipolar
Type of plant	Long-distance transmission
Voltage levels	±400 kV DC, 230 kV, 60 Hz
Type of thyristor	Direct-light-triggered, 8 kV



East-South Interconnector II, India

In March 2000 Siemens received an order for a long-distance HVDC transmission project from the Power Grid Corporation of India Limited. From now on power is transmitted from the eastern region (Orissa province) to the southern part (Karnataka province) of the subcontinent by means of a bipolar HVDC system, thus integrating these two regional asynchronous networks into the national grid, ensuring a reliable and flexible power transfer nationwide. This is the sixth HVDC project in India, the largest so far regarding rated transmission power and transmission distance. Commercial operation started in 2003.

Technical Data

Customer	Power Grid Corporation of India Ltd.
Project name	East-South Interconnector II
Location	Orissa province to Karnataka province
Power rating	2,000 MW, bipolar
Type of plant	Long-distance transmission, 1,450 km
Voltage levels	± 500 kV DC, 400 kV, 50 Hz
Type of thyristor	Electrically-triggered-thyristor, 8 kV (100 mm Ø)

Moyle, Northern Ireland/Scotland

The Moyle Interconnector Project provides a vital link in electricity supply, enhancing both security and competition in the emerging market of Northern Ireland. The configuration of the transmission system is two monopolar submarine HVDC links operating in parallel on the AC systems. Each pole is rated 250 MW in both directions at 250 kV DC. For the first time in a commercial HVDC system, the converter stations are equipped with the latest achievement in highvoltage semiconductor technology: direct-light-triggered thyristors with integrated overvoltage protection. By introducing this new technology, the number of electrical parts in the HVDC thyristor valve is considerably reduced, resulting in better reliability and longer maintenance intervals. The contract for the Moyle Interconnector turnkey supply of the converter stations was awarded in September 1999. Taking-over certificate by the customer was issued in November 2001.

Technical Data

Customer	Moyle Interconnector Ltd. (MIL) Northern Ireland
Project name	Moyle Interconnector
Location	Northern Ireland, Scotland
Power rating	2 x 250 MW, monopolar
Type of plant	Submarine cable transmission, 64 km
Voltage levels	2 x 250 kV DC, 275 kV, 50 Hz
Type of thyristor	Direct-light-triggered, 8 kV

Thailand–Malaysia

This HVDC long-distance transmission system interconnecting the 230 kV AC network of Thailand with the 275 kV AC network of Malaysia is implemented in the first stage as a 300 MW monopolar metallic return scheme. As a turnkey project, complete HVDC system design and network integration, delivery of the converter stations, AC switchgear, and the interconnecting 300 kV DC overhead line was included in Siemens' scope of supply. Commercial operation started in 2001.

Technical Data

Customer	Electricity Generating Authority of Thailand (EGAT) Tenaga Nasional Berhad (TNB)
Project name	Thailand–Malaysia
Location	Khlong Ngae–Gurun
Power rating	300 MW, monopolar
Type of plant	Long-distance transmission, 110 km
Voltage levels	300 kV DC, EGAT: 230 kV, 50 Hz TNB: 275 kV, 50 Hz
Type of thyristor	Electrically-triggered-thyristor, 8 kV (100 mm Ø)

Tianshengqiao–Guangzhou, China

The HVDC long-distance transmission system Tian-Guang carries 1,800 MW of electrical power from the hydropower plant Tianshengqiao in southwest China to the load center of Guangzhou in the south. It is a bipolar system, each pole comprising a 12-pulse converter valve group, with the valve towers hanging from a special ceiling construction. The thyristors are water-cooled. The transformers are of the single phase three-winding type with bushings protruding into the valve hall. Active DC filters are implemented in this system for absorption of DC harmonics to avoid interference on neighboring communication lines. The contract was awarded in 1997; commercial operation started in 2000.

Technical Data

Customer	China Southern Power Grid
Project name	Tian-Guang
Location	Tianshengqiao–Guangzhou
Power rating	1,800 MW, bipolar
Type of plant	Long-distance transmission, 960 km
Voltage levels	±500 kV DC, 230 kV, 50 Hz
Type of thyristor	Electrically-triggered-thyristor, 8 kV

Sylmar East Valve Reconstruction, USA

The Pacific HVDC Intertie started its operation in 1970 at 1,440 MW. By addition of series and parallel connected converters it was later expanded to a rating of 3,100 MW. When a disastrous fire had destroyed the thyristor valves of converter 1 at Sylmar East Converter Station in 1993, the Los Angeles Department of Water and Power was under pressure to restore reliable power supply to the energy-hungry region. Siemens was awarded the reconstruction in August 1994, due to the short delivery time, use of fire-retardant valve material (UL94 VO), the anti-corrosion cooling system concept, and the excellent seismic performance of the valves (0.5 g horizontal). The installation was finished in September 1995.
The scope of supply comprises one complete 12-pulse converter, including DC hall equipment, and an advanced monitoring and alarm system.

Technical Data

Customer	Los Angeles Department of Water and Power, California, USA (LADWP)
Project name	Sylmar East Valve Reconstruction
Location	Sylmar Converter Station East, Los Angeles
Power rating	550 (825) MW, bipolar
Type of plant	Long-distance transmission, approx. 1,200 km
Voltage levels	±500 kV DC, 230 kV, 60 Hz
Type of thyristor	Electrically-triggered-thyristor, 8 kV

Welsh, USA

The back-to-back tie links the two different networks of the Energy Reliability Council of Texas (ERCOT grid) with the Southwest Power Pool (SPP grid) of the eastern US system. The Welsh Converter Station allows an additional power transfer to the existing connection (at Oklaunion) between the two networks. The arrangement and the design of the station are comparable to Etzenricht. The reliable and proven converter technology of Etzenricht, along with the same control and protection systems, is therefore used.

Technical Data

Customer	American Electric Power, Ohio, USA (AEP)
Project name	Welsh HVDC Converter Station
Location	Texas, Titus County near Mount Pleasant
Power rating	600 MW
Type of plant	Back-to-back tie
Voltage levels	170 kV DC, 345/345 kV, 60/60 Hz
Type of thyristor	Electrically-triggered-thyristor, 5.5 kV

Wien-Suedost, Austria

The back-to-back tie links the Austrian UCPTE network with the Hungarian and, hence, the RGW network. The modular water-cooled air-insulated valves are of a new, compact, and universal design. The rectifier and inverter are in 12-pulse connection and are accommodated in a building along with the bushings of the converter-transformers and the smoothing reactors. This HVDC plant southeast of Vienna was put in operation in July 1993.

Technical Data

Customer	Österreichische Elektrizitäts-wirtschafts-Aktiengesellschaft (Verbundgesellschaft, VG)
Project name	GK-Wien-Südost (GK-SO)
Location	Southeast of Vienna, Austria
Power rating	600 MW
Type of plant	Back-to-back tie
Voltage levels	145 kV DC, 380/380 kV, 50/50 Hz
Type of thyristor	Electrically-triggered-thyristor, 5.5 kV

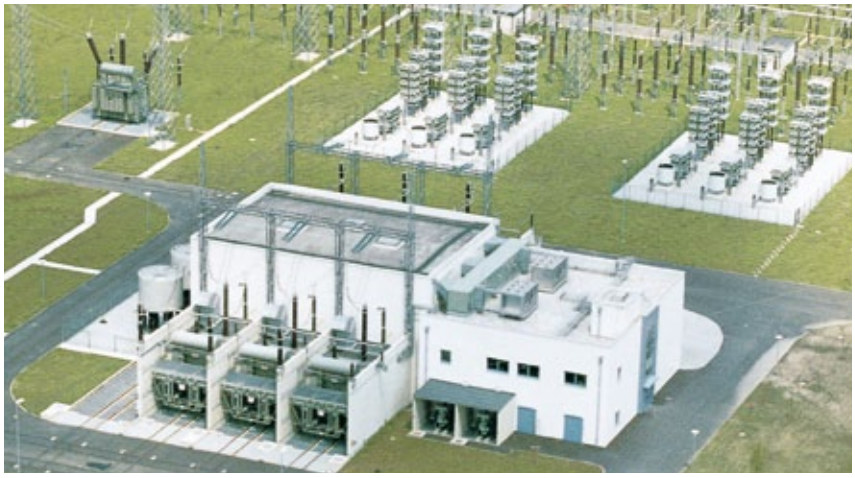
Etzenricht, Germany

The back-to-back tie links the two different networks of the Czech Republic and the Federal Republic of Germany, that is, the Western European network UCPTE with the Eastern European network RGW.

The HVDC plant considerably improved the availability of electrical energy in both countries and, at the same time, reduced the need for investment in reserve generating capacity. Standardized modular converters allow for much smaller valve halls than previously permitted and therefore offer major advantages in terms of economy. The converter transformers are arranged outside the valve hall. Their insulating bushings for connection to the thyristors are led directly into the converter hall. The HVDC plant in Etzenricht near Weiden/Oberpfalz was commissioned in June 1993.

Technical Data

Customer	E.ON AG Munich, Germany
Project name	Etzenricht
Location	Etzenricht, near Weiden/Oberpfalz
Power rating	600 MW
Type of plant	Back-to-back tie
Voltage levels	160 kV DC, 380/380 kV, 50/50 Hz
Type of thyristor	Electrically-triggered-thyristor, 5.5 kV



Gezhouba–Nan Qiao, China

The Gezhouba-Nan Qiao HVDC plant transmits electric power from the hydroelectric plant in Gezhouba in the Hubei province, central China, to the Shanghai conurbation. The power transmission system is bipolar, each pole consisting of a 12-pulse converter valve group. The valve towers are suspended from a special structure on the ceiling of the valve hall. The single-phase three-winding converter-transformers and their bushings project into the hall, where the star delta connections are made. The thyristors are water-cooled. Commercial operation started in 1989 (Pole 1), and in 1990 (Pole 2).

Technical Data

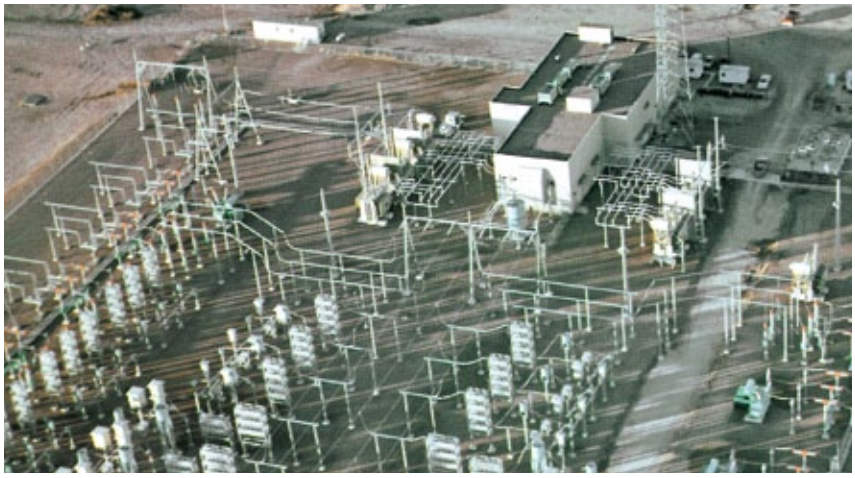
Customer	China National Technical Import & Export Corporation (CNTIC)
Project name	Ge-Nan
Location	Rectifier station in Gezhouba (Central China), Inverter station in Nan Qiao (about 40 km from Shanghai)
Power rating	1,200 MW, bipolar
Type of plant	Long-distance transmission, about 1,000 km
Voltage levels	±500 kV DC, 525/230 kV, 50/50 Hz
Type of thyristor	Electrically-triggered-thyristor, 5.5 kV

Virginia Smith, USA

The HVDC back-to-back tie at Virginia Smith Converter Station in Nebraska, USA, links the asynchronous networks in the East of the United States with those in the West. The station is controlled via the WAPA communications system from the load control center in Loveland, Colorado, 150 miles away. 200 MW can be transmitted in either direction. Despite power input in networks with low power ratings, voltage stability is assured within narrow limits. Temporary overvoltage limiters can be switched in to keep transient overvoltages within 1.25 p.u. The HVDC plant has been in operation since December 1987.

Technical Data

Customer	Western Area Power Administration (WAPA)
Project name	Virginia Smith Converter Station
Location	Sidney, Nebraska, USA
Power rating	200 MW
Type of plant	Back-to-back tie
Voltage levels	50 kV DC, 230/230 kV, 60/60 Hz
Type of thyristor	Electrically-triggered-thyristor, 4.52 kV

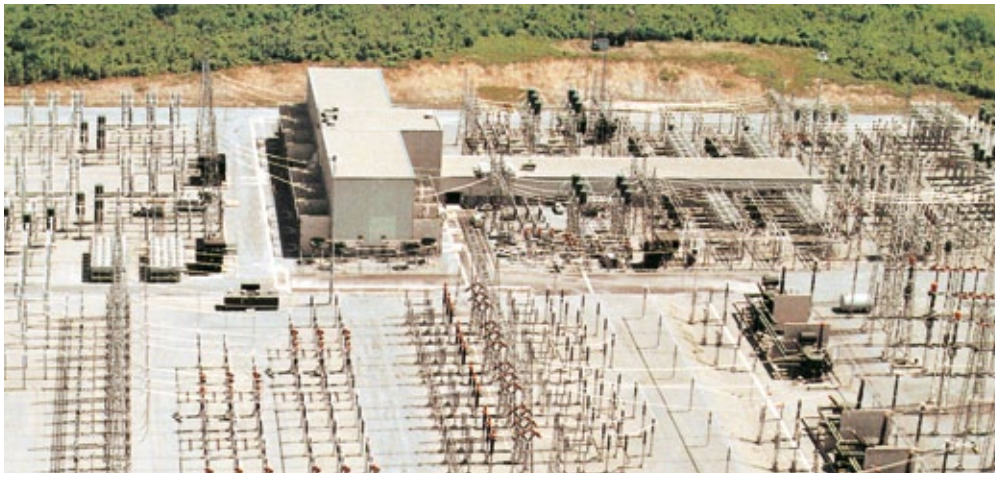


Poste Châteauguay, Canada

The Poste Châteauguay back-to-back tie effects the exchange of power between Canada (Hydro Quebec) and the USA (NYPA). The plant comprises two poles and has a power rating of 500 MW per pole. Overload operation up to 1,200 MW is possible. Each of the two poles is accommodated in a valve hall with two 12-pulse groups. One group is connected with the 120 kV system in the USA, and the other with the 315 kV system in Canada. The project, which was jointly awarded to BBC and Siemens, was completed on July 1, 1984, after a construction time of about one year.

Technical Data

Customer	Hydro Quebec, Montreal, Canada
Project name	Poste Châteauguay
Location	Beauharnois, Quebec, Canada
Power rating	2 x 500 MW
Type of plant	Back-to-back tie
Voltage levels	145 kV DC, 120/315 kV, 60/60 Hz
Type of thyristor	Electrically-triggered-thyristor, 4.5 kV



Dürnrohr, Austria

The HVDC back-to-back tie between Austria and the Czech Republic linked the then-asynchronous networks of Western and Eastern Europe. The contract was placed in 1980. The thyristor valves are watercooled and air-insulated; for the first time, high-voltage thyristors with a wafer diameter of 100 mm were used. The system consists of two 12-pulse groups in a common building and the transformers and smoothing reactors which are installed outdoors, with DC-side bushings protruding through the walls. Siemens, partnering with the German HVDC Group, supplied all thyristor modules and the station control system. Commercial operation started in 1983.

Technical Data

Customer	Österreichische Elektrizitäts-wirtschafts-Aktiengesellschaft (Verbundgesellschaft, VG)
Project name	Dürnrohr
Location	Dürnrohr, near Zwentendorf, Austria
Power rating	550 MW
Type of plant	Back-to-back tie
Voltage levels	145 kV DC, 380/380 kV, 50/50 Hz
Type of thyristor	Electrically-triggered-thyristor, 4.2 kV

Acaray, Paraguay

The HVDC back-to-back tie in Paraguay links the Brazilian 60 Hz network with the Paraguayan 50 Hz network. In times of drought and low output from the hydropower plants, Paraguay imports power from Brazil, while power can be exported to Brazil in times of water surplus. The frequency regulation of the HVDC back-to-back tie also helps stabilize the Paraguayan network frequency to 50 Hz. Commercial operation started in 1981.

Technical Data

Customer	A.N.D.E.
Project name	Acaray
Location	Paraguay
Power rating	55 MW
Type of plant	Back-to-back tie
Voltage levels	25 kV DC, 220/138 kV, 50/60 Hz
Type of thyristor	Electrically-triggered-thyristor, 4.2 kV

Nelson River, Bipole 2, Canada

The power plants on the Nelson and Churchill Rivers in the north of Manitoba, Canada, generate more than 50 % of the demand of this province: the double-bipolar HVDC link supplies the power to the load centers in the south of the province. Bipole 2 is the first HVDC system using highly efficient water cooling for the thyristor valves – a technology that has since become the industry standard. Siemens, partnering in the German HVDC Group, supplied all thyristor modules and the 500 kV smoothing reactors. Commercial operation started in 1977 with stage 1; the project was completed in 1985 with stage 3.

Technical Data

Customer	Manitoba Hydro (Winnipeg)
Project name	Nelson River, Bipole 2
Location	Henday Converter Station near Nelson River Dorsey Converter Station near Winnipeg both in Manitoba, Canada
Power rating	1,800 MW (summer) 2,000 MW (winter), bipolar
Type of plant	Long-distance transmission, about 1,000 km
Voltage levels	±500 kV DC, 230/230 kV, 60/60 Hz
Type of thyristor	Electrically-triggered-thyristor, 3.2 kV

Cahora Bassa, South Africa/Mozambique

The Cahora Bassa HVDC system is used to transmit the power generated in a hydroelectric plant on the Sambesi river in Mozambique to South Africa. The contract for the HVDC system, the dam, and the powerhouse was awarded to the ZAMCO consortium, including the German HVDC Group (AEG, BBC, Siemens). Cahora Bassa is the first HVDC contract placed that used thyristor valves. An outdoor, oil-cooled, and oil-insulated design was used. Commercial operation started in 1975 with phase 1; the system was completed in 1979 with phase 3.

During the 1980s the transmission line was heavily damaged by terrorist attack and the system was down until the nineties, when Siemens undertook the refurbishment of the converter stations. Besides the careful restoration of the main equipment, the complete DC control was exchanged by a fully digital, computerized system including a modern Human-Machine Interface (HMI). The new system increases the availability and reliability of the complex HVDC system considerably in terms of operator guidance. The most powerful HVDC transmission link in Africa has been back in operation since 1998.

Technical Data

Customer	1. HCB, Lisbon, Portugal 2. ESCOM, Johannesburg, South Africa
Project name	Cahora Bassa
Location	Songo, Mozambique Apollo, South Africa
Power rating	1,920 MW, bipolar
Type of plant	Long-distance transmission, 1,456 km
Voltage levels	±533 kV DC, 220/275 kV, 50 Hz
Type of thyristor	Electrically-triggered-thyristor, 1.65 kV/2.5 kV

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